PORT AUTHORITY OF ALLEGHENY COUNTY

NORTH SHORE CONNECTOR

CONTRACT NO. NSC-009

Technical Provisions
Volume 3

NSC TRAIN SYSTEM (SYSTEM WIDE)
(NSC-009)

FTA PROJECT NO. PA-03-0315

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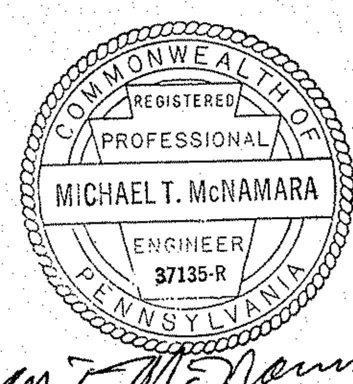

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SECTION 15400

TUNNEL SERVICES SCOPE OF WORK

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for the tunnel services scope of work in accordance with the Contract Documents. This Section describes the tunnel services scope of work for systems described in the Related Sections. This Section is additional to any other scope documentation for the NSC-009 Contract and shall be read in conjunction with all Related Sections.

B. The tunnel services scope of work includes, but is not limited to, the following:
   1. Tunnel ventilation and associated fire life safety systems
   2. Mechanical drainage systems
   3. Mechanical fire protection systems

C. The work of this Section includes, but is not limited to, the following activities:
   1. The design detailing, manufacture detailing, supply, delivery, off-loading, storage, furnish, install, testing and commissioning of the equipment required to meet the performance specification for the tunnel services systems.

D. The Contract Documents provide the performance parameters and Design Criteria to complete certain portions of the Work of this Section and Related Sections. The Contractor shall be responsible to provide a completed design for these portions of the Work.

1.02 RELATED SECTIONS

A. Section 01815, "Construction Dust Control"

B. Section 01920, "Cutting and Patching"

C. Section 01940, "Cleaning"

D. Section 02220, "Demolition"

E. Section 05120, "Structural Steel"

F. Section 05520, "Miscellaneous Metal Work"

G. Section 07841, "Fire Stop and Barrier Systems"

H. Section 09902, "Painting"

I. Section 15445, "Tunnel Mechanical Drainage Systems"

J. Section 15884, "Tunnel Fire Extinguishers and Cabinets"

K. Section 15885, "Tunnel Dry Standpipe Systems"

L. Section 15887, "Tunnel Ventilation and Balancing Dampers"

M. Section 15888, "Tunnel Ventilation Noise Attenuators"

N. Section 15889, "Tunnel Ventilation Fans"

O. Section 15890, "Tunnel Ventilation Jet Fans"

P. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

Q. Section 16060, "Grounding and Bonding"

R. Section 16111, "Conduit"

S. Section 16120, "Low Voltage Power Cables"

T. Section 16130, "Raceways and Boxes"

U. Section 16702, "Copper Outside Plant"

V. Section 16742, "SCADA System"

W. Section 16889, "Tunnel Services Electrical Testing and Commissioning"

X. Section 16890, "Tunnel Services Electrical Requirements of Mechanical Equipment"

Y. Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center"

Z. Section 16892, "Tunnel Services Uninterruptible Power Supply"

AA. Section 16893, "Tunnel Services Power Factor Correction"

BB. Section 16894, "Tunnel Emergency Rail Lighting and Lighting Receptacles"

CC. Section 16985, "Tunnel Services Low Voltage AC Variable Speed Drive"

1.03 REFERENCE STANDARDS

A. AMCA

B. ANSI

C. Anti-Friction Bearing Manufacturer's Association (AFBMA)

D. ASHRAE

E. ASME

F. ASTM

G. AWS

H. BOCA

I. British Standards (BS)

J. IEEE

K. ISO

L. NEC

M. NEMA

N. NFPA

O. Port Authority of Allegheny County, North Shore Connector Manual of Design Criteria.

P. SMACNA

Q. SSPC

R. UL

1.04 DEFINITIONS

A. Experienced Contractor: A Contractor who is familiar and competent with the detailed design and installation of tunnel services, in particular, tunnel ventilation. That is, not a general Mechanical/Electrical Contractor or a Building Services Contractor. The Contractor shall submit details of their experience on at least three similar projects to the satisfaction of Authority and the Engineer.

B. Tunnel Ventilation Fan: This type of fan is to be understood to be an axial fan used in the tunnel ventilation system. These fans shall be installed as an assembly that includes attenuators and evases on the inlet and outlet side of the fans. These fans are to be located in fan rooms as indicated on the Contract Drawings. These fans provide air flow in ducted pathways between the tunnels and surface.

C. Tunnel Ventilation Jet fan: This type of fan is to be understood to be an axial fan mounted to the tunnel roof or tunnel walls to be located as indicated on the Contract Drawings. Jet fans are to be installed as an assembly that includes attenuators (silencers) on the inlet and outlet of the actual fan. These fans are used to add momentum to air in the tunnels to generate air flow in the tunnels.

D. Saccardo Nozzle: An arrangement of duct work used to inject momentum into the tunnels similar to a jet fan. Saccardo Nozzles are used at the Northern end of Gateway Station due to the tunnel geometry not allowing jet fans to be installed.

E. Attenuator: For a tunnel ventilation fan this is a section of ductwork that includes splitters for the purpose of reducing the noise from the fans. For a jet fan, this is also referred to as a silencer and is an attachment typically a function of the jet fan diameter used to reduce the noise level from the jet fans.

F. Damper: A device installed in the ventilation ductwork or plenums used to control the air flow in order to achieve a particular ventilation mode. These devices are electrically actuated and can be either modulating (multiple set-point operation) or non-modulating (open or closed operation).

G. Balancing damper: This is a device similar to a damper, but it is not electrically actuated. A balancing damper has a given open area or set point that is determined at system commissioning to evenly distribute flow over a given length of ductwork. This position shall be permanently locked once determined at system commissioning.

H. Set-point: A single damper can be used for multiple ventilation modes. This may require the flowrate through a particular damper to be varied depending on the ventilation mode. A set-point describes the damper position required to achieve a given flow rate through the damper that is determined at the time of system commissioning.

I. Evase: Ductwork that provides for a smooth air path transition from a tunnel ventilation fan (smaller area, round section) to an attenuator (larger area, rectangular section).

J. Normal Operations: Conditions where trains are moving through the tunnels generally to timetable, stopping only at stations.

K. Congested Operations: Conditions when one train comes to a halt in a running tunnel between stations, either because of signaling problems or traffic congestion or other reasons, but where there is no immediate risk to people.

L. Emergency Operations: Conditions when a fire or other serious event has occurred underground, with possible risk to people and requiring use of the ventilation system.

M. Tunnel Maintenance Operations: Conditions when no trains are running within the system but authorized personnel are performing maintenance within the tunnels and ventilation is required for fresh air supply and cooling.

N. Ventilation Zone: A length of running tunnel or platform bounded at each end by a station, a station ventilation shaft, a portal or a crossover box.

O. Ventilation Mode: A preprogrammed ventilation response that involves the use of sets of fans and/or jet fans to supply or exhaust air to a section of tunnel. This requires certain sets of dampers to open or close depending on the response required.

P. Design Stopping Location: Intended at-rest location of train within station.

Q. Low Voltage: Any voltage exceeding 50V AC or 100V DC but not exceeding 600V AC or 1500V DC, either between conductors or between conductors and earth.

R. High Voltage: Any voltage exceeding low voltage.

S. TBC: Items labeled "TBC" shall be confirmed by the Contractor or the Engineer as required by the Contract Documents or shown on the Contract Drawings.

T. TBA: Items labeled "TBA" are to be confirmed by the Engineer, Project or Authority as required by the Contract Documents or shown on the Contract Drawings.

1.05 SCOPE OF WORK

A. The scope of work included under all this Section and all Related Sections shall include complete systems as shown in the Contract Documents and specified herein. Any work reasonably inferable or required to result in a complete installation or the intended operation and performance of the systems, shall be included in the Work except where there is specific reference to exclusion and incorporation in other Sections.

B. The Equipment to be provided shall include, but not be limited to, the following;
   1. All fans, jet fans, dampers, balancing dampers, evases, noise attenuators, control actuators, motor control centers (MCC), low voltage switchboards, variable speed drives, centralized emergency lighting, uninterruptible power supply (UPS), luminaries, control panels, PLC/RTUs, sensors, cables, marshalling terminals and cabinets, steelwork, conduit, supports, fixings, platforms, ladders, lifting apparatus and other materials necessary for the tunnel ventilation systems, as noted in the Contract Documents.
   2. All power and control cables and wiring between the fire control panels, the tunnel ventilation system equipment and the MCCs.
   3. Spare parts.
   4. Special tools and test apparatus.
   5. Operating and maintenance manuals for all equipment.

6. Mesh screens at all potential debris ingress points on the ventilation equipment and above horizontally mounted dampers.
7. Fire rated cladding on steel ductwork where combustible material could reasonably be positioned within 4 inches of the duct surface, or where cladding is required for the fire integrity of the tunnel ventilation system.
8. Insulation on exterior surfaces of attenuators, transition ducts, fan casings and any other steel surfaces with could transfer heat into the fan rooms from the air being handled by the fans.
9. Instrumentation as specified and wiring of the instrumentation either to the relevant MCC, control panel or junction box as required.
10. Painting and/or galvanizing of all equipment, ductwork and supports.
11. Local PLC/RTU in each fan room, MCC and all connections between the PLC/RTU and MCC.
12. Programming of the local PLCs/RTUs to control station operating modes and to interface with the SCADA system.
13. Fire stopping at all penetrations required for the related work.
14. Guarding around equipment.
15. Design, supply and install all equipment mountings. Major items of equipment will be provided by the vendors complete with mounting points. It is the Contractor's responsibility to provide frames and other supports required to mount the equipment to the fixed locations.
16. Design, supply and install all associated ductwork, ductwork connections and fan assembly connections, inspection hatches, flexible connections, turning vanes and evases. Some elements are by others as described in the Contract Documents and as indicated on the Contract Drawings.

C. The general work to be undertaken shall include, but not be limited to, the following;
   1. Except as otherwise expressly provided herein, the Contractor shall supply all labor, supervision, project management, scheduling, equipment, services and materials for the complete installation and commissioning of the equipment described in this Section.

D. The Contractor shall include all costs associated with, but not be limited to, the following activities;
   1. Demolition
   2. Design detailing
   3. Manufacture detailing
   4. Catalogue cuts
   5. Supply
   6. Fabrication
   7. Delivery
   8. Off-loading
   9. All storage
   10. Shop Drawings
   11. Erection

12. Installation
13. Clean up
14. Shop testing
15. Site testing and commissioning
16. System testing and commissioning
17. Site acceptance testing and documentation
18. Handover acceptance of the Contractor supplied or modified equipment to Authority
19. Operation and Maintenance manuals
20. As built drawings
21. Undertaking of all of the above activities shall be in accordance with the relevant standards, drawings, manufacturers' requirements and the Contract Documents.

E. The Work of this Section shall include, but not be limited to:
   1. Mobilization to sites, including the completion of all necessary training and induction of personnel and obtaining of permits for plant and equipment, and the establishment of all construction plant, equipment, buildings, facilities and personnel necessary for the execution of the Works.
   2. Demobilization from the sites of any and all Contractor supplied construction plant, equipment, buildings, facilities and personnel.
   3. Checking of the Contract Drawings, Contract Documents, levels, dimensions, clearances and measurements prior to the commencement of the work. The Contractor shall be responsible for verifying the actual levels, dimensions and measurements to meet the requirements of the Contract Documents.
   4. Supply and installation of minor items not expressly mentioned in the Contract Documents, which are necessary for the satisfactory completion, operation, and performance of the works in order to meet the design intent to the satisfaction of the Engineer.
   5. Provision and submission for approval of Traffic Management, Environmental (including waste management) and Workplace Health and Safety plans associated with this Section and all Related Sections.
   6. Cost for personnel to prepare and execute the work of this Section and all Related Sections.
   7. Costs for other personnel and equipment vendor representatives during commissioning of the equipment and systems.
   8. Obtaining appropriate approval from the Authority in writing and advising the venues and notification times of when the work will proceed.
   9. The provision of suitable containers for safe and secure storage of construction and waste materials during all stages of construction.
   10. Clean up of the site on a daily basis and on completion of the work and disposal of all waste materials in a timely fashion to the satisfaction of the Engineer.
   11. Safeguarding of, and the protection against, the degrading effects of moisture, dust, fumes etc. on all existing and new structures, plant and equipment whilst in storage and during all stages of construction.

12. Supply of all 'as built' drawings, 'as configured' data and documentation for all equipment and tunnel services systems.
13. Providing protection of the equipment being installed and the surrounding work areas, to prevent damage and deterioration. The protection shall be in accordance with the manufacturers' requirements and as approved by the Engineer. This shall be during the interim period following Notice to Proceed up to and including wiring, testing and system commissioning.
14. Providing repairs and touch up painting of structures and equipment accidentally damaged during construction by the Contractor. The Contractor shall provide written details for approval by the Engineer before this work may proceed.

F. The information contained within this Section, the Related Sections and Contract Drawings are for bid purposes only. The Contractor shall be responsible for checking these documents and for verifying that the equipment offered by the Contractor suits the actual duty and dimensions of all available mounting spaces prior to procuring and installing.

G. The work of this Section does not include the following activities:
1. Pressure in-fill and block work walls will be provided by other Authority Contracts.
2. All structural works forming the reinforced concrete ventilation shaft and ducts will be provided by other Authority Contracts.
3. All pads, openings and cast-in fixings in the civil works will be provided by other Authority Contracts unless indicated otherwise on Contract Drawings.
4. All doors and hatches opening onto (or within) the tunnel ventilation plantrooms, concrete ducts and adits will be provided by other Authority Contracts.
5. All external louvers aboveground in ventilation buildings serving the tunnel ventilation ducts will be provided by other Authority Contracts.
6. All ductwork in the platform area of North Side Station will be provided by other Authority Contracts unless noted otherwise in the Contract Documents.
7. All Low Voltage (LV) power supplies to each MCC room will be provided and connected by other Authority Contracts. (Dual independent 'A' & 'B' supplies will be provided for each MCC).
8. Lighting, small power and room ventilation in fan rooms and MCC rooms will be provided by other Authority Contracts.

1.06 COORDINATION

A. Interfaces
1. The tunnel ventilation system interacts closely with many other Authority Contracts. The detailing and installation of the system shall be fully coordinated with the following;
   i. The geometry, layouts and finishes of the tunnels, stations, shafts, adits, ducts and plantrooms as defined in the civil, structural and architectural drawings (including duct and louver air resistance).

ii. LV power distribution systems.
iii. Fire alarm systems.
iv. SCADA communications system.
v. Service duct and cable support provision by other Authority Contracts.
vi. Statutory Authorities – liaison as required for approval of the system design.

B. Coordinate and furnish in writing to the Engineer information necessary to permit the work to be installed satisfactorily and with the least possible interference or delay.

C. When work is installed without proper coordination, changes to this work deemed necessary by the Engineer shall be made to correct the conditions at no additional cost to Authority.

D. Coordinate arrangement, mounting, and support of mechanical and electrical equipment:
1. To allow maximum possible headroom unless specific mounting heights that reduce headroom are indicated.
2. To provide for ease of disconnecting the equipment with minimum interference to other installations.
3. To allow right of way for piping and conduit installed at required slope.
4. So connecting cables, pipes and ducts will be clear of obstructions and of the working and access space of other equipment.

E. Coordinate installation of required penetrations and embedded conduit and other structural components as they are constructed.

F. Coordinate electrical testing of electrical and mechanical items, so equipment and systems that are functionally interdependent are tested to demonstrate successful interoperability.

1.07 INTENT OF CONTRACT DOCUMENTS

A. Provide complete and functional systems for the Work. The systems shall conform to the details indicated in the Contract Documents. Items or work not shown or specified, but required for complete systems, shall be provided and conform with accepted trade practices. The Contract Documents are typical and diagrammatic and indicate the general arrangement and routing of the systems included in the Work.

B. Do not scale the Contract Drawings.

C. Carefully investigate conditions affecting the work associated with this Project. Install systems in a manner that interfaces between pipes, conduit, ducts, equipment, architectural and structural features are avoided. Provide items required to meet the Project conditions without additional cost to Authority.

D. These documents may not explicitly disclose final details required for a complete system installation; however, the Contractor shall possess the expertise to include the necessary appointments of complete operating systems.

E. The Contractor shall be "Experienced" in this type of construction and realize the extent of work required and include all incidental work in the payment for each of the Related Sections.

F. Reference standards are listed as ISO (International Standards Organization) or the US equivalent. If the US equivalent is not specified then the Contractor may substitute the US equivalent with the approval of the Engineer. The Contractor shall submit a copy of the substitute standard to the Engineer at no extra cost to Authority.

1.08 TUNNEL VENTILATION SYSTEM DESCRIPTION

A. The tunnel ventilation system is intended to provide environmental control of the running tunnels under all conditions. The system is intended to serve the following functions;
   1. Removal of heat during normal, congested and emergency conditions and during tunnel maintenance operations.
   2. Provision of forced ventilation for the cooling of stationary (congested) trains.
   3. Provision of forced ventilation for the control of smoke.
   4. Provision of sufficient fresh air.

B. Station Ventilation Shafts
   1. Ventilation shafts are provided at each station as shown on the Contract Drawings and are constructed by other Authority Contracts.
   2. At the stations, the ventilation fan rooms and shaft structures are integrated with the station box structures.
   3. Station ventilation shafts shall be used to provide forced tunnel ventilation. All tunnel ventilation equipment shall be located within these ventilation shafts and fan rooms.
   4. For forced ventilation, two tunnel ventilation fans in parallel shall be connected between the tunnel side plenum, and the duct to atmosphere (in parallel).

C. Principles of Operation
   1. It is the nature of the tunnel ventilation system that the fans and dampers can be configured in a large number of different combinations.
   2. The ventilation control system shall be designed to enable the equipment to be set up manually in any combination (except as restricted by any necessary safety interlocks). However it shall also control the equipment automatically following configurations listed in the system mode table in the Contract Drawings. The general principles are as follows:
      i. During normal and congested operations the equipment shall be controlled by a ventilation mode instigated by the OCC controller. The mode will be

automatic in that fans and dampers will automatically operate at given set points once the operator selects a mode (i.e. the operator does not have to manually operate individual fans and dampers). The operator will be able to override the automatic mode if there is information requiring an alternative response.

ii. During emergency operations, the operator will set the equipment into an automatic mode, following a recommendation made to the operator by the SCADA system. The operator will be given time to override (or confirm) the recommended configuration prior to activation.

D. Normal Operations

1. In hot conditions ('summer') it may be necessary to run the tunnel ventilation fans to increase the air exchange in the tunnels. In cold conditions ('winter'), the tunnel dampers would be shut and no fans would operate to allow the train heat to stay underground, improving conditions. This can only be done so long as the air quality is acceptable. Some flushing may be required at peak times. In mid-seasons either mode could be applied as selected by operators.

E. Congested Operations

1. The system can accommodate single incident congestion.
2. The tunnel ventilation fans shall be controlled to provide forced ventilation past the train which has had to stop in a running tunnel for reasons of signaling or congestion (in other words apart from a fire situation). The pattern of flow directions in different ventilation zones shall be coordinated so as to avoid having to reverse flow directions as additional trains possibly come to a halt.
3. The time delay for initiation of forced ventilation shall be determined so as to ensure that the response is timely.
4. The SCADA system shall make a recommendation on the required direction of forced ventilation in the current section.
5. The lack of any similarity between the two underground stations of the Pittsburgh North Shore LRT Connector Project requires that the method of achieving the congested mode airflows is different for each tunnel section. The modal operation of the ventilation is given in the mode table as part of the Contract Drawings.

F. Emergency Operations

1. The system can accommodate single incident emergency.
2. If fire breaks out on a train in a running tunnel, the first response will be for the train to continue to the next station or portal in order to allow rapid evacuation of passengers and staff. If this is not possible and the train cannot continue, it will be necessary to provide forced ventilation past the train in a tunnel to control the movement of smoke.
3. Operation of the ventilation equipment in response to a fire will be initiated manually by the Operator, with the ventilation control system presenting a recommended response which the Operator can accept or reject with a one button

press. If accepted, the response shall be carried out immediately and automatically.

4. The fire will have been detected by one or several different methods such as radio or telephone from the train staff, train passengers or from station staff.
5. It shall be possible for the Operator to input the following details into the control system in a simple and rapid manner.
   i. The ventilation zone(s) (tunnel or station) in which the train is stopped.
   ii. In which half of the train the fire is located (front, rear or quite possibly unknown).
   iii. In tunnels it is obviously desirable to ventilate such that the smoke passes over the shortest possible section of train, however this preference shall be weighed against the risks of indecision or decision reversal.
   iv. The control system shall then determine the recommended response to the incident as per the mode table as shown in the Contract Drawings.

1.09 MECHANICAL DRAINAGE SYSTEM DESCRIPTION

A. The mechanical drainage system provides de-watering for the tunnels to accommodate seepage, rain water ingress and in the event of emergency, fire-fighting water.

B. The system is comprised of a series of sump pits fed by a gravity drainage system. The sump pits and gravity drains form part of other Authority Contracts. The location of the sump pits is shown on the Contract Drawings.

C. This portion of the Work includes the installation, testing and commissioning of mechanical pumps, outlet drainage pipework, valves, level detection, controls and cabling.

D. The mechanical drainage system shall operate automatically controlled by the level detectors. Each sump pit consists of duty and standby submersible pumps. The standby pump is used in the event of failure at the duty pump.

E. The outlet pipework will either discharge to a sump pit of a higher level or to a pipework connection provided by other Authority Contracts. This is shown on the Contract Drawings.

F. System control is by local control panels near each sump pit. Monitoring and override control at the OCC shall be provided by the Contractor.

1.10 MECHANICAL FIRE PROTECTION SYSTEM DESCRIPTION

A. The mechanical fire protection system provides a means for fighting fires in the tunnels.

B. The system is comprised of a dry standpipe with dual head outlet valves approximately every 200 feet. Also located at each outlet is a fire extinguisher housed in a cabinet. The location of the outlets is shown on the Contract Drawings.

C. This portion of the Work includes the installation, testing and commissioning of the dry standpipe, valves, fire extinguishers and cabinets.

D. The dry standpipe system is manually operated by the fire department connection at the surface. At each station there is a set of Siamese connections which can be used to charge the appropriate pipework.

E. The dry standpipe connects to pipework in the tunnels at the station ends. The pipe work is connected to the Siamese connections at the surface. The tunnel to surface connection is provided by other Authority Contracts, unless shown otherwise on the Contract Drawings. Recesses in the tunnels for cabinets and pipework is provided by other Authority Contracts.

1.11 SUBMITTALS

A. The Contractor shall be an "Experienced" Contractor who is familiar and competent with the detailed design and installation of tunnel services, in particular, tunnel ventilation. That is, not a general Mechanical/Electrical Contractor or a building services Contractor. The Contractor shall submit details of their experience on at least three similar projects to the satisfaction of Authority and the Engineer.

B. All drawing, calculation and design submittals shall be sealed by a Professional Engineer.

C. Submit Product Data, Shop Drawings, operation and maintenance manuals, samples, test and balance report, control manufacturer's certification, certified test reports, and manufacturers certificates of compliance for equipment, materials and finish, and pertinent details for each system or piece of equipment specified in Related Sections and in accordance with the Contract Documents and have them approved prior to procurement, fabrication, delivery or installation. Delivery, storage or installation of equipment or material, which has not been approved, shall not be permitted at the job site.

D. All submittals shall include adequate descriptive literature, catalog cuts, Shop Drawings and other data necessary to ascertain that the proposed equipment and materials comply with the specification requirements. Catalog cuts submitted for approval shall be legible and shall clearly identify the equipment being submitted.

E. Submittals for individual systems and equipment assemblies which consist of more than one item or component shall be made for the system or assembly as a whole. Partial submittals shall not be acceptable and shall be returned without review. If equipment is disapproved, drawings shall be revised to show acceptable equipment and be resubmitted. Provide submittals with equipment designations, capacities, sizes, components, accessories, weights and other pertinent information which is required to evaluate the equipment submittal.

F. Submittals shall include manufacturer's name, trade name, catalog or model number, name plate data, size, layout dimensions, capacity, performance or characteristic curves, catalog cuts, Shop Drawings, pictures, test reports when required, and other information specified or necessary to establish contract compliance for each item to be furnished.

G. Submittals on all fans shall be complete with performance curves with design operating points and power clearly marked.

H. Submittals on electrically operated mechanical equipment shall be complete with all power and control wiring diagrams.

I. Call attention in writing to any deviation from the contract requirements. Use only final or corrected drawings or data for construction.

J. Submit samples when specified or requested. Properly labeled or identified samples of materials which manufacturer will actually provide shall be submitted for approval.

K. Submit Test and Balance Report prior to Final Inspection.

L. Submit Certified Test Reports when specified or required. Testing requirements in referenced publications for materials may be waived provided copies of the manufacturer's original certificates are submitted stating that previously manufactured materials have been tested by approved laboratories, that such materials meet testing requirements specified and that the materials furnished for this project are of the same type, quality, manufacture and make as that tested.

M. Submit Manufacturer's Certificate of Compliance when specified or required. Certificates of compliance shall be submitted by the manufacturer attesting that materials and equipment to be furnished for this project comply with the requirements of the Contract Documents and of the referenced publications. Pre-printed certifications shall not be acceptable. Certifications shall be the manufacturer's original and shall not be more than one year old. The certification shall not contain statements that could be interpreted to imply that the product does not meet all requirements specified, such as "as good as", "achieve the same end use and results as materials formulated in accordance with the referenced publications equal or exceed the service and performance of the specified material". The certification shall simply state that the product conforms to the requirements specified. The manufacturer's official authorized to sign certificates of compliance shall sign the certificates.

N. Submit As Built Drawings for all tunnel mechanical systems that are included in this Section and Related Sections. These drawings shall show layout, location, size of system components, installation conditions, attachments, fixtures, interfacing with other Authority Contracts and any other relevant information. These drawings shall be submitted to the Engineer for approval upon Substantial Completion of the tunnel services portion of the Work.

1.12 PERMITS, FEES, CODES, ORDINANCES AND REGULATIONS

A. Obtain and pay for all permits, inspections and connection fees required by governing bodies in connection with this portion of the Work. Deliver Certificates of Inspection to the Engineer.

B. All work shall comply with governing codes, ordinances, and regulations of the City of Pittsburgh, Commonwealth of Pennsylvania, and the National Electrical Code.

C. All work shall be coordinated and submitted to the authorities having jurisdiction as indicated in the Contract Documents and required for the Work.

1.13 QUIET OPERATION AND VIBRATION CONTROL

A. Equipment and associated items shall operate under conditions of load without sound or vibration deemed objectionable by the Engineer. In the case of moving equipment, sound or vibration noticeable outside of the room in which it is installed, or noticeable within the room in which it is installed, or in excess of any specified criteria, shall be deemed objectionable. Sound or vibration deemed objectionable shall be corrected in a manner approved by the Engineer. Vibration control shall be provided by means of approved vibration isolators and installed in accordance with the isolator manufacturer's recommendations.

B. The sound pressure levels around mechanical equipment (motors, sump pumps etc.) in equipment spaces shall not exceed 85 dBA at any point three (3) feet from the equipment, with all equipment in the room operating. This applies to the complete range of each piece of equipment. This does not apply to the main axial fans and jet fans which have their own criteria specified in the Related Sections.

1.14 JOB CONDITIONS

A. Protect materials, apparatus and equipment from damage, moisture, dirt, debris and work of other trades.

B. Use of paper, cardboard or other flimsy material for protection will not be permitted. Replace damaged protective materials immediately. Do not install damaged materials and equipment; remove from site.

1.15 GUARANTEES AND WARRANTIES

A. Temporary operation of the equipment for temporary conditioning, testing, etc., prior to final acceptance or approval from Authority will not be considered part of the warranty period.

B. Where extended Guarantees are called for herein and in Related Sections, a copy of each extended guarantee shall be inserted in each Operation and Maintenance Manual.

1.16 AUTHORITY INSTRUCTION

A. After final tests and adjustments have been completed, furnish the services of qualified personnel to instruct representatives of Authority in the operation and maintenance procedures for equipment and systems installed as part of this portion of the Work. Operation and maintenance instructions for major items of equipment shall be directly supervised by the equipment manufacturer's representative. Supply qualified personnel to operate equipment for sufficient length of time as required to meet governing authorities' operation and performance tests and as required to assure that Authority's representatives are properly qualified to take over operation and maintenance procedures. Minimum instruction period shall be 40 man hours. The instruction period shall be broken into segments at the discretion of Authority.

B. Notify the equipment manufacturers' representatives, by letter, as to the time and date of operating and maintenance instruction periods approved by the Engineer at least one (1) week prior to conducting same.

C. Forward to the Engineer the signatures of all those present for the instruction periods within 1 week of the completion of instruction.

D. All work and cost associated with Authority instruction shall be included in the payment for Related Sections.

1.17 QUALITY ASSURANCE

A. Industry Standards and Codes: Unless modified by this Section or Related Sections, the design, manufacture, testing and method of installing all materials, apparatus and equipment shall conform to the following:
   1. Standards of National Fire Protection Association (NFPA).
   2. BOCA Building, Mechanical, Plumbing and Fire Codes.

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Products used in the execution of this Work shall conform to the Contract Documents.

B. All materials and equipment shall be new. Systems shall be provided complete, and each system as a whole, and in all its parts, shall function correctly up to the specified capacity. Should a system, or any part thereof fail to meet performance requirements, necessary replacements, alterations or repairs, as required by the Engineer, shall be made to bring performance up to specified requirements and all building construction and finishes damaged or marred by such replacements, alterations or repairs shall be restored to prior condition, at no additional cost to Authority.

C. Where multiple items of equipment or materials are required they shall be the product of a single manufacturer.

D. Before ordering any equipment, the size of all equipment shall be coordinated with other Authority Contracts as required to ensure the equipment can be properly installed without alteration to the work of others.

E. Piping assemblies of equipment shown on the drawings are diagrammatic. All piping and appurtenances required for the proper operation of all equipment shall be provided.

F. Design Life
   1. Fans, jet fans, dampers, evases, noise attenuators, control panels, motor controls, sensors, cabling and all other associated equipment, shall be designed for an operating life of 20 years unless noted otherwise. All auxiliary equipment (e.g. access ladders, platforms mounting frames etc.) shall be designed for an operating life of at least 20 years unless noted otherwise.

G. Serviceability of Electrical and Mechanical Equipment
   1. Serviceability of electrical and mechanical equipment shall be considered in the detailed design. Items such as knock-out panels, double doors, lifting eyes and access hatches shall be provided, and their locations shall be coordinated with other Authority Contracts.
   2. Duct access doors shall be provided as required for inspection and/or adjustment of the fans, dampers and attenuators.
   3. Equipment shall be able to be accessed and serviced safely.
   4. Equipment shall be arranged with sufficient clear space to facilitate equipment or component removal, maintenance and replacement, and to allow for ease in equipment servicing. Provision shall be made for access door swings and the removal of miscellaneous components.
   5. Fans shall be readily removable from the ductwork.
   6. Control system schematic diagrams shall be posted in the vicinity of all control panels.

H. Equipment Mounting
   1. Equipment to be mounted on the floor shall be placed on reinforced concrete equipment pads. Minimum pad height shall be 4 inches. The work shall be

coordinated with other Authority Contracts as necessary. Equipment to be mounted from the ceiling or tunnel walls (e.g. jet fans) shall be mounted on frames. All other pads shall be by the Contractor. Wall mounted equipment (e.g. electrical racks) shall be fixed directly to the walls.

2. The Contractor shall submit to the Engineer details of any proposed pads for approval to proceed before undertaking construction of pads.
3. In the event that any of the Contractor's equipment requires special mounting details (e.g. cast in place fixtures) the Engineer shall be notified in a timely manner for incorporation into the civil or structural packages.
4. Some mounting fixtures as designated in the Contract Drawings shall be provided by other Authority Contracts. The Contractor may need to provide steelwork framing to allow equipment to be positioned at the correct level and position. All support steelwork shall conform to Section 05120, "Structural Steel" and Section 05520, "Miscellaneous Metal Work". All support steelwork for equipment in the tunnel (jet fans etc.) shall be designed to withstand temperatures of 482°F for a 1 hour period without failure while equipment is operating in accordance with NFPA130.
5. The Contractor shall submit to the Engineer details of any mounting frames for approval to proceed before undertaking construction of the frames.

I. Equipment Identification
   1. Equipment and control devices shall be permanently labeled after installation. All labels shall be of a uniform format. This format shall identify individual equipment items and provide information regarding equipment type, equipment function, flow direction and other such data as appropriate. Identification shall include the equipment designator given in the schedules.

J. Plantrooms and Layouts
   1. The Contract Drawings show the layout of tunnel ventilation fan rooms and the positioning of dampers and attenuators. Alternative layouts are not precluded if the merits of the alternatives can be clearly demonstrated, to the satisfaction of the Engineer.
   2. An allowance for circulation space of not less than 24 inches in width shall be provided around all plant and equipment, with additional space where necessary for withdrawal and servicing.
   3. Within the plant rooms, provision shall be made for lifting equipment for the major servicing of plant, particularly for handling fans and dampers.
   4. Lifting beams and monorail trolleys of appropriate capacity shall be provided to enable usage of the access hatches and roller doors. These shall remain in place after installation.

2.02 MANUFACTURER'S NAMES AND CATALOG NUMBERS

A. Specific references have been made to one or more manufacturer's names and model or catalog numbers.

B. This does not indicate that the material and equipment specified is necessarily an "off the shelf" item; requirements for specific finishes, materials or other modifications may introduce variances from manufacturers' standards. Contractor shall ascertain that such modifications are fully considered.

2.03 VENTILATION CONTROL SYSTEM

A. Overview
   1. The Ventilation Control System shall include all hardware and software necessary to locally monitor and control the tunnel ventilation equipment as described by this Article.
   2. The ventilation equipment is distributed across several physical locations. The system shall include facilities for monitoring and control locally by a local PLC/RTU with facilities for SCADA communication of monitoring and control signals to OCC at a remote central location.
   3. The Ventilation Control System shall conform to Section 16742, "SCADA System" and Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center".

B. The ventilation control system shall include the following;
   1. Located in the MCC Room near each fan room;
      i. A MCC serving all the fan motors and ancillary equipment.
   2. All conduit, tray and trunking for the cables and wiring defined above.
   3. Local Programmable Logic Controllers (PLC).

C. The Contractor shall design, supply, install, test and commission (as part of the SCADA system) the following:
   1. The SCADA system operator work station in the OCC which shall provide facilities for monitoring and control (both manual and automatic) of all the equipment from a central location (OCC).
   2. All cabling between the ventilation control system PLC SCADA interface points and the SCADA communications network.

D. The Contractor shall be responsible for providing fully detailed information to allow coordination between the tunnel ventilation system and the SCADA system in order to meet the specified performance requirements. Therefore the Contractor shall be responsible for;
   1. A detailed schedule of all the equipment status signals to be transmitted to the SCADA network.
   2. A detailed schedule of all the command signals to be sent from the SCADA network to equipment.
   3. A detailed and structured description of all the rules and algorithms that the SCADA system shall contain and carry out in order to meet the specified performance requirements.

4. A detailed and structured description of all the information that shall be displayed on the SCADA system and the controls that shall be provided in order to meet the performance specified in the tunnel ventilation report.

E. Twin independent LV power supply cables will be provided and landed at each ventilation MCC room by other Authority Contracts. The LV power supply cables will be terminated in the MCC room.

2.04 FANS

A. The tunnel ventilation fans shall conform to Section 15889, "Tunnel Ventilation Fans" except where indicated otherwise. The tunnel ventilation fans required are designated in Table 15889-1 of Section 15889, "Tunnel Ventilation Fans" and on the Contract Drawings.

B. The Contractor is responsible for ensuring that all requirements in Section 15889, "Tunnel Ventilation Fans" for submittals, manufacturing hold points and witnessing of shop tests of the fans are met to the satisfaction of the Engineer and Authority.

C. Documentation

1. Section 15889, "Tunnel Ventilation Fans" require certain schedules and documentation to be provided after Notice to Proceed and testing results and other documentation to be supplied prior to shipment of the equipment from the manufacturer's works. The Contractor is responsible for ensuring that those same documentation requirements are fulfilled to the satisfaction of the Engineer.

2.05 EVASES

A. Evases are required to transition from the axial fans to the attenuators.

B. Evases shall be installed as shown on the Contract Drawings.

C. Evases shall be supplied as part of the fan assembly in accordance with Section 15889, "Tunnel Ventilation Fans".

2.06 JET FANS

A. The tunnel ventilation jet fans shall conform to Section 15890, "Tunnel Ventilation Jet Fans" except where indicated otherwise. The jet fans required are designated in Table 15890-1 of Section 15890, "Tunnel Ventilation Jet Fans" and as shown on the Contract Drawings.

B. The Contractor is responsible for ensuring that all requirements in Section 15890, "Tunnel Ventilation Jet Fans" for submittals, manufacturing hold points and witnessing of shop tests of the jet fans are met to the satisfaction of the Engineer and Authority.

C. Noise (attenuators)
   1. The jet fans shall be supplied complete with attenuators such that when the jet fans are mounted according to the Contract Documents and all operating together, the noise level 5 feet above any part of the tunnel walkway does not exceed 85dBA.
   2. Attenuators shall be of the same cylindrical type and conform to the same elevated temperature requirements of the fans.
   3. Supports for the attenuators may also be required.

D. Equipment Mounting
   1. Depending on the location, jet fans are to be mounted in configurations from tunnel ceilings and/or walls.
   2. Jet fans shall be provided complete with mounting frames, or points to enable mounting in the orientation shown on Contract Drawings. The Contractor shall provide steel frames to enable mounting of jet fans to mounting fixtures.

E. Documentation
   1. Section 15890, "Tunnel Ventilation Jet Fans" require certain schedules and documentation to be provided upon Notice to Proceed and testing results and other documentation to be supplied prior to shipment of the equipment from the manufacturer's works. The Contractor shall be responsible for ensuring that those same documentation requirements are fulfilled to the satisfaction of the Engineer.

2.07 TUNNEL VENTILATION DAMPERS

A. The following dampers shall conform to Section 15887, "Tunnel Ventilation and Balancing Dampers":
   1. Tunnel isolation dampers
   2. Plenum/in-duct dampers
   3. Nozzle dampers

B. The particular dampers required are designated in Table 15887-1 and Table 15887-2 of Section 15887, "Tunnel Ventilation Dampers".

C. Documentation`
   1. Section 15887, "Tunnel Ventilation Dampers" requires certain schedules and documentation to be provided upon Notice to Proceed and testing results and other documentation to be supplied prior to shipment of the equipment from the manufacturer's works. The Contractor shall be responsible for ensuring that those same documentation requirements are fulfilled to the satisfaction of the Engineer.

2.08 BALANCING DAMPERS

A. Balancing dampers shall conform to Section 15887, "Tunnel Ventilation and Balancing Dampers".

B. Balancing dampers are located as shown on the Contract Drawings at the exhaust inlets along the length of the platforms. Each balancing damper shall have an adjustable slide plate or opposed blade damper for adjusting the opening free area, in order to balance the flow along a length of duct during system commissioning. This device shall be adjustable from the track way side of the exhaust plenum. It shall be possible to adjust the balancing damper free areas so that the air flowrate through any individual balancing damper does not vary by more than 10% from the mean flowrate per exhaust inlet along that run of duct. Once adjusted, the positions shall be locked to prevent tampering.

2.09 SCREENS

A. Hot dipped galvanized mesh screens shall be provided over the ends of those attenuators or dampers which are connected directly to the tunnel ventilation fan transition ducts, in order to prevent ingress of trash and debris when the fans are running in either flow direction. Similar screens shall be provided on the tunnel side of all tunnel dampers, on top of all horizontal dampers and on the end of jet fan attenuators. Screens above horizontal dampers shall support 250 lb at any point without interfering with the damper blades. The flow resistance of all screens shall be the minimum practical.

B. Screens shall be provided as part of the damper assembly in accordance with Section 15887, "Tunnel Ventilation and Balancing Dampers" or the jet fan assembly in accordance with Section 15890, "Tunnel Ventilation Jet Fans".

2.10 NOISE ATTENUATORS

A. Noise attenuators shall be required to meet the system noise performance defined and required by section 15888, "Tunnel Ventilation Noise Attenuators".

B. The Contractor is responsible for ensuring that all requirements in Section 15888 "Tunnel Ventilation Noise Attenuators" for submittals, manufacturing hold points and witnessing of factory tests of the noise attenuators are met to the satisfaction of the Engineer and Authority.

C. Documentation
   1. Section 15888 "Tunnel Ventilation Noise Attenuators" requires certain documentation and schedules to be provided upon Notice to Proceed and testing results and other documentation to be supplied prior to shipment of the equipment from the manufacturer's works. The Contractor shall be responsible for ensuring that those same documentation requirements are fulfilled to the satisfaction of the Engineer.

2.11 DUCTWORK

A. All tunnel ventilation airflows pass through airways formed as part of the station and tunnel structures (either concrete or blockwork or fabricated ductwork). These airways are provided by other Authority Contracts except as indicated on the Contract Drawings or as required for a fully functional ventilation system to meet the design intent of the Contract Documents.

2.12 STEELWORK

A. Steelwork to be supplied and installed by the Contractor shall include the following:
   1. Steelwork to support and mount all the tunnel ventilation equipment.
   2. Steelwork to form a seal around dampers fixed in structural openings.
   3. Permanent ladders for maintenance access to all items of equipment, particularly in plantrooms (e.g. fan assemblies) and plenums (e.g. dampers).
   4. Permanent access landings for equipment inspection and maintenance. When sited in vertical airways (e.g. horizontally mounted dampers), these shall be open grid hot dipped galvanized mesh floors with the minimum practical flow resistance.

B. Steelwork shall comply with Section 05120, "Structural Steel" and Section 05520, "Miscellaneous Metal Work". Site drilling and welding are to be avoided. Design of steelwork shall acknowledge the need for integrity at 482°F for 1 hour in accordance with NFPA 130. All support steelwork for jet fans in the tunnel needs to be designed to accommodate temperatures of 482°F for 1 hour without failure while the equipment is operating. Steelwork components shall be hot dipped galvanized where possible. Steelwork shall provide free access for equipment maintenance and removal.

C. All exposed steelwork shall be electrically bonded to the local grounding system in accordance with Section 16060, "Grounding and Bonding".

D. All design and installation of steelwork shall be included in the payment of Related Sections.

2.13 TUNNEL MECHANICAL DRAINAGE SYSTEMS

A. The tunnel mechanical drainage systems shall conform to Section 15445, "Tunnel Mechanical Drainage Systems" except where indicated otherwise in the Contract Documents.

B. The tunnel mechanical drainage systems shall include, but not be limited to, all sump pumps, isolation valves, check valves, piping, sump pump supports and fixings, piping supports and fixings and all other equipment and incidentals required for a fully function tunnel mechanical drainage system unless noted otherwise in the Contract Documents.

C. The sump pumps required are designated in Table 15445-1 of Section 15445, "Tunnel Mechanical Drainage Systems" and as shown on the Contract Drawings.

2.14 TUNNEL FIRE PROTECTION SYSTEMS

A. The tunnel fire protection systems shall conform to Section 15884, "Tunnel Fire Extinguishers and Cabinets" and Section 15885, "Tunnel Dry Standpipe System" except where indicated otherwise in the Contract Documents.

B. The tunnel fire protection systems consist of tunnel dry standpipes, fire extinguishers, fire extinguisher cabinets, piping supports and fixings, isolation valves, expansions joints, drain values, air vents and all other equipment and incidentals required for a fully function tunnel fire protection system unless noted otherwise in the Contract Documents.

C. The piping routes and typical installation details are provided on the Contract Drawings. The Contractor shall be responsible for a completed design in accordance with the requirements of NFPA 14 Class I Dry Standpipe Systems.

2.15 MOTORS

A. All motors shall be totally enclosed fan-cooled type, and where necessary, flameproof. Motors installed in non-environmentally treated areas shall be provided with anti-condensation heaters.

B. AC motors shall be capable of operating continuously under rated output conditions at any frequency between 58 and 61 Hz together with 10% voltage variation. Except where specified otherwise, AC motors shall be suitable for operation from a 480/277 V, 3 phase 3 wire 60 Hz supply.

C. AC motors shall be suitable for direct on line (across-the-line) starting at full voltage.

D. Motors shall be selected with a margin of 25% on the required form shaft power.

E. All motors and their connections shall be designed to operate in an ambient temperatures of 482°F for a period of at least one hour, as required by NFPA130.

F. Taconite bearing seals shall be used (i.e. single lip seal with grease purged labyrinth) on motor bearings. Grease lines shall be run in robust tubing from all required greasing points to a common greasing manifold, readily accessible on the outside of the fan casing.

2.16 MOTOR STARTERS

A. Motor starters shall be provided for all fan and damper motors and shall conform to Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control

Centers" and Section 16895, "Tunnel Services Low Voltage AC Variable Speed Drive".

2.17 MOTOR CONTROL CENTERS (MCC)

A. MCC shall be provided in each fan control room to power all fans and dampers. They shall conform to Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Centers".

B. Tunnel ventilation fans involved in emergency operation bring an additional critical requirement on MCC. Over temperature and vibration sensors shall be used only to indicate the condition and raise an alarm. The motors on such fans shall not be automatically tripped off by any apparent fault condition. In an emergency such as fire, the fans will be expected to operate for as long as they are physically able.

C. If the fans include brakes in order to meet the reversal requirements, the PLC/RTU shall include the necessary interlocks between motor and brake to ensure safe operation.

2.18 CIRCUIT BREAKERS AND SWITCHES

A. All switchgear shown on Contract Drawings shall be supplied and shall conform to Section 16891, "Tunnel Services Low Voltage AC Variable Speed Drive".

2.19 METERING EQUIPMENT

A. Current transformers shall be compatible with, and provide the necessary accuracy, over-current factors, characteristics, performance and VA rating for the satisfactory operation of the relevant protection devices, instruments and meters.

B. Current transformers shall be capable of withstanding the maximum short time withstands current for the value and duration for the assembly within which it is mounted.

C. Test links shall be provided in the secondary connections of all current transformers to facilitate testing of instruments, meters and protection devices. These shall be so arranged as to ensure that the transformer secondary winding cannot be open circuited.

D. Voltmeters, ammeters, frequency indicators and power factor indicators shall comply with an internationally recognized standard.

E. The wiring to voltmeters and the potential coils of frequency indicators and power factor indicators shall be protected by separate fuses.

F. All instruments and meters shall be completely segregated in instrument compartments.

2.20 GUARDING

A. For all equipment supplied and installed by the Contractor, appropriate guarding shall be designed, supplied and installed to prevent injury from moving parts. Guards shall meet the requirements of relevant codes, standards or statutory authorities. Guards shall be formed of steel members with heavy galvanized steel mesh. Guards shall be easily removable for maintenance. For equipment with accessible rotating shafts an opening to enable tachometer readings without the removal of guards shall be provided.

B. Guards shall form part of the Related Sections.

2.21 NAMING AND NUMBERING STANDARD

A. Equipment naming and numbering shall be in accordance with the requirements of Authority. The Contractor is responsible for coordinating naming and numbering with Authority.

2.22 EQUIPMENT SURFACE PROTECTION

A. This Article specifies the minimum requirements for painting and galvanizing of plant and equipment installed by the Contractor. Equipment supplier's standard painting specifications may be acceptable upon approval of the Engineer.

B. Paint System
   1. All painting shall be in accordance with Section 09902, "Painting".
   2. The Contractor shall ensure that paint systems are appropriate for the possible high temperature duty to which equipment may be subjected.
   3. The Contractor shall provide proposed paint systems for approval by the Engineer.

C. Surface Preparation and Application
   1. In addition to these requirements, the procedures and criteria of the paint manufacturer shall be adhered to. Safety measures appropriate to the paint system in use shall also be taken.
   2. Weld spatter, slag, burrs and other surface irregularities shall be removed by grinding and sharp edges and corners shall be rounded off unless noted otherwise. Oil and grease shall be removed by solvent or steam cleaning.
   3. Steel surfaces shall be cleaned by dry abrasive blasting to achieve a uniform metallic color. All blasting dust and grit shall be removed using dry compressed air. Between cleaning and painting, the steel shall not be handled except using clean dry gloves.
   4. The first paint coat shall be applied as soon as possible and no more than 4 hours after blasting. Re-cleaning will be required after longer delays.
   5. Damaged or unsound paintwork shall be mechanically sanded or whip blasted down to an undamaged substrate, with sound coating feathered around the damage site. Remedial painting shall overlap the sound coating by a minimum of 2 inches

and shall restore minimum film thickness in all areas. Site touch-up shall be as for damaged paintwork above.

6. Flange connection bolts, nuts and washers and all bolts, nuts and washers requiring attention for maintenance or adjustment shall be hot dipped galvanized and not painted

D. Colors

1. A color scheme shall be proposed by the Contractor. This shall be submitted to the Engineer for approval.

E. Galvanized Surfaces

1. Galvanized items shall be hot dip galvanized according to procedures in a standard recognized internationally. All sharp edges and corners shall be ground to a minimum radius of 1/12 inch and all sharp irregularities, burrs, surface scale, slag and weld spatter shall be removed prior to galvanizing. A minimum coating of 2.35 oz/ft^2 shall be achieved. After galvanizing, surfaces shall be smooth and uniform with no defects, surplus zinc deposits or other residues.
2. Galvanizing shall be in accordance with 05520, “Miscellaneous Metal Work”.

2.23 CABLE TRUNKING

A. Trunking shall be in accordance with the highest standards, shall be of the steel type with steel covers and shall be hot dip galvanized or zinc plated finish.

B. The lengths of trunking, bends tee sections and offsets shall be coupled together by means of fish plates and the trunking manufacturer’s cadmium plated steel set screws, nuts and shake proof washers.

C. At each joint in the trunking continuity shall be maintained by means of copper links secured by brass nuts, locking washers and bolts.

2.24 CABLE TRAY

A. Cable tray shall be perforated full wrap around type not less than 16 gauge mild steel hot dip galvanized finish.

B. The cable tray shall be of sufficient width to take the cables without crowding. Double stacking of cable shall not be allowed except where specifically agreed by the Engineer.

C. The cable tray shall be fixed to purpose made galvanized steel brackets which shall in turn be fixed to the structure. The brackets shall be hot dip galvanized.

D. The fixing brackets shall rigidly support the cable tray and shall provide a clear space between the structure and/or obstructions and the back of the cable tray.

2.25 CABLE CONDUIT

A. All conduits shall be in accordance with Section 16111, "Conduit".

B. Steel conduit and fittings shall comply with local standards and shall be screwed classification. The requirements of NFPA 70 (NEC) shall be complied with.

C. The minimum size of conduit shall be 1 inch or equivalent.

D. To satisfy requirements for earth fault loop impedance, the layout of conduit, trunking and ducting and routing of cables shall ensure that the maximum circuit lengths allowable are not exceeded.

E. Bending of conduit shall be done without the use of heat using an appropriate bending machine.

F. No conduit shall be under mechanical stress.

G. Conduit that is cast in-situ is provided by other Authority Contracts.

H. At expansion and settlement joints, suitable provision shall be made in conduit, trunking and ducting to allow for movement of the structure. For trunking and ducting, purpose-made expansion couplings shall be used.

I. Temporary plugs shall be fitted to open ends of conduit and ducting to prevent ingress of water and solid material.

2.26 GROUNDING AND BONDING

A. The grounding and bonding shall be in accordance with Section 16060, "Grounding and Bonding"

B. Grounding and bonding conductors shall be sized to pass fault currents without undue stress and to minimize impedance such that protective devices operate to clear faults in the requisite time before dangerous situations develop.

C. Mechanical services circuit protection conductors shall be provided with, and emanate from a suitable sized ground bar located within the relevant MCC, connected to the incoming sub-main cable supply ground.

D. Each of the entire conduit installations shall be electrically continuous throughout, forming completely bonded systems.

E. All equipment not solidly connected to the conduit systems, shall be connected to the grounding system. A separate connection shall be made from apparatus grounding terminals to the grounding terminal in the serving outlet box of the conduit system.

F. All grounding and bonding cable shall be copper with green insulation or over-sheath.

G. Grounding shall be carried out to allow safety equipment to operate properly and to maintain touch voltages to below 50V in the event of a short circuit in any part of the system.

H. Where necessary, supplementary equipotential bonding shall be provided. In areas where the system of wiring is concealed, the supplementary bonding conductor shall also be concealed up to the point of termination.

2.27 SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM (SCADA)

A. Tunnel ventilation systems equipment shall have provision for remote SCADA monitoring and control via a data highway connection. The output signal final characteristics shall be as specified in Section 16742, "Supervisory Control and Data Acquisition (SCADA) System".

B. The Contractor shall coordinate space provisions for the SCADA system equipment and cabling within the scheme. The location of SCADA remote terminal units (in this case the TV PLC I/O rack) shall be agreed with the Engineer and Authority. I/O to the SCADA system should be allowed for in all fan control rooms.

C. Detailed coordination shall be carried out to ensure that the correct operation of the tunnel ventilation systems is performed and monitored by the SCADA system.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Execution of the Work of the Section shall conform to the Contract Documents.

3.02 INSTALLATION AND WORKMANSHIP

A. The work shall be performed by qualified installers and all materials, apparatus and equipment shall be installed in neat, workmanlike manner. Any material, apparatus or equipment, which, in the opinion of the Engineer, is improperly installed shall be removed and re-installed in an approved manner at no additional cost to Authority.

B. The work shall be coordinated with the work of other Authority Contractors. Where the work is dependent upon work of other Authority Contractors or work already in place, such other work and work in place shall be examined and shall be in proper condition and state of completion before continuing the installation. Coordination of the work of this Contract shall be the responsibility of the Contractor.

C. The installation of the systems shall, in general, be in accordance with the Contract Drawings with regards to location of equipment, conduit, pipes, and the like. Piping and conduit indicated shall be followed as accurately as actual construction will permit and any deviations there from shall be called to the attention of the Engineer. Where necessary, as determined by the Engineer, the Contractor shall furnish drawings showing proposed changes.

D. All conduits shall be installed tight to underside of structure with space for insulation, if required, unless otherwise noted.

3.03 CUTTING AND PATCHING

A. Provide cutting and patching necessary to install the work specified herein. Patching shall match adjacent surfaces. Refer to Section 01920, "Cutting and Patching" for specific directions.

B. No structural members shall be cut without prior approval of the Engineer.

3.04 WATERPROOFING

A. Do not cut or penetrate waterproofed surfaces, or waterproofing membranes, without first making arrangements for repair by a method approved by the Engineer.

3.05 FIRESTOPPING

A. It is the responsibility of the Contractor to install or arrange for the installation of fire stopping at all penetrations directly related to the work through fire rated walls and ceilings. Fire stopping shall be installed by a suitably qualified installer to ensure that the resistance rating of the structure is maintained.

B. Apply fire stopping to mechanical penetrations of fire-rated floor and wall assemblies to restore original fire-resistance rating of assembly. Fire stopping materials and installation requirements are specified in Section 07841, "Fire Stop and Barrier Systems".

C. The Contractor shall coordinate with other Authority Contracts as required before undertaking the fire stopping work.

3.06 ACCESSIBILITY

A. Coordinate to ensure the sufficiency of the size of shafts, and chases and other areas required for the proper installation of this work.

B. Locate equipment which must be serviced, operated or maintained in fully accessible positions. Equipment requiring access shall include, but is not necessarily limited to, valves, fans, pumps, MCC etc.

C. Indicate the locations of access doors for each concealed valve, piece of equipment, components, or other device concealed behind finished construction and requiring service on the Shop Drawings. Equipment below floor slab or finished grade shall be also be indicated on the Shop Drawings.

3.07 PAINTING

A. Painting of equipment shall be in accordance with Section 09902, "Painting".

B. Provide surface preparation, priming, and final coat application in strict accordance with manufacturer's recommendations.

3.08 EQUIPMENT FOUNDATIONS, SUPPORTS, PIERS AND ATTACHMENTS

A. Provide necessary foundations, auxiliary steel, supports, pads, bases and piers required for equipment specified in Related Sections. Submit Shop Drawings in accordance with Shop Drawing submittal requirements of Related Sections prior to the purchase, fabrication or construction of same.

3.09 CLEANING

A. General cleaning requirements shall be in accordance with Section 01940, "Cleaning".

B. Upon completion of the work, clean the exterior surface of equipment, accessories, and trim installed. Clean, polish, and leave equipment, accessories, and trim in first-class condition.

3.10 PROTECTION

A. Protection of Surfaces
   1. Protect surfaces from damage during the construction period.
   2. Provide plywood or similar material under equipment or materials stored on floors or roofs. Provide protection in areas where construction may damage surfaces.
   3. Surfaces damaged during the construction shall be repaired or replaced at no additional cost to Authority. The method of repairing or replacing the surface shall be approved by the Engineer.

B. Protection of Services
   1. Protect services from damage during the construction period.
   2. Repair, replace and maintain utilities, facilities or services (underground, above ground, interior or exterior) damaged, broken or otherwise rendered inoperative during the course of construction at no additional cost to Authority.
   3. Services damaged during the construction shall be replaced at no additional cost to Authority. The method used in repairing, replacing or maintaining the services shall be approved by the Engineer.

C. Protection of Equipment and Materials

1. Equipment and materials shall be stored in a manner that shall maintain an orderly, clean appearance. If stored on Worksite in open or unprotected areas, equipment and material shall be kept off the ground and out of standing water by means of pallets or racks, and covered with tarpaulins.
2. Equipment and material, if left unprotected and damaged, shall be repainted or otherwise refurbished at the discretion of the Engineer and at no additional cost to Authority. Equipment and material is subject to rejection and replacement if, in the opinion of the Engineer or manufacturer the equipment has deteriorated or been damaged to the extent that its immediate use or performance is questionable, or that its normal life expectancy has been curtailed.
3. During the construction period, protect piping, fittings, valves, equipment, and associated appurtenances from damage and dirt. Each system of piping shall be flushed to remove grit, dirt, sand, and other foreign matter for as long a time as required to thoroughly clean the systems.

3.11 ADJUSTMENT

A. After the entire installation has been completed, make required adjustments to balancing dampers, fan blades and similar devices requiring adjustment until performance requirements are met.

B. Adjustment of equipment shall be undertaken as part of Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

3.12 SPECIAL TOOLS

A. Provide Authority with two (2) sets of all special tools required for operation and maintenance of equipment provided.

3.13 INSTRUCTION OF AUTHORITY'S OPERATING PERSONNEL

A. The Contractor shall include the cost of the services of qualified instructor(s) to instruct Authority's operating personnel in the operation, adjustment, care and maintenance of all equipment and systems installed as part of this Work. The instruction services shall consist of a minimum of 40 hours of instruction of Authority's operating personnel.

B. Instruction shall be performed at a time approved by Authority after all equipment and systems are installed, completed, adjusted and operating to specified requirements. The Contractor shall notify the Engineer when instructions will be given.

C. Qualification of instructor(s) shall be subject to approval of Authority and equipment manufacturer.

D. Additional requirements concerning operation and maintenance of equipment and systems may be specified in other Sections.

E. Instruction of Authority's operational personnel shall be included as part of the Related Sections.

3.14 DEMOLITION

A. Demolition shall be phased in accordance with the Contract Documents.

B. Demolition shall be in accordance with Section 02220, "Demolition".

C. The work shall consist of providing selective demolition as indicated on the Contract Drawings and as otherwise required for proper and timely completion of this Contract.

D. Demolition shall be defined as the complete or partial dismantling and removal of existing equipment, and other items so indicated in the Contract Documents. Equipment including all related items supporting structures, electrical and mechanical connections, shall be completely removed, unless otherwise indicated in the Contract Documents.

E. Material or equipment which Authority desires to salvage will be removed or clearly designated by Authority prior to Notice to Proceed. Otherwise, material or equipment shall be the Contractor's salvage.

F. Before bidding, determine the requirements and restrictions imposed by utility companies, City of Pittsburgh, and other regulatory agencies in connection with this demolition work.

G. Permits shall be secured and paid for by the Contractor.

H. Notify the proper authorities of public utilities, City of Pittsburgh, and Allegheny County, of work. Conform to their respective requirements and restrictions, and present to the Engineer a written approval from each agency indicating acceptance of the respective procedures, before starting demolition. Contractor shall comply with all regulations pertaining to environmental protection.

I. Where special procedures are required, such as barriers, flagmen, safety devices and temporary disconnection of utility services the work shall be performed in accordance with such requirements and in accordance with the Contract Documents.

J. The Contractor shall be responsible for all costs associated with requirements and restrictions, including fees to utility companies and other agencies. Copies of all receipts showing proof of payment for all such permits, fees or services shall be provided to the Engineer.

K. Maintain, support, disconnect, remove, and restore utilities in accordance with the Contract Documents.

L. Verify material sizes, dimensions, and existing conditions before proceeding with the work in a safe manner.

M. Conduct demolition operations and debris removal in such fashion as to ensure the minimum interference with Authority operations, roads, streets, walks, and other facilities both public and private. Do not close or obstruct streets, walkways, or other facilities.

N. All demolition items shall be removed from the Worksite as it accumulates. Demolished materials shall not be stored at the Worksite. Do not conduct the sale of demolition items within the limits of the Worksite. Do not burn demolition items at the Worksite.

O. Do not begin demolition until Notice to Proceed has been given, in writing, by the Engineer.

P. Upon receipt of Notice to Proceed, the Contractor shall immediately assume responsibility for the structures, and protect the structures causing them to remain undamaged. Demolition work shall begin within 7 days of receipt of notice that the structures are available for demolition.

Q. Use water sprinkling, temporary enclosures, and/or dust barriers, to limit, to the lowest practical level, the spread of dust and dirt created by the demolition work. Water sprinkling shall not be utilized when it may create hazardous or objectionable conditions. Use calcium chloride to prevent street icing. Water conditions shall be removed at completion of demolition work.

R. The Contractor shall restore disturbed and damaged areas to their original condition, to the satisfaction of Authority and the Engineer.

S. The Contractor shall not utilize any demolition practices which will not ensure that all work is strictly confined within the limits of the demolition area, and is without hazard to adjacent property, or to the public.

T. Make arrangements for the disposal of all demolition items outside of Authority right-of-way and pay costs involved. Upon completion of demolition, the Worksite shall be left in a safe, clean and sanitary condition.

3.15 TEMPORARY VENTILATION

A. All temporary ventilation at the worksite shall be provided by the Contractor.

B. It is the responsibility of the Contractor to ensure that temporary ventilation satisfies the requirements for, but not limited to, the following:
   1. Workplace Health and Safety,
   2. Fire life safety, and

3. Pollution and dust control.

3.16 PHASING

A. Phasing shall be conducted in accordance with the Contract Documents.

B. The Contractor shall provide Authority a minimum of 7 calendar days advance notice of any construction activities which may require modification of routine, daily operations of the facility.

C. The Contractor shall provide protection of all trenching in vehicle circulation areas with traffic weight covers until permanent paving is installed.

D. The Contractor shall maintain continuity of all maintenance related utilities to maintenance bays, including: air, lubricants, water and electricity.

3.17 SHOP TESTING

A. The Contractor shall complete all shop testing as prescribed in the Related Sections.

B. The Contractor shall submit all relevant test results and documentation produced during the shop testing to the Engineer for approval.

3.18 SITE TESTING AND COMMISSIONING

A. The Contractor shall complete all site testing and commissioning as prescribed in the Related Sections.

B. The Contractor shall submit all relevant test results and documentation produced during the site testing and commissioning to the Engineer for approval.

3.19 SYSTEM TESTING AND COMMISSIONING

A. The system commissioning is an important element of the tunnel services systems. This is necessary to verify that all the tunnel services systems and associated equipment are operating and performing in accordance with the Contract Documents and the design intent to the satisfaction of the Engineer and Authority.

B. The Contractor shall complete all system testing and commissioning as required by, but not limited to, Section 15891, "Tunnel Services Mechanical Testing and Commissioning" to the satisfaction of the Engineer and Authority.

C. The Contractor shall submit all relevant test results and documentation produced during the system testing and commissioning to the Engineer for approval.

3.20 FINAL INSPECTION

A. With notice to the Engineer that the work is ready for final inspection, the Contractor shall:
   1. Submit all testing and commissioning reports as required by the Related Sections and complete requirements as noted.
   2. Submit letter from control manufacturer certifying that controls have been checked for proper operation and calibration and that system is operating as intended.

B. The Contractor shall furnish necessary mechanics to operate system, make necessary adjustments and assist with final inspection.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 15445

TUNNEL MECHANICAL DRAINAGE SYSTEMS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for the tunnel mechanical drainage, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design detailing, manufacture detailing, supply, delivery, off-loading, storage, furnish, install, testing and commissioning of the new tunnel mechanical drainage system and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel mechanical drainage portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data"

B. Section 01911, "Operations, Maintenance and Repair Database"

C. Section 09902, "Painting"

D. Section 05120, "Structural Steel"

E. Section 07841, "Fire Stop and Barrier Systems"

F. Section 15400, "Tunnel Services Scope of Work"

G. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

H. Section 16889, "Tunnel Services Electrical Testing and Commissioning"

I. Section 16890, "Tunnel Services Electrical Requirements for Mechanical Equipment"

J. Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center"

1.03 REFERENCE STANDARDS

A. ANSI

B. ASTM

C. AWS

D. British Standards (BS)

E. IEEE

F. ISO

G. SSPC

1.04 SUBMITTALS

A. All drawing, calculation and design submittals shall be sealed by a Professional Engineer.

B. Submit copies of Working Plans and Certificates to the Engineer in compliance with the requirements of Article 3.02 and Article 3.03 of this Section.

C. Shop Drawings
   1. Submit Shop Drawings for the tunnel mechanical drainage systems, showing layout, location, size of system components, installation requirements and details of materials and methods of attachments. These shall be submitted to the Engineer for approval prior to procurement and installation of any components of the tunnel mechanical drainage systems.

D. As Built Drawings
   1. Submit As Built Drawings for tunnel mechanical drainage systems, showing layout, location, size of system components, installation conditions, attachments, fixing of sump pumps, installation of detection levels, all outlet piping and fittings, all valves and any other relevant information. These shall be submitted to the Engineer for approval upon Substantial Completion of the tunnel mechanical drainage systems portion of the Work.

E. Operation and Maintenance Data
   1. Submit complete instructions, including catalog cuts, diagrams, drawings and other descriptive data covering proper operation, maintenance of each type of system installed, and necessary information for ordering replacement parts.

F. Manufacturer's Literature
   1. Submit literature completely describing products installed as part of the Work.

G. The documentation provided shall include key manufacturing quality assurance reports, including particularly the testing procedures carried out for material quality and structural integrity and the results in terms of defects noted.

H. The Contractor shall submit the following sump pump manufacturer certificates and details on the sump pumps and all associated equipment within 60 days of Notice to Proceed.
   1. Evidence that the materials selected and the assembled product will have a service life expectancy of not less than 20 years with reasonable maintenance.
   2. Provide a list of 3 other projects where comparable sump pumps have been in satisfactory operation for a minimum period of 5 years.
   3. Factory quality control plan and manufacturing schedule.
   4. Manufacturer recommendations for handling and long term storage of any spare equipment.
   5. Estimated mean time between failure (MTBF).
   6. Estimated mean time between service failure (MTBSF).
   7. Mean time to repair (MTTR).
   8. Recommended planned maintenance schedule.
   9. Proposed galvanizing and/or painting regime.
   10. Dimensioned general arrangement and interface Shop Drawings of the tunnel mechanical drainage systems.
   11. Completed equipment schedule as per Table 15445-1 of this Section.

I. The Contractor shall submit the following manufacturer certificates and details below before delivery to the Worksite. The documentation delivery Schedule shall be proposed by the Contractor in the Project Schedule and submitted to the Engineer for approval.
   1. Evidence that the materials selected and the assembled product will have a service life expectancy of not less than 20 years with reasonable maintenance.
   2. Factory quality control records, inspection checklists and test reports.
   3. Manufacturer recommendations for handling and long term storage of any spare equipment.
   4. Estimated mean time between failure (MTBF).
   5. Estimated mean time between service failure (MTBSF).
   6. Mean time to repair (MTTR).
   7. Recommended planned maintenance schedule.
   8. Operation and maintenance manuals – these manuals shall describe the recommended maintenance, all design parameters and the designations, part numbers and commercial sources of spare parts. Manual formats and numbers shall be in accordance with Authority requirements. As a minimum three copies shall be provided.
   9. Dimensioned general arrangement and interface Shop Drawings of the tunnel mechanical drainage systems.
   10. Completed equipment schedule as per Table 15445-1 of this Section.

J. Equipment requirements are listed in Table 15445-1 of this Section and are shown on the Contract Drawings. The items in Table 15445-1 of this Section listed as "By Contractor" shall be completed by the Contractor as required by the Submittals of this Section. Equipment information and/or data sheets shall be submitted with the completed Table 15445-1.

TABLE 15445-1 Nominal Sump Pump Performance Requirements

Equipment Number	GW-SSP-101	GW-SSP-102	NS-SSP-201
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type/Notes	Submersible	Submersible	Submersible
Depth (in)	By Contractor	By Contractor	By Contractor
Width (in)	By Contractor	By Contractor	By Contractor
Length (in)	By Contractor	By Contractor	By Contractor
Flow Rate (gpm)	500	500	500
Pump Head (feet) (TBC)	37 (estimate)	37 (estimate)	111 (estimate)
Power (HP) (TBC)	By Contractor	By Contractor	By Contractor

Equipment Number	NS-SSP-202	NS-SSP-203	NS-SSP-204
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type/Notes	Submersible	Submersible	Submersible
Depth (in)	By Contractor	By Contractor	By Contractor
Width (in)	By Contractor	By Contractor	By Contractor
Length (in)	By Contractor	By Contractor	By Contractor
Flow Rate (gpm)	500	500	500
Pump Head (feet) (TBC)	111 (estimate)	115 (estimate)	115 (estimate)
Power (HP) (TBC)	By Contractor	By Contractor	By Contractor

Equipment Number	NS-SSP-205	NS-SSP-206	NS-SSP-207
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type/Notes	Submersible	Submersible	Submersible
Depth (in)	By Contractor	By Contractor	By Contractor
Width (in)	By Contractor	By Contractor	By Contractor
Length (in)	By Contractor	By Contractor	By Contractor
Flow Rate (gpm)	500	500	500
Pump Head (feet) (TBC)	42 (estimate)	42 (estimate)	41 (estimate)
Power (HP) (TBC)	By Contractor	By Contractor	By Contractor

Equipment Number	NS-SSP-208	Level Detectors
Make	By Contractor	By Contractor

Model	By Contractor	By Contractor
Type/Notes	Submersible	Float Type
Depth (in)	By Contractor	-
Width (in)	By Contractor	-
Length (in)	By Contractor	-
Flow Rate (gpm)	500	-
Pump Head (feet) (TBC)	41 (estimate)	-
Power (HP) (TBC)	By Contractor	-

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Materials
1. The Contractor shall provide all manufactured items, materials, labor, cartage, tools, plant, appliances and fixings necessary for the proper execution of the work, together with all minor and incidental works.
2. Should the Contractor propose any deviations from the specified requirements, such variations shall be submitted in writing to the Engineer for approval.
3. This Section shall be read in conjunction with the relevant Contract Drawings.

B. Design Life
1. Elements of the tunnel mechanical drainage system shall be design for an operating life of 20 years. Pipework elements shall have a minimum life of 50 years.

C. Serviceability of Electrical and Mechanical Equipment
1. Serviceability of elements shall be considered in the detailed design and shall be clearly identified in the Shop Drawings.
2. Equipment shall be accessible and serviced safely to the satisfaction of the Engineer.

D. Equipment Identification
1. All items shall be permanently labeled after installation. All labels shall be of a uniform format. Metal tags are acceptable for valves. Naming and numbering shall be in accordance with any Authority requirements and shall be coordinated with Authority.

E. Equipment Locations
1. The Contract Drawings and schematics show the location and arrangement of the tunnel mechanical drainage system equipment.

2.02 SUMP PUMPS

A. Sump Pump Performance

1. Duty and standby pumps shall be installed. Pumps shall be of the submersible type, each having a flow capacity of 500gpm.
2. Required pump head is estimated in Table 15445-1. The Contractor shall confirm the required pump head based on the detailed installation conditions.
3. Control of the tunnel sump pumps shall be by level detection.
4. The sump pumps shall be capable of at least 15 starts per hour without adverse impact on their performance or life expectancy.

B. Level Detection
1. The Low Level Alarm and Duty Pump stop levels shall be confirmed upon the selection of the pump by the Contractor. All other detection levels shall be provided as shown in the Contract Drawings.
2. Levels shall be reported to the control system. Level detectors shall be of the float type.

C. Sump Pump Fixing
1. The Contractor shall propose a method of locating and fixing the sump pumps and also supporting of any pipework and valves. Pump rails can be used if space permits. Any proposed fixing system shall be approved by the Engineer.

D. Control System
1. Control of the tunnel mechanical drainage systems shall be by level detection.
2. The mechanical drainage system shall be able to operate automatically without intervention from the OCC.
3. The duty and standby sump pumps for each mechanical drainage system shall be alternated by the control system to ensure regular operation of each sump pump. The control system shall allow for the alternation of sump pumps on a monthly rotation.

E. General Electrical Requirements
1. Electrical requirements are given in Section 16890, "Tunnel Services Electrical Requirements for Mechanical Equipment".

2.03 VALVES

A. Check Values
1. Check valves shall be provided as indicated on the Contract Drawings.
2. Each check valve shall be supplied with a ball drip to prevent freezing.
3. Check valves shall be non-slam, silent operating, wafer type, cast iron body, lapped and balanced twin bronze flappers loaded with stainless steel torsion spring, and stainless steel trim.
4. Valves shall be able to withstand the pressure and fluid conditions associated with the tunnel mechanical drainage systems.

B. Isolation Valves

1. Valves shall be provided to facilitate maintenance of the mechanical drainage system as indicated on the Contract Drawings.
2. Valves shall be of the gate or butterfly type.
3. Valves shall be able to withstand the pressure and fluid conditions associated with the tunnel mechanical drainage systems.

2.04 PIPEWORK

A. Pipework
   1. ASTM A53, galvanized steel, Schedule 40, with square-cut grooved ends.
   2. Pipework shall meet the requirements of ANSI B21, B31 and B125.
   3. All pipework shall be sized as indicated on the Contract Drawings.

B. Fittings
   1. Galvanized malleable iron with square-cut grooved ends.
   2. Pipe fittings shall meet the requirements of ANSI B16.

C. Couplings
   1. Provide couplings designed for use with grooved pipe, galvanized malleable iron, complete with galvanized nuts and bolts.
   2. Nuts
      a. Tamperproof type.
   3. Gaskets
      a. As recommended by manufacturer.

D. Inlet Pipework
   1. Tunnel drainage collection networks into the sump pits will be installed by other Authority Contracts.

E. Outlet Pipework
   1. Outlet pipework and associated valves shall be provided as shown on the Contract Drawings. The Contractor shall be responsible for all work and approvals associated with connection of this pipework to fittings provided by other Authority Contracts. This work will need to be coordinated with other Authority Contracts. Contract limits are shown on Contract Drawings.

F. Bored Tunnel Pipework
   1. The bored tunnel mechanical drainage system discharges into the sump pit located at the egress stairwell in the TBM launch pit. The Contractor is responsible for the discharge pipework that shall be located along the bored tunnel wall. Contract limits are indicated on the Contract Drawings.

2.05 INSTALLATION

A. Lifting
   1. Permanent or portable lifting equipment shall be supplied by the Contractor for the installation and maintenance of the sump pumps and associated equipment.

2. The installation equipment and any associated equipment required for maintenance and installation shall remain the property of Authority after the installation of the mechanical drainage systems.
3. Any portable installation equipment shall be suitably packed for handling and for long term storage in accordance with manufacturer recommendations that have been approved by the Engineer. Clear identification of the equipment shall be provided on the packaging. The Contractor shall be responsible for the transport and off-loading of any portable installation equipment to a site nominated by Authority.

B. Conduits and Trenches
1. Certain provisions have been made in other Authority Contracts for conduits for the sump pump cables. The Contractor shall allow for the pulling of all required cables.

C. Cables
1. The Contractor shall provide power and control cables. These shall run from the devices in the sump pit to a local control panel. This panel shall be provided by the Contractor. Controls will be to contacts in the local control panel.

D. Equipment Surface Corrosion Protection
1. Unless specified, appropriate anti-corrosion provisions shall be made by the Contractor for all components, based on SSPC standards suitable for installation conditions. The Contractor shall provide information regarding material selections, galvanizing and painting schemes.

2.06 SPARES

A. The Contractor shall supply a spare sump pump, valves and level detectors of each type installed.

B. The spares shall be suitably packed for handling and for long term storage in accordance with manufacturer recommendations that have been approved by the Engineer and coordinated with Authority. Clear identification of the equipment shall be provided on the packaging. The Contractor shall be responsible for the transport and off-loading of any spares to a site nominated by Authority.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Examination
1. Verification of Conditions
   a. Examine areas and conditions under which the work is to be installed, and notify the Engineer in writing, of any conditions detrimental to the proper and timely completion of the work. Do not proceed with the work until unsatisfactory conditions have been corrected.

b. Beginning of the work shall indicate acceptance of the areas and conditions as satisfactory to the Contractor.

B. All equipment shall be installed in readily accessible positions.

C. Where equipment is mounted along the emergency walkway it shall be positioned such that it does not present a hazard or obstruction to occupants or personnel using the emergency walkway.

D. The Contractor shall ensure that the mechanical drainage system and all associated equipment does not encroach into the LRV or pantograph clearance envelope.

E. All fastenings shall be galvanized. Spring and flat washers shall be provided under nuts or bolt heads where necessary. Other fastenings shall be securely locked. Each bolt or stud shall be shortest standard length, which will show at least one full thread beyond its nut after assembly. Studs shall be screwed home at least $1^1/_4$ diameters.

F. All work specified, shall be installed in an approved manner to meet structural, architectural and other site and/or service conditions.

G. All pipework and pipework supports must be constructed so that it is free for contraction and expansion movements so that it shall not damage any other work or itself.

H. Provide for thermal expansion of piping by provision of expansion joints spaced at least every 200ft and around isolation valves. The Contractor shall consider the ambient temperature at the time of installation to ensure that the expansion joints have been installed for adequate expansion and contraction over the range of expected operating temperatures. It is estimated that temperatures will range between 32 °F and 104 °F.

I. Support piping so that hangers or saddle clamps shall sustain load and properly secure piping to prevent vibration when piping is in use. Support intervals shall not exceed 10 feet. Provide at least one hanger for each pipe section. Hangers and clamps shall also be installed at each offset or change in direction and at each valve connection.

J. Provide piping passing through walls and other locations as indicated with sleeves with annular space between pipe and sleeve in an approved manner. Where fire isolation is required between spaces separated by walls, fire stopping shall be provided in accordance with Section 07841, "Fire Stop and Barrier Systems".

K. Special care shall be taken in the management of piping to ensure neat and workmanlike appearance and true alignment and grade.

L. All pipes and fittings shall be thoroughly cleared before erection, removing all scale, burrs, fins and obstructions and the section shall be blown out to remove all scale, slug, pipe-cutting residue, etc. before final flushing.

M. Grooved piping
   1. Prepare and groove piping in accordance with the coupling manufacturer's instructions. Pipe shall be free from indentations, projections, or roll marks for proper gasket seating.
   2. Before installation, verify that gasket supplied is as specified for service intended.
   3. Apply gasket lubricant supplied by coupling manufacturer so that gasket will not be pinched upon assembly. Apply a uniform coat over exterior surface of gasket on the pipe and coupling surface.
   4. Install gasket and coupling in accordance with the manufacturer's instructions.

N. Protection
   1. Throughout the installation of all piping, special care shall be continuously exercised to protect all openings to prevent the admission of any dirt, stones or other foreign substances that would subsequently obstruct the system. Close pipe openings with caps or plugs during installations.
   2. Throughout the installation of all piping special care shall be continuously exercised to protect all galvanizing from damage. Any galvanizing that is damaged shall be reported to the Engineer and repaired to the satisfaction of the Engineer.

3.02 PAINTING AND CORROSION PROTECTION

A. The Contractor shall make provisions for painting and corrosion protection based on SSPC standards suitable for installation conditions.

B. The Contractor's standard for painting and corrosion protection shall be subject to approval by the Engineer.

C. The Contractor shall provide full details of the proposed painting and corrosion protection system to the Engineer for approval.

D. All painting shall be in accordance with Section 09902, "Painting".

E. Final color of any paintwork shall be as agreed with the Engineer.

3.03 FIELD QUALITY CONTROL

A. Preparation
   1. Prior to any testing and commissioning, pipe work associated with the tunnel mechanical drainage systems shall be flushed.
   2. Flush tunnel mechanical drainage systems with clean water until it is free of scale, slag, dirt, grease or other foreign materials that may cause damage to the work of other Authority Contracts.

3.04 SITE TESTING AND COMMISSIONING

A. Testing and commissioning shall include, but not be limited to, the following:

1. Operation of the sump pumps (flow rate and direction);
2. Operation of level detection and pump control;
3. Pressure testing of pipework (as required), and
4. Impeller trim to adjust for any variation in the actual pump head encountered.

B. All tests shall be documented for submission.

C. All mechanical drainage system testing shall be shown as a witness point in the Contractor's Schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Site testing carried out without sufficient notice will be deemed to have not been done and those tunnel mechanical drainage systems will be re-tested when the Engineer can be in attendance.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 15445.001 – Tunnel Mechanical Drainage Systems and all Associated Equipment shall be measured as a lump sum unit, complete in place.

B. Item 15445.002 – Spare Tunnel Mechanical Drainage Equipment shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 15445.001 – Tunnel Mechanical Drainage Systems and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

B. Item 15445.002 – Spare Tunnel Mechanical Drainage Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 15446

TPSS SUMP PUMPS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for the Traction Power Substation (TPSS) sump pumps, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design detailing, manufacture detailing, supply, delivery, off-loading, storage, furnish, install, testing and commissioning of the new TPSS sump pumps and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the TPSS sump pump portion of the work. The Contractor shall be responsible to provide a completed design for this portion of the work.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data"

B. [NOT USED]

C. [NOTUSED]

D. [NOTUSED]

E. [NOTUSED]

1.03 REFERENCE STANDARDS

A. ANSI

B. ASTM

C. AWS

D. British Standards (BS)

E. IEEE

F. ISO

G. SSPC

1.04 SUBMITTALS

A. Submit copies of Working Plans and Certificates to the Engineer in compliance with the requirements of Article 3.03 of this Section.

B. Shop Drawings
   1. Submit drawing for sump pump systems, showing layout, location, size of system components, installation requirements and details of materials and methods of attachments.

C. Operation and Maintenance Data
   1. Submit complete instructions, including catalog cuts, diagrams, drawings and other descriptive data covering proper operation and, maintenance of each type of system installed, and necessary information for ordering replacement parts.

D. Maintenance Materials
   1. Submit in manufacturer's standard unopened containers, with label affixed, showing manufacturer's name, brand name, and type of item contained within, one spare valve of every type installed.

E. Manufacturer's Literature
   1. Submit literature completely describing products installed as part of the work.

F. The documentation provided shall include key manufacturing quality assurance reports, including the testing procedures carried out for material quality and structural integrity and the results in terms of defects noted.

G. The Contractor shall submit the following sump pump manufacturer certificates and details on the sump pumps upon Notice to Proceed.
   1. Evidence that the materials selected and the assembled product will have a service life expectancy of not less than 20 years with reasonable maintenance.
   2. Provide a list of 3 other projects where comparable sump pumps have been in satisfactory operation for a minimum period of 5 years.
   3. Factory quality control plan and manufacturing schedule.
   4. Estimated mean time between failure (MTBF).
   5. Estimated mean time between service failure (MTBSF).
   6. Mean time to repair (MTTR).
   7. Recommended planned maintenance schedule.
   8. Proposed galvanizing and/or painting regime.
   9. Completed equipment schedule as per Table 15446-1 of this Section.

H. The Contractor shall submit the following manufacturer certificates and details below before delivery to the Worksite. The documentation delivery schedule is to be proposed by the Contractor in the Project Schedule.
   1. Evidence that the materials selected and the assembled product will have a service life expectancy of not less than 20 years with reasonable maintenance.

2. Factory quality control records, inspection checklists and test reports.
3. Estimated mean time between failure (MTBF).
4. Estimated mean time between service failure (MTBSF).
5. Mean time to repair (MTTR).
6. Recommended planned maintenance schedule.
7. Operation and maintenance manuals – these manuals shall describe the recommended maintenance, all design parameters, and the designations, part numbers and commercial sources of spare parts. Manual formats and numbers shall be in accordance with Project requirements. As a minimum three copies shall be provided.
8. Completed equipment schedule as per Table 15446-1 of this Section.

I. Equipment requirements are listed in Table 15446-1 of this Section and are shown on the Contract Drawings. The items in Table 15446-1 of this Section listed as "By Contractor" shall be completed by the Contractor as required by the Submittals of this Section. Equipment information and/or data sheets shall be submitted with the completed Table 15446-1.

TABLE 15446-1 Nominal Sump Pump Performance Requirements

Equipment Number	TPSS-SSP-101	TPSS-SSP-102
Make	By Contractor	By Contractor
Model	By Contractor	By Contractor
Type/Notes	Submersible with in-built float switch	Submersible with in-built float switch
Depth (in)	By Contractor	By Contractor
Width (in)	By Contractor	By Contractor
Length (in)	By Contractor	By Contractor
Flow Rate (gpm)	By Contractor	By Contractor
Pump Head (in wg)	5 (estimate)	5 (estimate)
Power (hp)	By Contractor	By Contractor

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Materials
1. The Contractor shall provide all manufactured items, materials, labor, cartage, tools, plant, appliances and fixings necessary for the proper execution of the work, together with all minor and incidental works.
2. Should the Contractor propose any deviations from the specified requirements, such variations shall be submitted in writing to the Engineer for approval.

3. This Section shall be read in conjunction with the relevant Contract Drawings.

B. Design Life
   1. Elements of the sump pump system shall be designed for an operating life of 20 years. Pipework elements shall have a minimum life of 20 years.

C. Serviceability of Electrical and Mechanical Equipment
   1. Serviceability of elements shall be considered in the detailed design.

D. Equipment Identification
   1. All items shall be permanently labeled after installation. All labels shall be of a uniform format. Metal tags are acceptable for valves.

E. Equipment Locations
   1. The Contract Project Drawings and schematics show the location and arrangement of the sump pump system equipment.

2.02 SUMP PUMPS

A. Sump Pump Performance
   1. Duty and standby pumps shall be installed. Pumps shall be of the submersible type. Flow capacity is to be determined by the contractor. Required pump head is estimated in Table 15446-1. Pump motors shall be flame proof.
   2. Control of the TPSS sump pumps shall be by level detection.

B. Level Detection
   1. The Low Level Alarm and Duty Pump stop levels shall be confirmed upon the selection of the pump by the Contractor. All other detection levels shall be provided as shown in the Contract Drawings.
   2. Levels shall be reported to the control system. Level detectors shall be of the float type.

C. Agitators
   1. Depending on the pump selection, agitators may be required. The Contractor shall determine this requirement.

D. Oil Detection
   1. Oil smart pump switch shall be provided and installed with the TPSS sum pumps.
   2. Oil detection shall be reported to the control system

2.03 PIPEWORK

A. Outlet Pipe work and Valves
   1. Outlet pipework and valves shall be provided by the contractor sufficient to discharge over the south edge of the oil retention pit. The Contractor shall be

responsible for all work and approvals associated with connection of this pipe work.

2.04 INSTALLATION

A. [NOT USED]

B. Cables
   1. The Contractor shall provide power and control cables. These shall run from the devices in the sump pit to a local control panel. This panel shall be provided by Contractor. Electrical connection will be a D-Contactor plug. Controls will be to contacts in the local control panel.

C. Equipment Surface Corrosion Protection
   1. Appropriate anti-corrosion provisions shall be made by the Contractor for all components, based on SSPC standards suitable for installation conditions. The Contractor shall provide information regarding material selections and galvanizing and painting schemes.

2.05 [NOT USED]

ARTICLE 3 EXECUTION

3.01 GENERAL

A. All equipment shall be installed in readily accessible positions.

B. All fastenings shall be galvanized. Spring and flat washers shall be provided under nuts or bolt heads where necessary. Other fastenings shall be securely locked. Each bolt or stud shall be shortest standard length, which will show at least one full thread beyond its nut after assembly. Studs shall be screwed home at least $1^1/_4$ diameters.

C. All work specified, shall be installed in an approved manner to meet structural, architectural and other site and/or service conditions.

D. All pipework must be constructed so that it is free for contraction and expansion movements so that it shall not damage any other work or itself.

E. Special care shall be taken in the management of piping to ensure neat and workmanlike appearance and true alignment and grade.

F. All pipes and fittings shall be thoroughly cleared before erection, removing all scale, burrs, fins and obstructions. The section shall be blown out to remove all scale, slug, pipe-cutting residue, etc. before final flushing.

G. Protection

1. Throughout the installation of all piping, special care shall be continuously exercised to protect all openings to prevent the admission of any dirt, stones or other foreign substances that would subsequently obstruct the system. Close pipe openings with caps or plugs during installations.

3.02 PAINTING AND CORROSION PROTECTION

A. The Contractor shall make provisions for painting and corrosion protection based on SSPC standards suitable for installation conditions.

B. Submit painting and corrosion protection data to the Engineer for approval.

C. The Contractor shall provide full details of the proposed painting and corrosion protection system.

D. Final color shall be as agreed with the Engineer.

3.03 SITE TESTING AND COMMISSIONING

A. Testing and commissioning shall include, but not be limited to, the following:
   1. Operation of the TPSS sump pumps (flow volume and direction);
   2. Operation of level detection and pump control; and
   3. Operation of TPSS sump pump for oil detection.

B. All tests shall be documented for submission.

C. All sump pump testing shall be shown as a witness point in the Project Schedule. At least 2 weeks notice of testing shall be given to the Engineer.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 15446.001 – TPSS Sump Pumps shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 15446.001 – TPSS Sump Pumps will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 15884

TUNNEL FIRE EXTINGUISHERS AND CABINETS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, material, tools, equipment, and incidentals necessary for tunnel fire extinguishers and cabinets, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design detailing, manufacture detailing, supply, delivery, off-loading, storage, furnish, install, testing and commissioning of the tunnel fire extinguishers and cabinets and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel fire extinguisher and cabinets portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data"

B. Section 01911, "Operations, Maintenance and Repair Database"

C. Section 09902, "Painting"

D. Section 15400, "Tunnel Services Scope of Work"

E. Section 15885, "Tunnel Dry Standpipe Systems"

F. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

1.03 REFERENCE STANDARDS

A. ASTM

B. NAAMM

C. NFPA

D. SSPC

E. UL

1.04 SUBMITTALS

A. All drawing, calculation and design submittals shall be sealed by a Professional Engineer.

B. Submit copies of Working Plans and Certificates to the Engineer in compliance with the requirements of Article-3.03 of this Section.

C. Product Data
   1. Submit Product Data showing material proposed. Submit sufficient information to determine compliance with the Contract Documents. Product Data shall include, but shall not be limited to, construction details, material descriptions, dimensions of individual components and profiles, and finishes for fire extinguishers and cabinets, and as follows:
      a. Fire Extinguishers: Include rating and classification.
      b. Cabinets: Include roughing-in dimensions, details showing mounting methods, relationships of box and trim to surrounding construction, door hardware, cabinet type, trim style and panel style.

D. Shop Drawings
   1. Submit Shop Drawings for each product and accessory required to the Engineer prior to procurement and installation. Include information not fully detailed in manufacturer's standard product data, including, but not limited to the following:
      a. For fire protection cabinets, include plans, elevations, sections, details, and attachments to other work.

E. As Built Drawings
   1. Submit As Built Drawings for the fire extinguishers and cabinets, showing layout, location, installation details and naming and numbering of each installation. These shall be submitted to the Engineer upon Substantial Completion of the fire extinguisher and cabinet systems.

F. Samples
   1. Submit samples for verification purposes. Submit 6 inch by 6 inch samples of each type of cabinet finish indicated, of same thickness and material used for the work. If finishes involve normal color and texture variations, include sets showing the full range of variations.

G. Qualification Data
   1. Submit qualification data for firms and persons specified in Article 1.05 of this Section to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names of engineers and owners, and other information specified.

H. Operation and Maintenance Data

1. Submit complete instructions, including catalog cuts, diagrams, drawings and other descriptive data covering proper operation, maintenance of each type of system installed, and necessary information for ordering replacement parts. Additionally, include a copy of NFPA 10.

I. Manufacturer's Literature
   1. Submit literature completely describing products installed within the system.
   2. Manufacturer recommendations for handling and long term storage of any spare equipment.

J. Certificates
   1. Submit certificates certifying compliance of materials and work with standards designated.

1.05 QUALITY ASSURANCE

A. Qualifications
   1. Manufacturer Qualifications
      a. Manufacturer shall be a firm engaged in the manufacture of fire extinguishers and cabinets of types and sizes required, and whose products have been in satisfactory use in similar service for a minimum of five years.
   2. Installer Qualifications
      a. Installer shall be a firm that shall have a minimum of five years of successful installation experience with projects utilizing fire extinguishers and cabinets similar in type and scope to that required for this Project.

B. Regulatory Requirements
   1. Comply with applicable requirements of the laws, codes, ordinances, and regulations of Federal, State, and local authorities having jurisdiction. Obtain necessary approvals from such authorities.

C. Standards for Fire Extinguishers
   1. Fabricate and label fire extinguishers to comply with NFPA 10. Fire extinguishers shall be listed and labelled for type, rating, and classification by an independent inspecting and testing agency acceptable to authorities having jurisdiction.

D. Single Source Responsibility
   1. Obtain extinguishers and cabinets from one source from a single manufacturer.

E. Coordination
   1. Coordinate size of fire extinguisher cabinets to ensure that type and capacity of fire extinguishers indicated are accommodated.
   2. Coordinate sizes and locations of fire extinguisher cabinets with wall depths provided by other Authority Contracts.

F. Requirements of Regulatory Agencies

1. Provide fire extinguishers and cabinets conforming to the requirements of NFPA 10 and the requirements of governmental agencies having jurisdiction.
2. Working Drawings and Certificates: Provide Working Drawings, calculations and materials lists and test certificates to the governmental agencies having jurisdiction as required for approval of the Work.
3. Fire-Rating Testing Agency Requirements: Testing agency for fire-rating certification shall have approval of the Engineer.

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Design Life
   1. Tunnel fire extinguishers and cabinets shall be designed for an operating life of 20 years unless noted otherwise.

B. Serviceability of Equipment
   1. Serviceability of elements shall be considered in the detailed design and shall be clearly identified in the Shop Drawings.
   2. Equipment must be accessible and serviced safely to the satisfaction of the Engineer.

C. Equipment Mounting
   1. Depending on the location, the fire extinguishers and cabinets are to be mounted in wall recesses or from the bored tunnel walls (i.e. two types of cabinets will be required – recessed and non-recessed).
   2. Fire extinguishers and cabinets shall be provided complete with mounting frames or points to enable mounting in the orientation as shown on Contract Drawings. The Contractor shall design and supply all mounting fixtures.

D. Equipment Identification
   1. Tunnel fire extinguishers and cabinets shall be permanently labeled after installation. All labels shall be of a uniform format. This format shall identify and provide information regarding extinguisher type, manufacturer and any other data required by authorities having jurisdiction and NFPA 10. Naming and numbering shall be in accordance with and Authority requirements and shall be coordinated with Authority.

E. Equipment Location
   1. The Contract Drawings show the intended locations of the fire extinguishers and cabinets.

2.02 MATERIALS

A. Provide materials and equipment that have fire rating certification, listing and label where applicable, complying with requirements of NFPA 10.

B. The Contractor shall provide all manufactured items, materials, labor, cartage, tools, plant, appliances and fixings necessary for the proper execution of the work, together with all minor and incidental works.

C. The fire extinguisher system shall be designed and installed in accordance with the requirements of NFPA 10 – Class C.

D. Should the Contractor propose any deviations from the specified requirements, such variations shall be submitted in writing to the Engineer for approval.

E. Stainless Steel
   1. ASTM A 666, Type 304.

2.03 FIRE EXTINGUISHERS

A. This Article shall be read in conjunction with the relevant Contract Drawings.

B. Manufacturers
   1. Fire extinguishers shall be manufactured by Potter-Roemer, or equivalent approved by the Engineer.

C. Provide fire extinguishers for each cabinet and other locations indicated, in colors and finishes selected by the Engineer from manufacturer's standard that comply with authorities having jurisdiction.
   1. Handles and Levers: Manufacturer's standard stainless steel.
   2. Instruction Labels: Include pictorial marking system complying with NFPA 10, Appendix B and bar coding for documenting fire extinguisher location, inspections, maintenance, and recharging.

D. Multi Purpose Dry Chemical Type: Provide UL -10A:120B:C, 20 pound nominal capacity, in enameled steel container.

2.04 FIRE EXTINGUISHER CABINETS

A. This Article shall be read in conjunction with the relevant Contract Drawings.

B. Manufacturers
   1. Recessed fire extinguisher cabinets shall be Model No. FRC-1706 as manufactured by Potter-Roemer, or equivalent approved by the Engineer.
   2. Surface mounted fire extinguisher cabinets shall be Model No. 1756 as manufactured by Potter-Roemer, or equivalent approved by the Engineer.

C. Cabinet Construction
   1. Provide manufacturer's standard box, with trim, frame, door, and hardware to suit cabinet type, trim style, and door style indicated. Weld joints and grind smooth.

D. Cabinet Type

1. The cabinet type shall be suitable for containing the fire extinguishers in Article 2.03 of this Section.

E. Cabinet Metal
   1. Stainless steel sheet.

F. Recessed Cabinet Mounting
   1. Provide cabinet box fully recessed in walls of sufficient depth to suit style of trim indicated.
      a. Trimless with Hidden Flange: Trimless with hidden flange of same metal and finish as box that overlaps surrounding wall finish and concealed from view by an overlapping door.

G. Doors
   1. Fabricate doors according to manufacturer's standards, of materials indicated, and coordinated with cabinet types and trim style selected. Provide minimum 1/2 inch thick door frames, fabricated from tubular stiles and rails, and hollow metal design. Miter and weld perimeter door frames.
      a. Door Material: Stainless steel.
      b. Door Style: Provide manufacturer's standard design, as follows:
         1) Flush opaque panel, frameless, with no exposed hinges.
      c. Door Hardware: Provide manufacturer's standard door operating hardware of proper type for cabinet type, trim style, and door material and style indicated. Provide either lever handle with cam action latch, or exposed or concealed door pull and friction latch. Provide concealed or continuous type hinge permitting door to open 180 degrees.

2.05 ACCESSORIES

A. Mounting Brackets
   1. Provide manufacturer's standard steel brackets, designed to secure extinguisher, of sizes required for type and capacity of extinguisher indicated, in plated or baked enamel finish.

B. Lettered Door Handle
   1. Provide one piece cast iron door handle with the word "FIRE" embossed into face.

C. Door Locks
   1. Provide cylinder lock with all cabinets keyed alike.

D. Identification
   1. Provide lettering to comply with authorities having jurisdiction for letter style, color, size, spacing, and location. Locate as indicated by the Engineer.
      a. Identify fire extinguisher in cabinet with "FIRE EXTINGUISHER" lettering applied to door.

1) Application Process: Engraved.

b. Identify bracket mounted extinguishers with "FIRE EXTINGUISHER" in red letter decals applied to wall surface.

2.06 FINISHES

A. General

1. Comply with NAAMM MFM for recommendations relative to applying and designating finishes.
2. Protect mechanical finishes on exposed surfaces from damage by applying temporary strippable protective covering prior to shipping.

B. Stainless Steel Finishes

1. Remove or blend tool and die marks and stretch lines into finish. Grind and polish surfaces to produce uniform directional textured polished finish indicated, free of cross scratches. Run grain with long dimension of each piece.
2. Bright, Directional Polish: AISI No. 4 finish.
3. Cleaning: Passivate and rinse surfaces after polishing. Remove embedded foreign matter and leave surfaces chemically clean.

2.07 SPARES

A. The Contractor shall provide the following spares:

1. Fire extinguishers – Two of each type installed.
2. Fire extinguisher cabinets – One of each type installed.

B. The spares shall be suitably packed for handling and for long term storage in accordance with manufacturer recommendations that have been approved by the Engineer and coordinated with Authority. Clear identification of the equipment shall be provided on the packaging. The Contractor shall be responsible for the transport and off-loading of any spares to a site nominated by Authority.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Examination

1. Verification of Conditions
   a. Examine areas and conditions under which the work is to be installed, and notify the Engineer in writing of any conditions detrimental to the proper and timely completion of the work. Do not proceed with the work until unsatisfactory conditions have been corrected.
   b. Examine walls and partitions for thickness and framing for cabinets to verify cabinet depth and mounting prior to cabinet installation.
   c. Beginning of the work shall indicate acceptance of the areas and conditions as satisfactory by the Contractor.

B. Installation
   1. Comply with manufacturer's written instructions for installing fire extinguishers and cabinets.
   2. Install in locations and at mounting heights indicated or, if not indicated, at heights to comply with applicable regulations of governing authorities.
      a. Prepare recesses in walls for cabinets as required by type and size of cabinet and style of trim and to comply with manufacturer's instructions.
      b. In the bored tunnel the surface mounted cabinets shall be installed such that they do not cause obstruction to the emergency walkway.
      c. Fasten mounting brackets to structure and cabinets, square and plumb.
      d. Fasten cabinets to structure, square and plumb.

C. Adjusting
   1. Adjust cabinet doors that do not swing or operate freely. Refinish or replace cabinets and doors damaged during installation, as acceptable to the Engineer.

D. Protection
   1. Provide final protection and maintain conditions in a manner acceptable to the Contractor, that shall ensure that the fire extinguishers and cabinets shall be without damage at time of Substantial Completion.
   2. Where equipment is mounted along the emergency walkway it shall be positioned such that it does not present a hazard or obstruction to occupants or personnel using the emergency walkway.

E. All fastenings shall be galvanized. Spring and flat washers shall be provided under nuts or bolt heads where necessary. Other fastenings shall be securely locked. Each bolt or stud shall be shortest standard length, which will show at least one full thread beyond its nut after assembly. Studs shall be screwed home at least 1 ¼ diameters.

F. All work shall be installed in an approved manner to meet structural, architectural and other site and/or service conditions.

3.02 PAINTING AND CORROSION PROTECTION

A. The Contractor shall make provisions for painting and corrosion protection based on SSPC standards suitable for installation conditions.

B. The Contractor's standard for painting and corrosion protection shall be subject to approval by the Engineer.

C. The Contractor shall provide full details of the proposed painting and corrosion protection system.

D. All painting shall be in accordance with Section 09902, "Painting".

E. Final color shall be as agreed with the Engineer.

3.03 FIELD QUALITY CONTROL

A. Preparation
   1. Prior to acceptance testing, fire extinguishers and cabinets shall be cleaned in preparation for acceptance tests.

B. Acceptance Testing Certification and Approvals
   1. Perform acceptance testing and certification of fire protection systems and obtain approvals in accordance with applicable requirements of NFPA 10 and Authority.

3.04 SITE TESTING AND COMMISSIONING

A. Testing and commissioning shall include, but not be limited to, the following:
   1. System acceptance tests in accordance with NFPA 10.

B. All tests shall be documented for submission in accordance with NFPA 10.

C. All testing shall be shown as a witness point in the Contractor's Project Schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Site testing carried out without sufficient notice will be deemed to have not been done and shall be re-tested when the Engineer can be in attendance.

D. Upon completion of the site testing and commissioning to the satisfaction of the Engineer, the Contractor shall secure the fire extinguisher cabinets with plastic ties. The fire extinguisher cabinets shall remain unlocked.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 15884.001 – Tunnel Fire Extinguishers and all Associated Equipment shall be measured as a lump sum unit complete in place.

B. Item 15884.002 – Tunnel Fire Extinguisher Cabinets and all Associated Equipment shall be measured as a lump sum unit complete in place.

C. Item 15884.003 – Spare Tunnel Fire Extinguishers and Cabinets shall be measured as a lump sum unit complete in place.

4.02 PAYMENT

A. Item 15884.001 – Tunnel Fire Extinguishers and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

B. Item 15884.002 – Tunnel Fire Extinguisher Cabinets and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

C. Item 15884.003 – Spare Tunnel Fire Extinguishers and Cabinets will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 15885

TUNNEL DRY STANDPIPE SYSTEMS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for the tunnel fire protection systems, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
  1. Design detailing, manufacture detailing, supply, delivery, off-loading, storage, furnish, install, testing and commissioning of the new mechanical tunnel fire protection system and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel fire protection systems portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data"

B. Section 01911, "Operations, Maintenance and Repair Database"

C. Section 09902, "Painting"

D. Section 05120, "Structural Steel"

E. Section 07841, "Fire Stop and Barrier Systems"

F. Section 15400, "Tunnel Services Scope of Work"

G. Section 15884, "Tunnel Fire Extinguishers and Cabinets"

H. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

1.03 REFERENCE STANDARDS

A. ASME

B. ASTM

C. AWS

D. NFPA

E. SSPC

F. UL

1.04 SUBMITTALS

A. All drawing, calculation and design submittals shall be sealed by a Professional Engineer.

B. Submit copies of Working Plans and Certificates to the Engineer in compliance with the requirements of Article-3.03 of this Section.

C. Submit copies of Plans, specifications and hydraulic calculations to the authorities having jurisdiction prior to installation of the system in accordance with NFPA 14.

D. Shop Drawings
   1. Submit Shop Drawings for tunnel dry standpipe systems, showing layout, location, size of system components, installation requirements and details of materials and methods of attachment and sleeve construction. These shall be submitted to the Engineer for approval prior to procurement and installation of any components of the tunnel dry standpipe systems.

E. As Built Drawings
   1. Submit As Built Drawings for the tunnel dry standpipe systems, showing layout, location, size of system components, installation conditions, attachments, expansions joints, isolation valves and any other relevant information. These shall be submitted to the Engineer for approval upon Substantial Completion of the tunnel dry standpipe systems portion of the Work.

F. Samples
   1. Submit samples for verification purposes. Submit 6 inch samples of each type of pipework indicated, of same thickness and material used for the work.

G. Qualification Data
   1. Submit qualification data for firms and persons specified in Article 1.05 of this Section to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names of engineers and owners, and other information specified.

H. Operation and Maintenance Data
   1. Submit complete instructions, including catalog cuts, diagrams, drawings and other descriptive data covering proper operation, maintenance of each type of system installed, and necessary information for ordering replacement parts. Additionally, include a copy of NFPA 13 and 14.

I. Manufacturer's Literature
   1. Submit literature completely describing products installed within the system.

2. Manufacturer recommendations for handling and long term storage of any spare equipment.

J. Certificates
   1. Submit certificates certifying compliance of materials and work with standards designated.

1.05 QUALITY ASSURANCE

A. Qualifications
   1. Manufacturer Qualifications
      a. Manufacturer shall be a firm engaged in the manufacture of fire protection systems of the types and sizes required, and whose products have been in satisfactory use in similar service for a minimum of five years and has experience in the manufacture of systems in accordance with NFPA 13 and 14.
   2. Installer Qualifications
      a. Installer shall be a firm that shall have a minimum of five years of successful installation experience with projects utilizing fire protection systems similar in type and scope to that required for this Project and has experience in the installation of systems in accordance with NFPA 13 and 14.

B. Regulatory Requirements
   1. Comply with applicable requirements of the laws, codes, ordinances, and regulations of Federal, State, and local authorities having jurisdiction. Obtain necessary approvals from such authorities.

C. Standards for Tunnel Fire Protection Systems
   1. Fabricate and label fire protection systems to comply with NFPA 13 and 14. The tunnel fire protection systems shall be listed and labelled for type, rating, and classification by an independent inspecting and testing agency acceptable to authorities having jurisdiction.

D. Single Source Responsibility
   1. Obtain each type of valve and pipework from one source from a single manufacturer.

E. Coordination
   1. Coordinate size of standpipes and valves to ensure that type and location of equipment are accommodated by other Authority Contracts and adequate clearance is maintained between the tunnel fire protection system and the walkway.
   2. Coordinate with other Authority Contracts to ensure that the fill time of the standpipe system does not exceed 10 minutes.
   3. Coordinate sizes and locations of standpipes and valves with the other Authority Contracts responsible for the installation of the emergency walkway.

4. Coordinate connection to other pipe work which forms part of other Authority Contracts.
5. Coordinate connection to tunnel wall and under walkway with other Authority Contracts.
6. Coordinate with the local fire department the water supply (flow rate and pressure) available from a fire department pumper truck.

F. Requirements of Regulatory Agencies
1. Provide tunnel dry standpipe systems conforming to the requirements of NFPA 13 and 14, ASTM Standards, and the requirements of governmental agencies having jurisdiction.
2. Working Drawings and Certificates: Provide Working Drawings, calculations and materials lists and test certificates to the governmental agencies having jurisdiction as required for approval of the Work.
3. Fire-Rating Testing Agency Requirements: Testing agency for fire-rating certification shall have approval of the Engineer.

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Design Life
1. Tunnel fire protection systems shall be designed for an operating life of 20 years unless noted otherwise.

B. Serviceability of Equipment
1. Serviceability of elements shall be considered in the detailed design and shall be clearly identified in the Shop Drawings.
2. Equipment must be accessible and serviced safely to the satisfaction of the Engineer.

C. Equipment Mounting
1. Depending on the location, the tunnel dry standpipe systems are to be mounted in configurations from tunnel ceilings, tunnel walls and the tunnel walkways.
2. Tunnel dry standpipe systems shall be provided complete with mounting frames or points to enable mounting in the orientation as shown on Contract Drawings. The Contractor shall design and supply all mounting fixtures.

D. Equipment Identification
1. All items shall be permanently labeled after installation. All labels shall be of a uniform format. Metal tags are acceptable for values. Naming and numbering shall be in accordance with any Authority requirements and shall be coordinated with Authority.

E. Equipment Location

1. The Contract Drawings show the intended locations of the tunnel fire protection system.

2.02 MATERIALS

A. Provide materials and equipment that have fire rating certification, listing and label where applicable, complying with requirements of NFPA 13 and 14.

B. The Contractor shall provide all manufactured items, materials, labor, cartage, tools, plant, appliances and fixings necessary for the proper execution of the work, together with all minor and incidental works.

C. The standpipe system shall be designed and installed in accordance with the requirements of NFPA 14 – Class I.

D. The standpipe system shall be designed and installed for a minimum flow rate of 500 gpm at 100 psi at the hydraulically most remote location.

E. The tunnel fire protection systems shall include the following:
   1. A dry standpipe system including all associated equipment in the tunnel as indicated on the Contract Drawings.
   2. Tunnel fire extinguishers and cabinets are part of Section 15884, "Tunnel Fire Extinguishers and Cabinets".

F. The tunnel fire protection system outlined in this Section does not include the following:
   1. The pipework between the surface fire department connections and the tunnel dry standpipe at the Contract limits between Contracts, unless specified otherwise on the Contract Drawings.

G. Should the Contractor propose any deviations from the specified requirements, such variations shall be submitted in writing to the Engineer for approval.

H. This Section shall be read in conjunction with the relevant Contract Drawings.

2.03 DRY STANDPIPE

A. Pipework
   1. ASTM A53, galvanized steel, Schedule 40, with square-cut grooved ends.
   2. Pipework shall meet the requirements of ANSI B21, B31 and B125.
   3. All pipework shall be sized as indicated on the Contract Drawings.

B. Fittings
   1. Galvanized malleable iron with square-cut grooved ends.
   2. Pipe fittings shall meet the requirements of ANSI B16.

C. Couplings

1. Provide couplings designed for use with grooved pipe, galvanized malleable iron, complete with galvanized nuts and bolts.
2. Nuts
   a. Tamperproof type.
3. Gaskets
   a. As recommended by manufacturer.

D. Fire Hose Valves
   1. 2-½ inch valve as approved by the local fire department (6 tpi).

E. Isolation Valves
   1. Gate valve or butterfly valve, 300 psi working pressure, iron body, bronze trim.
   2. Isolation values shall be able to be locked in the open position.

F. Drain Valves
   1. 2 inch full port ball valve, 300psi working pressure, iron body, bronze trim.

G. Air Vents
   1. Automatic air vents to release air for testing.
   2. To be installed at high points in the system as indicated on the Contract Drawings.

H. Combination Air Vents/Vacuum Breaker
   1. 2 inch APCO 145C.

2.04 SPARES

A. The Contractor shall provide the following spares:
   1. Valves – One of each type installed.

B. The spares shall be suitably packed for handling and for long term storage in accordance with manufacturer recommendations that have been approved by the Engineer and coordinated with Authority. Clear identification of the equipment shall be provided on the packaging. The Contractor shall be responsible for the transport and off-loading of any spares to a site nominated by Authority.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Examination
   1. Verification of Conditions
      a. Examine areas and conditions under which the work is to be installed, and notify the Engineer in writing, of any conditions detrimental to the proper and timely completion of the work. Do not proceed with the work until unsatisfactory conditions have been corrected.
      b. Beginning of the work shall indicate acceptance of the areas and conditions as satisfactory by the Installer.

B. The tunnel standpipes are fed from surface connections that form part of other Authority Contracts unless noted otherwise on the Contract Drawings. The Contractor shall coordinate the connection at each end of the stations with the other Authority Contracts.

C. Welding will not be permitted except with the specific written authorization of the Engineer. When authorized, welding shall be in accordance with NFPA 13 and 14 and AWS D109 level AR-3. At least 10% of field welds shall be x-rayed and at least 10% of shop welds shall be x-rayed.

D. Provide for thermal expansion of piping by provision of expansion joints in accordance with requirements of NFPA 13 and 14. Additionally, provide anchors, guides and other devices as required for proper support and as indicated on the Contract Drawings.

E. Valves
   1. Valves
      a. Install isolation valves as indicated on the Contract Drawings.
      b. Install drain valves as indicated on the Contract Drawings. Drain valves shall be installed on the underside of pipework to allow full drainage of pipework. All drain valves shall be capped after installation.
      c. Install fire hose valves as indicated on the Contract Drawings.
      d. Install automatic air vents as indicated on the Contract Drawings.
      e. Install combination air vents/vacuum breaker as indicated on the Contract Drawings.

F. Connections and Joints
   1. Provide threaded connections or grooved joints complying with requirements of NFPA 13 and 14.

G. All equipment shall be installed in readily accessible positions.

H. Where equipment is mounted along the emergency walkway it shall be positioned such that it does not present a hazard or obstruction to occupants or personnel using the emergency walkway.

I. The Contractor shall ensure that the dry standpipe system and all associated equipment does not encroach into the LRV or pantograph clearance envelope.

J. All fastenings shall be galvanized. Spring and flat washers shall be provided under nuts or bolt heads where necessary. Other fastenings shall be securely locked. Each bolt or stud shall be shortest standard length, which will show at least one full thread beyond its nut after assembly. Studs shall be screwed home at least 1 ¼ diameters.

K. All work shall be installed in an approved manner to meet structural, architectural and other site and/or service conditions.

L. All pipework must be so constructed that it shall be free for contraction and expansion so that it shall not damage any other work or itself.

M. Provide for thermal expansion of piping by provision of expansion joints spaced at least every 200ft and around isolation valves. The Contractor shall consider the ambient temperature at the time of installation to ensure that the expansion joints have been installed for adequate expansion and contraction over the range of expected operating temperatures. It is estimated that temperatures will range between 32°F and 104°F.

N. Special care shall be taken in the arrangement of piping to ensure neat and workmanlike appearance and true alignment and grade.

O. All pipes and fittings shall be thoroughly cleaned before erection, removing all scale, burrs, fins and obstructions and the section shall be blown out to remove all scale, slag, pipe-cutting residue, etc. before final flushing.

P. Support piping so that hangers or saddle clamps shall sustain load and properly secure piping to prevent vibration when piping is in use. Support intervals shall not exceed 10 feet. Provide at least one hanger for each pipe section. Hangers and clamps shall also be installed at each offset or change in direction and at each hose valve connection.

Q. Grade piping where necessary so that the entire system can be drained. Provide 2 inch full port drain valves at low points in system not drained by a fire hose valve.

R. Provide piping passing through walls and other locations as indicated with sleeves with annular space between pipe and sleeve sealed in an approved manner. Where fire isolation is required between spaces separated by walls, fire stopping shall be provided in accordance with Section 07841, "Fire Stop and Barrier Systems".

S. Grooved Piping
   1. Prepare and groove piping in accordance with the coupling manufacturer's instructions. Pipe shall be free from indentations, projections, or roll marks for proper gasket seating.
   2. Before installation, verify that gasket supplied is as specified for service intended.
   3. Apply gasket lubricant supplied by coupling manufacturer so that gasket will not be pinched upon assembly. Apply a uniform coat over exterior surface of gasket on the pipe and coupling surface.
   4. Install gasket and coupling in accordance with the manufacturer's instructions.

T. Protection
   1. Throughout the installation of all piping, special care shall be continuously exercised to protect all openings to prevent the admission of any dirt, stones or other foreign substances that would subsequently obstruct the system. Close pipe openings with caps or plugs during installation.

2. Throughout the installation of all piping, special care shall be continuously exercised to protect all galvanizing from damage. Any galvanizing that is damaged shall be reported to the Engineer and repaired to the satisfaction of the Engineer.

3.02 PAINTING AND CORROSION PROTECTION

A. The Contractor shall make provisions for painting and corrosion protection based on SSPC standards suitable for installation conditions.

B. The Contractor's standard for painting and corrosion protection shall be subject to approval by the Engineer.

C. The Contractor shall provide full details of the proposed painting and corrosion protection system.

D. All painting shall be in accordance with Section 09902, "Painting".

E. Final color of any paintwork shall be as agreed with the Engineer.

3.03 FIELD QUALITY CONTROL

A. Preparation
1. Prior to acceptance testing, dry standpipe systems shall be flushed.
2. Flush fire protection systems with clean water until it is free of scale, slag, dirt, grease or other foreign material in accordance with applicable requirements of NFPA 14.
3. The Contractor shall provide the water supply for flushing of the system and ensure that the tunnels can be drained of any water that results from these activities.

B. Acceptance Testing Certification and Approvals
1. Perform acceptance testing and certification of dry standpipe systems and obtain approvals in accordance with applicable requirements of NFPA 14.
2. Perform acceptance testing and certification of dry standpipe systems and obtain approvals as required by the City of Pittsburgh.

3.04 SITE TESTING AND COMMISSIONING

A. Testing and commissioning shall include, but not be limited to, the following:
1. System acceptance tests in accordance with NFPA 14

B. All tests shall be documented for submission in accordance with NFPA 14.

C. All testing shall be shown as a witness point in the Contractor's Project Schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Site testing carried out without sufficient notice will be deemed to have not been done and shall be re-tested when the Engineer can be in attendance.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 15885.001 – Tunnel Dry Standpipe System and all Associated Equipment shall be measured as a lump sum unit complete in place.

B. Item 15885.002 – Spare Tunnel Dry Standpipe Valves shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 15885.001 – Tunnel Dry Standpipe System and all Associated Equipment will be paid at the lump sum price and shall include the cost of all work specified in this Section.

B. Item 15885.002 – Spare Tunnel Dry Standpipe Valves will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 15887

TUNNEL VENTILATION AND BALANCING DAMPERS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for tunnel ventilation dampers, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design detailing, manufacture detailing, supply, delivery, off-loading, storage, furnish, install, testing and commissioning of the new tunnel ventilation dampers and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel ventilation dampers portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data"

B. Section 01911, "Operations, Maintenance and Repair Database"

C. Section 07841, "Fire Stop and Barrier Systems"

D. Section 05120, "Structural Steel"

E. Section 05520, "Miscellaneous Metal Work"

F. Section 15400, "Tunnel Services Scope of Work"

G. Section 15888, "Tunnel Ventilation Noise Attenuators"

H. Section 15889, "Tunnel Ventilation Fans"

I. Section 15890, "Tunnel Ventilation Jet Fans"

J. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

K. Section 16889, "Tunnel Services Electrical Testing and Commissioning"

L. Section 16890, "Tunnel Services Electrical Requirements for Mechanical Equipment"

M. Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center"

1.03 REFERENCE STANDARDS

A. Anti-friction Bearing Manufacturer's Association (AFBMA)

B. AMCA

C. ANSI

D. ASTM

E. AWS

F. British Standards (BS)

G. IEEE

H. ISO

I. NEMA

J. NFPA

K. SSPC

L. UL

1.04 SUBMITTALS

A. All drawing, calculation and design submittals shall be sealed by a Professional Engineer.

B. Submit certified results and details from the required shop testing prior to shipment of the dampers from the place of fabrication.

C. The documentation provided shall include key manufacturing quality assurance reports, including the testing procedures carried out for material quality and structural integrity and the results in terms of defects noted.

D. Shop Drawings
   1. Submit Shop Drawings for tunnel ventilation and balancing dampers showing layout, location, size of system components, installation conditions, mounting details, actuator details and any other relevant information. These shall be submitted to the Engineer for approval prior to procurement and installation of any components of the tunnel ventilation and balancing dampers.

E. As Built Drawings
   1. Submit As Built Drawings for tunnel ventilation and balancing dampers showing layout, location, size of system components, installation conditions, mounting details, actuator details and any other relevant information. These shall be submitted to the Engineer for approval upon Substantial Completion of the tunnel ventilation and balancing dampers portion of the Work.

F. The Contractor shall submit the following manufacturing certificates and details within 60 days of Notice to Proceed.
   1. Certified performance curves and data for leakage and pressure drop for similar application damper modules at the specified conditions (UL555).
   2. Recent 482°F temperature and thermal shock tests on modules as proposed for the complete dampers.
   3. Evidence that materials selected and the assembled product has a service life expectancy of not less than 20 years with reasonable maintenance. This shall include details of corrosion protection.
   4. Certified differential pressure and cycle tests for modules as proposed.
   5. Schedule of at least 3 locations where comparable multiple module dampers have been in satisfactory operation for a minimum period of 5 years.
   6. Certified fire tests for a multiple module damper of similar construction and arrangement, indicating compliance with tests ISO 834 (BS 476 Part 20) or the UL555 equivalent.
   7. Estimated mean time between failure (MTBF).
   8. Mean time between service failure (MTBSF).
   9. Mean time to repair (MTTR).
   10. Manufacturer recommendations for handling and long term storage of any spare equipment.
   11. Estimated equipment loads and footing reactions for supporting structure.
   12. Details of proposed actuators.
   13. Dimensioned general arrangement and interface Shop Drawing of dampers for two representative arrangements.
   14. Details of quality test procedures and accreditation.
   15. Details of the instrumentation, including environmental specifications and standards to which they have been tested.
   16. Details of equipment surface corrosion protection.
   17. Completed equipment schedule as per Table 15887-1 and Table 15887-2.

G. The Contractor shall submit the manufacturing certificates and details below prior to delivery of the dampers to the Worksite. The documentation delivery Schedule shall be proposed by the Contractor in the Project Schedule and submitted to the Engineer for approval.
   1. Certified performance curves and data for leakage and pressure drop at the specified conditions (UL555).
   2. Recent 482°F temperature and thermal shock tests on modules as will be supplied for the complete dampers.

3. Evidence that materials selected and the assembled product has a service life expectancy of not less than 20 years with reasonable maintenance. This shall include details of corrosion protection.
4. Certified differential pressure and cycle tests for modules as will be supplied.
5. Certified fire tests for multiple module damper arrangements, indicating compliance with ISO 834 tests (BS 476 Part 20) or the UL555 equivalent.
6. Estimated mean time between failure (MTBF).
7. Mean time between service failure (MTBSF).
8. Mean time to repair (MTTR).
9. Manufacturer recommendations for handling and long term storage of any spare equipment.
10. Confirmation that each damper operates correctly prior to shipment.
11. Equipment loads and footing reactions for supporting steelwork.
12. Details of actuators for each damper.
13. Dimensioned general arrangement and interface Shop Drawing of all dampers.
14. Details of the instrumentation including environmental specifications and standards to which they have been tested.
15. Operation and maintenance manuals – these manuals shall describe the recommended maintenance, all design parameters and the designations, part numbers and commercial sources of spare parts. Manual format and numbers shall be in accordance with Authority requirements. As a minimum three copies shall be provided.
16. Details of equipment surface corrosion protection.
17. Completed equipment schedule as per Table 15887-1 and Table 15887-2.

H. High Temperature Testing
1. If manufacturing certificates are not available to certify the high temperature performance of dampers, the Contractor shall ensure that high temperature testing and all associated work is undertaken at no additional expense to Authority.
2. A high temperature testing plan and procedure shall be submitted to the Engineer for approval prior to undertaking the work.
3. A high temperature test report shall be submitted to the Engineer for approval prior to procuring the dampers and associated equipment. This report shall detail the tests completed, test results and all other relevant information to the satisfaction of the Engineer.

I. Equipment requirements are scheduled in Table 15887-1 and Table 15887-2 of this Section and are shown on the Contract Drawings. The items in Tables of this Section listed as "By Contractor" shall be completed by the Contractor as required by the Submittals of this Section. Equipment information and/or data sheets shall be submitted with the completed Table 15887-1 and Table 15887-2.

J. The damper width and depth in Table 15887-1 and Table 15887-2 are the overall internal dimensions when installed (i.e. dimension for air flow). The Contractor shall coordinate the required sizes with other Authority Contractors.

TABLE 15887-1 Tunnel Ventilation Damper Schedule – Gateway Station

Equipment Number	GW-TVD-101	GW-TVD-102	GW-TVD-103
Description	Fan isolation damper	Fan isolation damper	Tunnel bypass damper
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Parallel Blade
Depth (in) (nominal)	<12	<12	<12
Width (in) (nominal)	155	155	125
Length (in) (nominal)	110	110	125
Flange	By Contractor	By Contractor	By Contractor
Air Volume (kcfm)	159	159	159
Face Area (sft)	By Contractor	By Contractor	By Contractor
Pressure Loss Factor (K)	0.5 max	0.5 max	0.5 max
Actuation Type	Electric	Electric	Electric
Elevated Temperature Operations	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Modulating	No	No	No
Power Failure Position	Open	Closed	Closed

Equipment Number	GW-TVD-104	GW-TVD-105	GW-TVD-106
Description	Under platform damper (4 off)	Under platform damper (4 off)	Under platform damper (4 off)
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type	Aerofoil Multi-blade Opposed Blade	Aerofoil Multi-blade Opposed Blade	Aerofoil Multi-blade Opposed Blade
Depth (in) (nominal)	<12 (for each)	<12 (for each)	<12 (for each)
Width (in) (nominal)	80 (for each)	86 (for each)	80 (for each)
Length (in) (nominal)	42 (for each)	44 (for each)	42 (for each)
Flange	By Contractor	By Contractor	By Contractor
Air Volume (kcfm)	40 (for each)	40 (for each)	40 (for each)
Face Area (sft)	By Contractor	By Contractor	By Contractor
Pressure Loss Factor (K)	0.5 max	0.5 max	0.5 max
Actuation Type	Electric	Electric	Electric
Elevated Temperature Operations	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Modulating	Yes	Yes	Yes
Power Failure Position	Open	Open	Open

Equipment Number	GW-TVD-107	GW-TVD-108	GW-TVD-109
Description	Under platform damper (4 off)	Nozzle damper	Nozzle damper

Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type	Aerofoil Multi-blade Opposed Blade	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Parallel Blade
Depth (in) (nominal)	<12 (for each)	<12	<12
Width (in) (nominal)	86 (for each)	128	128
Length (in) (nominal)	44 (for each)	48	44
Flange	By Contractor	By Contractor	By Contractor
Air Volume (kcfm)	40 (for each)	80	80
Face Area (sft)	By Contractor	By Contractor	By Contractor
Pressure Loss Factor (K)	0.5 max	0.5 max	0.5 max
Actuation Type	Electric	Electric	Electric
Elevated Temperature Operations	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Modulating	Yes	No	No
Power Failure Position	Open	Closed	Closed

Equipment Number	GW-TVD-110	GW-TVD-111	GW-TVD-112
Description	Nozzle damper	Nozzle damper	Tunnel damper
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Parallel Blade
Depth (in) (nominal)	<12	<12	<12
Width (in) (nominal)	50	53	131
Length (in) (nominal)	108	108	102
Flange	By Contractor	By Contractor	By Contractor
Air Volume (kcfm)	80	80	159
Face Area (sft)	By Contractor	By Contractor	By Contractor
Pressure Loss Factor (K)	0.5 max	0.5 max	0.5 max
Actuation Type	Electric	Electric	Electric
Elevated Temperature Operations	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Modulating	No	No	No
Power Failure Position	Closed	Closed	Closed

Equipment Number	GW-TVD-113	Typical Platform Exhaust Inlet	Beardon Mural Exhaust Inlet
Description	Tunnel damper	Balancing damper (20 off)	Balancing damper (4 off)
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type	Aerofoil	Adjustable slide	Adjustable slide

	Multi-blade Parallel Blade	plate or opposed blade damper	plate or opposed blade damper
Depth (in) (nominal)	<12	< 12	< 12
Width (in) (nominal)	131	84	84
Length (in) (nominal)	107	40	20
Flange	By Contractor	By Contractor	By Contractor
Air Volume (kcfm)	159	30	30
Face Area (sft)	By Contractor	By Contractor	By Contractor
Pressure Loss Factor (K)	0.5 max	0.5 max	0.5 max
Actuation Type	Electric	Not Applicable	Not Applicable
Elevated Temperature Operations	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Modulating	No	Not Applicable	Not Applicable
Power Failure Position	Closed	Not Applicable	Not Applicable

TABLE 15887-2 Tunnel Ventilation Damper Schedule – North Side Station

Equipment Number	NS-TVD-201	NS-TVD-202	NS-TVD-203
Make	By Contractor	By Contractor	By Contractor
Description	Fan isolation damper	Fan isolation damper	Fan isolation damper
Model	By Contractor	By Contractor	By Contractor
Type	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Parallel Blade
Depth (in) (nominal)	<12	<12	<12
Width (in) (nominal)	150	150	150
Length (in) (nominal)	115	115	115
Flange	By Contractor	By Contractor	By Contractor
Air Volume (kcfm)	159	159	159
Face Area (sft)	By Contractor	By Contractor	By Contractor
Pressure Loss Factor (K)	0.5 max	0.5 max	0.5 max
Actuation Type	Electric	Electric	Electric
Elevated Temperature Operations	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Modulating	No	No	No
Power Failure Position	Open	Open	Open

Equipment Number	NS-TVD-204	NS-TVD-205	NS-TVD-206
Description	Fan isolation damper	Tunnel damper	Tunnel damper
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Parallel Blade
Depth (in) (nominal)	<12	<12	<12

Width (in) (nominal)	150	95	112
Length (in) (nominal)	115	72	72
Flange	By Contractor	By Contractor	By Contractor
Air Volume (kcfm)	159	40	40
Face Area (sft)	By Contractor	By Contractor	By Contractor
Pressure Loss Factor (K)	0.5 max	0.5 max	0.5 max
Actuation Type	Electric	Electric	Electric
Elevated Temperature Operations	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Modulating	No	No	No
Power Failure Position	Open	Open	Open

Equipment Number	NS-TVD-207	NS-TVD-208	NS-TVD-209
Make	By Contractor	By Contractor	By Contractor
Description	Tunnel damper	Tunnel damper	Platform duct damper
Model	By Contractor	By Contractor	By Contractor
Type	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Parallel Blade	Aerofoil Multi-blade Opposed Blade
Depth (in) (nominal)	<12	<12	<12
Width (in) (nominal)	129	146	TBA
Length (in) (nominal)	72	72	TBA
Flange	By Contractor	By Contractor	By Contractor
Air Volume (kcfm)	40	40	127
Face Area (sft)	By Contractor	By Contractor	By Contractor
Pressure Loss Factor (K)	0.5 max	0.5 max	0.5 max
Actuation Type	Electric	Electric	Electric
Elevated Temperature Operations	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Modulating	No	No	Yes
Power Failure Position	Open	Open	Open

Equipment Number	NS-TVD-210	NS-TVD-211	NS-TVD-212
Description	Platform duct damper	Mezzanine damper	Tunnel damper
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type	Aerofoil Multi-blade Opposed Blade	Aerofoil Multi-blade Opposed Blade	Aerofoil Multi-blade Parallel Blade
Depth (in) (nominal)	<12	<12	<12
Width (in) (nominal)	TBA	100	190
Length (in) (nominal)	TBA	96	100
Flange	By Contractor	By Contractor	By Contractor
Air Volume (kcfm)	127	64	159

Face Area (sft)	By Contractor	By Contractor	By Contractor
Pressure Loss Factor (K)	0.5 max	0.5 max	0.5 max
Actuation Type	Electric	Electric	Electric
Elevated Temperature Operations	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Modulating	Yes	Yes	No
Power Failure Position	Open	Open	Closed

Equipment Number	NS-TVD-213	Typical Platform Exhaust Inlet
Description	Tunnel damper	Balancing Damper (16 off)
Make	By Contractor	By Contractor
Model	By Contractor	By Contractor
Type	Aerofoil Multi-blade Opposed Blade	Adjustable slide plate or opposed blade damper
Depth (in) (nominal)	<12	<12
Width (in) (nominal)	190	TBA
Length (in) (nominal)	100	TBA
Flange	By Contractor	By Contractor
Air Volume (kcfm)	159	20
Face Area (sft)	By Contractor	By Contractor
Pressure Loss Factor (K)	0.5 max	0.5 max
Actuation Type	Electric	Electric
Elevated Temperature Operations	482°F for 1 hour	482°F for 1 hour
Modulating	No	Not Applicable
Power Failure Position	Closed	Not Applicable

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Materials
1. The Contractor shall provide all manufactured items, materials, labor, cartage, tools, plant, appliances and fixings necessary for the proper execution of the work, together with all minor and incidental works.
2. Should the Contractor propose any deviations from the specified requirements, such variations shall be submitted in writing to the Engineer for approval.
3. This Section shall be read in conjunction with the relevant Contract Drawings.

B. Design Life
1. Dampers and damper actuators shall be designed for an operating life of 20 years unless noted otherwise.

C. Serviceability of Dampers

1. Serviceability of dampers shall be considered in the detailed design and clearly identified in the Shop Drawings.
2. Lifting eyes shall be provided, and their locations shall be coordinated with the designs of the other Authority Contracts.
3. The modular design of the dampers, and the position of the actuators shall be coordinated with the building design and maintenance access around the installed damper.
4. Equipment shall be accessible and serviced safely to the satisfaction of the Engineer.

D. Movement
   1. The Contractor shall ensure that when installed, full operating movement is allowed for all dampers.

E. Equipment Mounting
   1. Dampers to be mounted on the floor shall be provided with galvanized steel upstands to keep the damper frame at least 4 inches above the floor except where specifically noted. The work shall be coordinated with other Authority Contracts as necessary.

F. Equipment Identification
   1. Dampers, actuators and control devices shall be permanently labeled after installation. All labels shall be of a uniform format. This format shall identify individual dampers and provide information regarding the damper type, function, flow direction and other such data as appropriate. Identification shall include the equipment designator given on Contract Drawings or in Table 15887-1 and Table 15887-2. Naming and numbering shall be in accordance with any Authority requirements and shall be coordinated with Authority.

G. Plantrooms and Layout
   1. The Contract Drawings show the layout of tunnel ventilation fan rooms and the positioning of dampers and attenuators. The inclusion of these layouts does not preclude alternative layouts if the merits of the alternatives can be clearly demonstrated, however, many dampers are located as coordinated with other Authority Contracts and can not be moved unless approved by the Engineer. Alternatives may not proceed without approval from the Engineer.

2.02 TUNNEL VENTILATION DAMPERS

A. Coordination

1. As the Contractor is procuring the tunnel ventilation noise attenuators in accordance with Section, "15888 Tunnel Ventilation Noise Attenuators", the Contractor is responsible for coordinating the size and arrangement of isolation dampers with the attenuator supplier. Other tunnel dampers need to be coordinated with other Authority Contracts.

B. Damper Types

1. All dampers shall be rectangular with multiple parallel blades (opening either parallel or opposed). They shall be suitable for horizontal, vertical or angled installation, but shall always be installed with the blade shafts horizontal.
2. Two-position (non-modulating) dampers shall be parallel blade type. Modulating or multi-position dampers shall be opposed blade type. The type is indicated in the equipment schedule, Table 15887-1 and Table 15887-2
3. The dampers shall all be supplied by a single manufacturer.

C. Damper Modules

1. Each damper shall be constructed of one or more modules. Each module shall be not greater than 6 feet in any dimension, and shall be a complete factory assembled unit contained in a steel channel frame. Each damper of more than one module shall be assembled at the Worksite by bolting each module onto a steelwork frame. It shall be possible to remove and install any module without having to remove other adjacent modules.
2. In order to reduce the effect of damper failures, each damper module shall be operated by at least one separate actuator. No damper module shall be greater than half the area of the total damper assembly.
3. Multiple actuators in one damper shall be controlled together, but failure of any one actuator shall generate a failure signal in the control system.
4. Dampers shall have a net free face area greater than 80 percent measured to the inside of the damper frame opening when blades are fully open.
5. To facilitate efficient management of replacement and spare parts, modules shall be interchangeable as far as possible between dampers.

D. Damper Frames

1. Damper module frames shall be constructed of galvanized steel formed into channel sections. Steel thickness shall be 1/8 inch or greater.
2. Lifting lugs shall be provided on the frame of each module and on the overall assembly frame.
3. All gaps between the damper frame, damper sub-frame and the structure shall be sealed using blanking plates fire rated at 482°F for 1 hour.
4. In some locations it may be necessary to mount dampers inside ductwork (i.e. on either side of the damper the duct dimension is equivalent to the damper dimension). In these instances, actuators, frames, mullions, etc. shall be arranged to minimize the duct pressure drop. The Engineer's approval is required for the

arrangement of any proposed dampers in this configuration. Where dampers can be face mounted over a floor or wall opening, the damper frame inside dimensions shall be at least as large as the opening, so that the damper frame provides no additional restriction.

5. Damper frames may be fabricated in multiple sections. The sections shall be sized such that they can be taken into fan rooms and vent shafts through access hatches provided.

E. Damper Blades

1. Damper blades shall be of double skin aerofoil cross-section, welded to stainless steel shafts. The blade width/depth in the direction of airflow shall not exceed 8 inches. The length shall not exceed 5 feet. Blades shall not extend beyond the damper frame when in the open position.
2. Blade shafts shall be carried in self-lubricating bearings housed in brackets welded to the outside of the module frame.
3. The gaps between the ends of the blades and the module frame shall be sealed by sprung stainless steel side seals.
4. Blades shall resist at least 2 million pressure cycles of ± 4 in wg without degradation of performance by fatigue.

F. Damper Actuators

1. Damper actuators shall be electrically operated, and mounted on the outside of the module frame.
2. Actuators shall be able to open or close dampers under the operating pressure of the fan systems.
3. Actuators shall be driven by electric motor designed for 120 V AC, 60 Hz supply. The motor enclosure rating shall be suited to the environment in which it is installed. A minimum NEMA 4X rating is required.
4. Where a single fail safe position is nominated, actuators shall have a spring return mechanism to allow fail-safe operation of the damper to the required fail safe position on loss of power. Where the requirement is to hold the current position on loss of power, the actuators shall drive both ways, with no spring return.
5. Actuators shall be designed with sufficient margin of torque to operate under all the specified conditions.
6. Modulating damper actuators shall be supplied with an analogue input to set the damper position and an analogue feedback of the actuator position.
7. Linkages shall be designed to withstand 150% of the maximum actuator torque.
8. One of each type and size of actuator module used shall have been tested under full load for at least 300,000 cycles with no sign of fatigue failure.
9. Actuators shall not obstruct the air stream unnecessarily. Where face mounted, actuators shall be outside the projection of the opening. Where mounted in-duct, actuators shall present the minimum possible profile to the airflow.
10. Actuators shall, as far as practical, be positioned on the side of the damper which allows best access for maintenance. Information on clearance to adjacent walls is provided on the contract drawings.

11. Each damper actuator shall be provided with a stainless steel nameplate permanently stamped with the name and address of the manufacturer, model number, supply voltage, spring rating, maximum output torque, angle of movement, operating pressure range, temperature endurance and designated damper number. All nameplates shall be fixed to the actuators such that they can be read when installed. Duplicate nameplates shall be fixed outside any covering required to meet the thermal tolerance requirements.

G. Pressure Loss, Leakage and Resistance

1. For all dampers, the loss coefficient when fully open (ratio of total pressure loss to full 'duct' or face area velocity pressure) shall be the minimum practical and shall not exceed 0.50.
2. When fully closed, the leakage through any damper shall not exceed 20 cfm/sqft of face area at 4 in wg differential pressure in either direction. The requirement for leakage shall be tested with an actuator of the same type to that which will be provided for the installed damper.
3. When fully closed, the dampers shall withstand a maximum differential pressure of 20 in wg in either direction without any permanent deformation or damage. Maximum blade deflection at this pressure shall not exceed 1/360 of blade span.
4. Damper manufacturers may propose an alternative recognized standard for leakage and strength. The Engineer's approval is required for alternatives to be used.

H. Damper Operation

1. Most dampers shall be controlled to move to either fully closed or fully open positions. Intermediate positions are required for some dampers nominated on the Contract Drawings or in Tables as 'modulating'. Motion shall be smooth without shock or slamming. Damper limit switches shall be installed on the damper shafts to indicate the open and closed positions. This applies to both non-modulating and modulating dampers. Position sensors wired back to the control panel shall be provided for modulating dampers. The switches and sensors shall be wired to a dedicated connection box. The limit switches, sensors and wiring must continue to be operable in the same high temperature regime specified for the dampers.
2. The time taken to move from one extreme position to the other, in either direction, shall not exceed 10 seconds.

I. Heat Resistance

1. Each damper, when installed and when open or closed, shall be able to withstand a temperature of 482°F for up to one hour, remaining operable without permanent distortion or buckling, and without damage to bearings, gaskets or seals or emission of toxic or noxious fumes. The actuators must continue to be operable under the same conditions. The Contractor shall ensure that electrical and communication connections to the damper actuators and limit switches maintain integrity under the same conditions.

2. For modulating dampers the actuation shall be configured to position the blades between 0% open and 100% open linearly on the application of a 4-20 mA control signal.
3. The dampers and actuators shall be capable of withstanding the thermal shock caused by temperature changing from 50°F to 482°F in 20 seconds.

J. Support Steelwork
1. Dampers shall be supplied complete with all support steelwork necessary;
   a. to support the damper modules;
   b. to provide sealing against leakage;
   c. to accommodate irregularities in the structural opening in which the damper is fitted; and
   d. to provide fire resistance to the same standard as that of the overall damper.
2. All support steelwork shall conform to Section 05120, "Structural Steel" and Section 05520, "Miscellaneous Metal Work". Support steelwork shall have the same thermal rating as the damper.

K. Other
1. Site Measurement
   a. The particular dampers required are designated on the Contract Drawings. The Contractor shall coordinate all plenum openings to be fitted with dampers and be responsible for correct fabrication to fit the openings.
2. Fixtures
   a. Dampers shall be supplied complete with all fixtures (nuts, bolts, spacers, washers, seals, packers etc) such that dampers and components supplied with the dampers can be completely assembled (e.g. damper modules are complete assemblies and fixtures are provided to bolt modules together). Fixtures to enable the mounting of dampers to ductwork openings shall be provided by the Contractor unless noted otherwise on the Contract Drawings.
3. Equipment Surface Corrosion Protection
   a. Unless specified, appropriate anti-corrosion provisions shall be made by the Contractor for all components based on SSPC standards suitable for installation conditions. The Contractor shall provide information regarding material selections and galvanizing and painting schemes.

2.03 BALANCING DAMPERS

A. General
1. Balancing dampers are located as shown on the Contract Drawings.
2. Balancing dampers are non-actuated dampers that shall be used at system commissioning to balance the ventilation air flow over a given length of ductwork.

B. Damper Types and Modules
1. The balancing dampers shall be supplied by a single manufacturer.

2. Each balancing damper shall be constructed of one or more modules. Each module shall be not greater than 6 feet in any dimension, and shall be a complete factory assembled unit contained in a steel channel frame. Each balancing damper of more than one module shall be assembled at the Worksite by bolting each module onto a steelwork frame.
3. To facilitate efficient management of replacement and spare parts, modules shall be interchangeable as far as possible between dampers.

C. Balancing Damper Operation

1. Each balancing damper shall have an adjustable slide plate or opposed blade damper for adjusting the opening free area in order to balance the flow during system commissioning.
2. All balancing dampers shall be adjustable from the platform side of the exhaust plenum.
3. It shall be possible to adjust the damper free area so that the air flow rate through any individual damper does not vary by more than 10% from the mean flow rate per damper along the length of duct required to be balanced. Once adjusted, the positions shall be locked to prevent tampering.

D. Pressure loss

1. For all balancing dampers, the loss coefficient (ratio of total pressure loss to full 'duct' area velocity pressure) shall be the minimum practical and shall not exceed 0.50 when the balancing damper is fully open.

E. Heat Resistance

1. Each balancing damper, when installed, shall be able to withstand a temperature of 482°F for up to one hour without permanent distortion or buckling, or emission of toxic or noxious fumes.
2. The balancing dampers shall be capable of withstanding the thermal shock caused by temperatures changing from 50°F to 482°F in 20 seconds.

F. Support Steelwork

1. Balancing dampers shall be supplied complete with all support steelwork necessary;
   a. To support the balancing damper modules;
   b. To accommodate irregularities in the structural opening in which the damper is fitted; and
   c. To provide fire resistance to the same standard as that of the overall damper.
2. The support steelwork shall comply with relevant United States codes. Support steelwork shall have (at the very least) the same thermal rating as the damper.

G. Other

1. Site Measurement
   a. The location of balancing dampers is designated on the Contract Drawings. The Contractor shall coordinate all plenum openings to be fitted with

balancing dampers and be responsible for correct fabrication to fit the openings.

2. Fixtures
   a. Balancing dampers shall be supplied complete with all fixtures (nuts, bolts, spacers, washers, seals, packers, etc) such that balancing dampers and components supplied with the balancing dampers can be completely assembled (e.g. balancing damper modules are complete assemblies and fixtures are provided to bolt modules together). Fixtures to enable the mounting of dampers to ductwork openings shall be provided by the Contractor unless noted otherwise on the Contract Drawings.
3. Equipment surface corrosion protection
   a. Unless specified, appropriate anti-corrosion provisions shall be made by the Contractor on all components based on SSPC standards suitable for installation conditions. The Contractor shall provide information regarding material selections, galvanizing schemes and painting schemes.

2.04 SCREENS

A. General
   1. The Contractor shall provide damper screens as described by this Section and as shown on the Contract Drawings.
   2. The screens shall be supplied complete with a mounting frame for rigidity.
   3. Reversibility of fans shall be accommodated.
   4. Screen flanges shall bolt to damper frame flanges.

B. Prevention of debris ingress
   1. Mesh screens shall be provided at all potential debris ingress points.
   2. These screens shall have an open area of greater than 95% of the net area.
   3. The loss coefficient shall be the minimum practical and shall not exceed 0.10 based on the face velocity.

C. Horizontally mounted dampers
   1. Horizontally mounted dampers above the track shall be supplied complete with mesh screens with mesh openings of 1 inch by 1 inch.
   2. These shall be located on the underside of the damper to prevent tools or other objects falling onto the catenary or tracks.
   3. These screens shall have an open area of greater than 80% of the net area.
   4. The loss coefficient shall be the minimum practical and shall not exceed 0.30 based on the face velocity.

D. Screens provided by other Authority Contracts
   1. Mesh screens at the platform exhaust inlets (all balancing dampers) will be provided by other Authority Contracts.
   2. The Contractor shall coordinate with the other Authority Contracts on the attachment of these screens to the balancing damper.

3. The Contractor shall ensure that any screens provided by other Authority Contracts do not adversely affect the flow or impact upon the fan pressures.
4. The Contractor shall ensure that any screens provided by other Authority Contracts do not impair the ability to adjust the balancing dampers at system commissioning.
5. The Contractor shall immediately inform the Engineer in writing of any concerns with the placement of screens over the balancing dampers by other Authority Contracts.

2.05 SPARES

A. The Contractor shall provide the following spares:
   1. Damper Modules – One of each type of module supplied.
   2. Actuators – Two of each type of damper actuator.
   3. Limit Switches – Two of each type of damper limit switch.

B. The spares shall be suitably packed for handling and for long term storage in accordance with manufacturer recommendations that have been approved by the Engineer and coordinated with Authority. Clear identification of the equipment shall be provided on the packaging. The Contractor shall be responsible for the transport and off-loading of any spares to a site nominated by Authority.

2.06 INSTRUMENTATION AND CABLING
   1. All instrumentation and leads within the air stream shall continue to operate in the same high temperature conditions required of the tunnel ventilation dampers.
   2. General Electrical Requirements. Additional electrical requirements are given in Section 16890, "Tunnel Services Electrical Requirements for Mechanical Equipment".

ARTICLE 3 EXECUTION

3.01 SHOP TESTING

A. Testing procedures shall be submitted to the Engineer for review and approval.

B. Shop testing shall include, but not be limited to, the following;
   1. Tests shall be conducted to UL555 and ISO 834 (BS 476) on the largest module size of each type of damper installed. These shall include tests for;
      a. Pressure loss when open (as a function of air flowrate, up to a uniform face velocity of 2000fpm);
      b. Air tightness when closed;
      c. Pressure resistance when closed;
      d. High temperature resistance when closed (operable after 1 hour at 482°F) and resistance to thermal shock; and
      e. Fatigue resistance of blades and actuators.

2. Every damper shall be trial assembled to the extent that all modules shall be fitted together, with the actuators and shown to operate to open and closed positions.
3. All tests shall be documented for submission to the Engineer for approval.

C. All damper testing shall be shown as a witness point in the manufacturing schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Shop testing carried out without sufficient notice will be deemed to have not been done and those dampers will be re-tested when the Engineer can be in attendance.

3.02 SITE TESTING AND COMMISSIONING

A. Site testing and commissioning shall be in accordance with Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

B. Site testing and commissioning shall include, but not be limited to, the following:
1. Once installed all dampers shall be operationally tested in the field. The tests shall show that dampers operate to open and closed positions.
2. All tests shall be documented for submission to the Engineer for approval.

C. Balancing dampers shall be commissioned as part of the system commissioning described in Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

D. All testing shall be shown as a witness point in the Contractor's Project Schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Site testing carried out without sufficient notice will be deemed to have not been done and those dampers will be re-tested when the Engineer can be in attendance.

3.03 SYSTEM COMMISSIONING

A. The tunnel ventilation dampers and balancing dampers are part of the overall ventilation system and shall be included in the ventilation system commissioning.

B. System commissioning shall be completed as part of Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 15887.001 –Tunnel Ventilation Dampers and all Associated Equipment shall be measured as a lump sum unit, complete in place.

B. Item 15887.002 – Balancing Dampers and all Associated Equipment shall be measured as a lump sum unit, complete in place.

C. Item 15887.003 – Spare Tunnel Ventilation Dampers, Balancing Dampers and all Associated Equipment shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 15887.001 – Tunnel Ventilation Dampers and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

B. Item 15887.002 – Balancing Dampers and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

C. Item 15887.003 – Spare Tunnel Ventilation Dampers, Balancing Dampers and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 15888

TUNNEL VENTILATION NOISE ATTENUATORS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for tunnel ventilation noise attenuators, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design detailing, manufacture detailing, supply, delivery, off-loading, storage, furnish, install, testing and commissioning of the new tunnel ventilation noise attenuators and other relevant equipment required to meet the performance specification.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel ventilation noise attenuators portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data"

B. Section 01911, "Operations, Maintenance and Repair Database"

C. Section 07841, "Fire Stop and Barrier Systems"

D. Section 05120, "Structural Steel"

E. Section 05520, "Miscellaneous Metal Work"

F. Section 15400, "Tunnel Services Scope of Work"

G. Section 15887, "Tunnel Ventilation Dampers"

H. Section 15889, "Tunnel Ventilation Fans"

I. Section 15890, "Tunnel Ventilation Jet Fans"

J. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

1.03 REFERENCE STANDARDS

A. Air Movement and Control Association (AMCA)

B. ANSI

C. ASTM

D. AWS

E. British Standards (BS)

F. ISO

G. NFPA

H. SSPC

I. UL

1.04 SUBMITTALS

A. All drawing, calculation and design submittals shall be sealed by a Professional Engineer.

B. Submit certified results and details from the required shop testing prior to shipment of attenuators from the place of fabrication.

C. The documentation provided shall include key manufacturing quality assurance reports, including particularly the testing procedures carried out for material quality, and structural integrity and the results in terms of defects noted.

D. Shop Drawings
   1. Submit Shop Drawings for tunnel ventilation noise attenuators showing layout, location, size of system components, installation conditions, mounting details, connection details to the evases and ancillary walls, and any other relevant information. These shall be submitted to the Engineer for approval prior to procurement and installation of any components of the tunnel ventilation noise attenuators.

E. As Built Drawings
   1. Submit As Built Drawings for tunnel ventilation attenuators, showing layout, location, size of system components, installation conditions, mounting details, connection details to the evases and ancillary walls, and any other relevant information. These shall be submitted to the Engineer for approval upon Substantial Completion of the tunnel ventilation attenuators portion of the Work.

F. The Contractor shall submit the following manufacturing certificates and details within 60 days of Notice to Proceed.
   1. Performance data for dynamic insertion loss.
   2. An acoustic analysis to show that the resultant noise levels are no greater than that specified in the performance requirements of this Section. This shall be determined at each noise sensitive location indicated in Article 2.02C of this Section.
   3. Pressure drop as a function of air flow.
   4. High temperature integrity of components and associated supports indicating continued operation at 482°F for one hour and likely ultimate failure conditions.
   5. Description of maintenance requirements.
   6. Manufacturer recommendations for handling and long term storage of any spare equipment.
   7. Evidence of a service life expectancy of not less than 20 years with reasonable maintenance for equivalent applications. This shall include details of corrosion protection.
   8. Dimensioned general arrangement and interface Shop Drawings including flange bolting patterns and bolt requirements.
   9. Completed equipment schedules as per Table 15888-1 and Table 15888-2.

G. The Contractor shall submit the manufacturing Certificates and details below prior to delivery to the Worksite. The documentation delivery Schedule shall be proposed by the Contractor in the Project Schedule and submitted to the Engineer for approval.
   1. Performance data for dynamic insertion loss.
   2. An acoustic analysis to show that the resultant noise levels are no greater than that specified in the performance requirements of this Section. This shall include the expected sound power levels for the proposed fans and the expected insertion loss of the proposed attenuators. This shall be determined at each noise sensitive location indicated in Article 2.02C of this Section.
   3. Pressure drop as a function of air flow.
   4. High temperature integrity of components and associated supports indicating continued operation at 482°F for one hour and likely ultimate failure conditions.
   5. Operation and maintenance manuals – these manuals shall describe the recommended maintenance, all design parameters and the designations, part numbers and commercial sources of spare parts. Manual format and numbers shall be in accordance with Authority requirements.
   6. Manufacturer recommendations for handling and long term storage of any spare equipment.
   7. Evidence of a service life expectancy of not less than 20 years with reasonable maintenance for equivalent applications. This shall include details of corrosion protection.
   8. Dimensioned general arrangement and interface Shop Drawings including flange bolting patterns and bolt requirements.
   9. Completed equipment schedule as per Table 15888-1 and Table 15888-2.

H. High Temperature Testing

1. If manufacturing certificates are not available to certify the high temperature performance of attenuators, the Contractor shall ensure that high temperature testing and all associated work is undertaken at no additional expense to Authority.
2. A high temperature testing plan and procedure shall be submitted to the Engineer for approval prior to undertaking the work.
3. A high temperature test report shall be submitted to the Engineer for approval prior to procuring the attenuators and associated equipment. This report shall detail the tests completed, test results and all other relevant information to the satisfaction of the Engineer.

I. Equipment requirements are scheduled in Table 15888-1 and Table 15888-2 of this Section and are shown on the Contract Drawings. The items in Table 15888-1 and Table 15888-2 of this Section listed as "By Contractor" shall be completed by the Contractor as required by the Submittals of this Section. Equipment information and/or data sheets shall be submitted with the completed Table 15888-1 and Table 15888-2.

J. The attenuator width and depth in Table 15888-1 and Table 15888-2 are the overall internal dimensions when installed (i.e. dimensions for air flow). The Contractor shall coordinate the required sizes with other Authority Contractors.

TABLE 15888-1 Tunnel Ventilation Attenuator Schedule – Gateway Station

Equipment Number	GW-TVA-101-T	GW-TVA-101-A*
Make	By Contractor	By Contractor
Model	By Contractor	By Contractor
Type	Splitter	Splitter
Width (in) (maximum)	130	155
Height (in) (maximum)	110	110
Length (in) (maximum)	130	130
Flange	Bolt on	Bolt on
Air Vol (kcfm) (maximum)	159	159
Passage Velocity (fpm)	By Contractor	By Contractor
Pressure Loss Factor (K) (based on face area)	5.0 max	5.0 max
Insertion Loss (dB)		
63	By Contractor	By Contractor
125	By Contractor	By Contractor
250	By Contractor	By Contractor
500	By Contractor	By Contractor
1000	By Contractor	By Contractor
2000	By Contractor	By Contractor
4000	By Contractor	By Contractor
8000	By Contractor	By Contractor

Equipment Number	GW-TVA-102-T	GW-TVA-102-A*

Make	By Contractor	By Contractor
Model	By Contractor	By Contractor
Type	Splitter	Splitter
Width (in) (maximum)	130	155
Height (in) (maximum)	110	110
Length (in) (maximum)	130	130
Flange	Bolt on	Bolt on
Air Vol (kcfm)	159	159
Passage Velocity (fpm)	By Contractor	By Contractor
Pressure Loss Factor (K) (based on face area)	5.0 max	5.0 max
Insertion Loss (dB)		
63	By Contractor	By Contractor
125	By Contractor	By Contractor
250	By Contractor	By Contractor
500	By Contractor	By Contractor
1000	By Contractor	By Contractor
2000	By Contractor	By Contractor
4000	By Contractor	By Contractor
8000	By Contractor	By Contractor

*Attenuators GW-TVA-101-A and GW-TVA-102-A may not be regular in shape. Reference shall be made to the Contract Drawings for details.

TABLE 15888-2 Tunnel Ventilation Attenuator Schedule – North Side Station

Equipment Number	NS-TVA-201-T	NS-TVA-201-A
Make	By Contractor	By Contractor
Model	By Contractor	By Contractor
Type	Splitter	Splitter
Width (in) (maximum)	150	150
Height (in) (maximum)	115	115
Length (in) (maximum)	120	120
Flange	Bolt on	Bolt on
Air Vol (kcfm)	159	159
Passage Velocity (fpm)	By Contractor	By Contractor
Pressure Loss Factor (K) (based on face area)	5.0 max	5.0 max
Insertion Loss (dB)		
63	By Contractor	By Contractor
125	By Contractor	By Contractor
250	By Contractor	By Contractor
500	By Contractor	By Contractor
1000	By Contractor	By Contractor
2000	By Contractor	By Contractor
4000	By Contractor	By Contractor
8000	By Contractor	By Contractor

Equipment Number	NS-TVA-202-T	NS-TVA-202-A
Make	By Contractor	By Contractor
Model	By Contractor	By Contractor
Type	Splitter	Splitter
Width (in) (maximum)	150	150
Height (in) (maximum)	115	115
Length (in) (maximum)	120	120
Flange	Bolt on	Bolt on
Air Vol (kcfm)	159	159
Passage Velocity (fpm)	By Contractor	By Contractor
Pressure Loss Factor (K) (based on face area)	5.0 max	5.0 max
Insertion Loss (dB)		
63	By Contractor	By Contractor
125	By Contractor	By Contractor
250	By Contractor	By Contractor
500	By Contractor	By Contractor
1000	By Contractor	By Contractor
2000	By Contractor	By Contractor
4000	By Contractor	By Contractor
8000	By Contractor	By Contractor

Equipment Number	NS-TVA-203-T	NS-TVA-203-A
Make	By Contractor	By Contractor
Model	By Contractor	By Contractor
Type	Splitter	Splitter
Width (in) (maximum)	150	150
Height (in) (maximum)	115	115
Length (in) (maximum)	120	120
Flange	Bolt on	Bolt on
Air Vol (kcfm)	159	159
Passage Velocity (fpm)	By Contractor	By Contractor
Pressure Loss Factor (K) (based on face area)	5.0 max	5.0 max
Insertion Loss (dB)		
63	By Contractor	By Contractor
125	By Contractor	By Contractor
250	By Contractor	By Contractor
500	By Contractor	By Contractor
1000	By Contractor	By Contractor
2000	By Contractor	By Contractor
4000	By Contractor	By Contractor
8000	By Contractor	By Contractor

Equipment Number	NS-TVA-204-T	NS-TVA-204-A
Make	By Contractor	By Contractor

Model	By Contractor	By Contractor
Type	Splitter	Splitter
Width (in) (maximum)	150	150
Height (in) (maximum)	115	115
Length (in) (maximum)	120	120
Flange	Bolt on	Bolt on
Air Vol (kcfm)	159	159
Passage Velocity (fpm)	By Contractor	By Contractor
Pressure Loss Factor (K) (based on face area)	5.0 max	5.0 max
Insertion Loss (dB)		
63	By Contractor	By Contractor
125	By Contractor	By Contractor
250	By Contractor	By Contractor
500	By Contractor	By Contractor
1000	By Contractor	By Contractor
2000	By Contractor	By Contractor
4000	By Contractor	By Contractor
8000	By Contractor	By Contractor

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Materials

1. The Contractor shall provide all manufactured items, materials, labor, cartage, tools, plant, appliances and fixings necessary for the proper execution of the work, together with all minor and incidental works.
2. Should the Contractor propose any deviations from the specified requirements, such variations shall be submitted in writing to the Engineer for approval.
3. This Section shall be read in conjunction with the relevant Contract Drawings.

B. Design Life

1. Serviceability of elements shall be considered in the detailed design and shall be clearly identified in the Shop Drawings.
2. Attenuators shall be designed for an operating life of 20 years unless noted otherwise.

C. Serviceability of Equipment

1. Equipment shall be accessible and serviced safely to the satisfaction of the Engineer.

D. Equipment Identification

1. Attenuators shall be permanently labeled after installation. All labels shall be of a uniform format. This format shall provide information regarding attenuator type, insertion loss by frequency band, flow direction and other such data as appropriate. Identification shall include the equipment designator given on the

Contract Drawings or in Table 15888-1 and Table 15888-2. Naming and numbering shall be in accordance with Authority requirements and shall be coordinated with Authority.

E. Plantrooms and Layout
   1. The Contract Drawings show the intended layout of the tunnel ventilation fan rooms and the positioning of dampers and attenuators. The inclusion of these layouts does not preclude alternative layouts if the merits of the alternatives can be clearly demonstrated. Alternatives may not proceed without approval from the Engineer.
   2. A general allowance for circulation space shall be provided around all plant and equipment, with additional space where necessary for withdrawal and servicing.

2.02 NOISE ATTENUATORS

A. General
   1. In the selection of attenuators, interchangeability of splitters shall be considered. All attenuators shall be from a single manufacturer.

B. Attenuator Design and Construction
   1. Noise attenuators are required as shown in the Contract Drawings to meet the system noise performance defined in this Section. They shall be rectangular with parallel splitter sections, and be designed for airflow in either direction. They shall be capable to withstanding an air temperature of 482°F for 1 hour without undue distortion or buckling resulting in an increase in flow resistance. The attenuator design shall aim to maximize the free area to minimize flow pressure losses.
   2. The atmosphere side attenuators (GW-TVA-101-A and GW-TVA-102-A) at Gateway Station may require the casing to be profiled to prevent interference with the capitol that forms part of the Gateway Station structural box. Suggested profiling of the attenuators is shown on the Contract Drawings.
   3. The attenuator sidewalls shall be faced with the same acoustic material and sheet steel as for the splitters, in order to minimize noise breakout.
   4. Attenuators shall be provided with casings. Casings shall be constructed of steel not less than 1/8 inch thick, hot dipped galvanized. They shall be designed in sections not exceeding 6 feet 5 inches long for bolting together on site, and with flanged ends for connection to ductwork.
   5. Attenuators shall accommodate pressure fluctuations of ± 4 in wg over 1 second without damage.
   6. Attenuators shall be supplied as modular components and may need to be supplied with the casings split into sections for assembly within relevant plant rooms to enable installation.

C. Performance Requirements
   1. Attenuators shall be designed to meet the following performance requirements
      a. Normal Operations

1) Station's mezzanine, headhouse, platform areas: 55 dBA (TBC)
2) Nearest property boundary (7am to 11pm): 60 dBA (TBC)
3) Nearest property boundary (11pm to 7am): 55 dBA (TBC)
4) Tunnel (5 feet above walkway level): 65 dBA (TBC)

b. Congested/Emergency Operations
1) Station's mezzanine, headhouse, platform areas: 75 dBA (TBC)
2) Tunnel (5 feet above walkway level): 85 dBA (TBC)

c. The Contractor shall confirm the performance requirements with the Engineer prior to procurement of the tunnel ventilation noise attenuators.

2. Consideration needs to be given to the fan performance data and to how many fans are functioning for any given operation. Consideration of the station geometry and distances to adjacent properties is required. Acoustic analysis will be required based on the proposed equipment selected by the Contractor.

D. Splitters
1. Splitters shall have rounded ends designed to minimize pressure loss, and shall be designed for equal pressure loss in either flow direction.
2. Splitter side walls shall be constructed of perforated galvanised sheet steel.
3. The acoustic absorption material inside the splitters shall be inert, rot-proof, vermin-proof, non-hygroscopic, dust resistant and non-combustible.
4. Attenuators shall be designed for easy removal of individual splitters, in order to allow cleaning.

E. Pressure Loss
1. The pressure loss for attenuators directly connected to fan transition ducts or attenuators in ducts shall be allowed for by the Contractor in meeting the specified overall pressure performance of the fan-attenuator assembly.
2. The resistance of attenuators either in ductwork common to two fans or remote from the fans will have been allowed for already in specifying the fan assembly performance in the Related Sections. Such attenuators shall have a loss coefficient (ratio of total pressure loss to face area velocity pressure) not exceeding 5.0 in the as installed configurations.

F. Others
1. Site measurement
a. The particular attenuators required are designated on the Contract Drawings. The Contractor shall coordinate all locations to be fitted with attenuators and shall be responsible for correct fabrication.
2. Fixtures
a. Attenuators shall be supplied complete with all fixtures (nuts, bolts, spacers, washers, seals, packers etc) such that attenuators and components supplied with the attenuators can be completely assembled. Fixtures to enable the mounting of attenuators to ductwork openings shall be provided by the Contractor unless noted otherwise in the Contract Drawings.
3. Equipment Surface Corrosion Protection

a. Unless specified, appropriate anti-corrosion provisions shall be made by the Contractor for all attenuator components based on installation conditions. The Contractor shall provide information regarding material selection, galvanizing schemes and painting schemes.

2.03 SPARES

A. The Contractor shall supply enough spare splitters and associated mountings to furnish one complete attenuator unit of each type installed.

B. The spares shall be suitably packed for handling and for long term storage in accordance with manufacturer recommendations that have been approved by the Engineer and coordinated with Authority. Clear identification of the equipment shall be provided on the packaging. The Contractor shall be responsible for the transport and off-loading of any spares to a site nominated by Authority.

ARTICLE 3 EXECUTION

3.01 SHOP TESTING

A. Testing procedures shall be submitted to the Engineer for review and approval.

B. Shop testing shall include, but not be limited to, the following:
   1. Insertion loss tests shall be carried out on one of each type and size of attenuator in accordance with ISO 7235.
   2. Pressure loss tests shall be carried out on one of each type and size of attenuator in accordance with ISO 7235.

C. All attenuator testing shall be shown as a witness point in the manufacturing schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Shop testing carried out without sufficient notice will be deemed to have not been done and those attenuators will be re-tested when the Engineer can be in attendance.

3.02 SITE TESTING AND COMMISSIONING

A. Site testing and commissioning shall be in accordance with Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

B. Measurement of noise levels under operation of equipment to confirm conformance with required performance requirements. Tests shall be carried out in accordance with ISO 11201.

C. All testing shall be shown as a witness point in the Contractor's Project Schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Site testing carried out without sufficient notice will be deemed to have not been done and those fans will be re-tested when the Engineer can be in attendance.

3.03 SYSTEM COMMISSIONING

A. The tunnel ventilation attenuators are part of the overall ventilation system and shall be included in the ventilation system commissioning.

B. System commissioning shall be completed as part of Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 15888.001 – Noise Attenuators and all Associated Equipment shall be measured as a lump sum unit, complete in place.

B. Item 15888.002 – Spares for the Noise Attenuators shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 15888.001 – Noise Attenuators and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

B. Item 15888.002 – Spares for the Noise Attenuators will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 15889

TUNNEL VENTILATION FANS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for tunnel ventilation fans, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design detailing, manufacture detailing, supply, delivery, off-loading, storage, furnish, install, testing and commissioning of the new tunnel ventilation fans and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel ventilation fans portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data"

B. Section 01911, "Operations, Maintenance and Repair Database"

C. Section 05120, "Structural Steel"

D. Section 05520, "Miscellaneous Metal Work"

E. Section 15400, "Tunnel Services Scope of Work"

F. Section 15887, "Tunnel Ventilation and Balancing Dampers"

G. Section 15888, "Tunnel Ventilation Noise Attenuators"

H. Section 15890, "Tunnel Ventilation Jet Fans"

I. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

J. Section 16889, "Tunnel Services Electrical Testing and Commissioning"

K. Section 16890, "Tunnel Services Electrical Requirements for Mechanical Equipment"

L. Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center"

1.03 REFERENCE STANDARDS

A. Anti-friction Bearing Manufacturer's Association (AFBMA)

B. AMCA

C. ANSI

D. ASHRAE

E. ASTM

F. AWS

G. British Standards (BS)

H. IEEE

I. ISO

J. NEMA

K. NFPA

L. SMACNA

M. SSPC

N. UL

1.04 SUBMITTALS

A. All drawing, calculation and design submittals shall be sealed by a Professional Engineer.

B. Certified results from the required shop testing shall be provided prior to shipment of the fans or components to the Worksite.

C. The documentation provided shall include key manufacturing quality assurance reports, including particularly the testing procedures carried out for material quality and structural integrity and the results in terms of defects noted.

D. Shop Drawing
   1. Submit Shop Drawings for the tunnel ventilation fans showing layout, location, size of system components, installation conditions, mounting details, evase details and any other relevant information. These shall be submitted to the Engineer for approval prior to procurement and installation of any components of the tunnel ventilation fans.

E. As Built Drawings
   1. Submit As Built Drawings for tunnel ventilation fans showing layout, location, size of system components, installation conditions, mounting details, evase details and any other relevant information. These shall be submitted to the Engineer for approval upon Substantial Completion of the tunnel ventilation fans portion of the Work.

F. The Contractor shall submit the following manufacturing certificates and details within 60 days of Notice to Proceed.
   1. Predicted performance curves (forward and reverse direction duty points) for the fans and certified performance curves from testing similar fans, if available. Performance values plotted as a function of flowrate shall include, but not be limited to, total pressure, static pressure, total efficiency, static efficiency, fan power and motor power. Performance curves shall also have all fan data included.
   2. Pressure loss allowances for fan assembly components shall also be provided.
   3. Verification documents that the fans can withstand a working gas temperature of 482°F for one hour and resist thermal shock (recent tests on comparable fans of the same manufacture and components may be acceptable with agreement from the Engineer).
   4. Evidence that the materials selected and the assembled product will have a service life expectancy of not less than 20 years with reasonable maintenance. This shall include details of corrosion protection.
   5. Evidence that the materials selected and the assembled product can withstand the stresses caused by a pressure transient of ± 4 in wg occurring 500 times per day.
   6. Schedule of at least 3 locations where comparable fans and drive systems have been in satisfactory operation for a minimum period of 5 years.
   7. Factory quality control plan and manufacturing schedule.
   8. Estimated mean time between failure (MTBF).
   9. Estimated mean time between service failure (MTBSF).
   10. Mean time to repair (MTTR).
   11. Recommended planned maintenance schedule.
   12. Manufacturer recommendations for handling and long term storage of any spare equipment.
   13. Equipment loads and footing reactions for supporting steelwork.
   14. Details of the brake selected (if a brake is required).
   15. Dimensioned general arrangement and interface Shop Drawing of the fans.
   16. Anticipated sound power spectrum for all duty points to ISO 3744.
   17. Proposed galvanizing and/or painting regime.
   18. Completed equipment schedule as per Table 15889-1.

G. The Contractor shall submit manufacturing certificates and details prior to delivery to the Worksite. The documentation delivery Schedule shall be proposed by the Contractor in the Project Schedule and submitted to the Engineer for approval.
   1. Certified performance curves (forward and reverse direction duty points) from testing the fans. Performance values plotted as a function of flow rate shall include, but not limited to, total pressure, static pressure, total efficiency, static

efficiency, fan power and motor power. Performance curves shall also have all fan data included.

2. Pressure loss allowances for fan assembly components shall also be provided.
3. Test reports to show that the fans can withstand a working gas temperature of 482°F for one hour and resist thermal shock. This requires testing of each type of fan.
4. Evidence that the materials selected and the assembled product will have a service life expectancy of not less than 20 years with reasonable maintenance. This shall include details of corrosion protection.
5. Evidence that the materials selected and the assembled product can withstand the stresses caused by a pressure transient of ± 4 in wg occurring 500 times per day.
6. Factory quality control records, inspection checklists and test reports.
7. Estimated mean time between failure (MTBF).
8. Estimated mean time between service failure (MTBSF).
9. Mean time to repair (MTTR).
10. Operation and maintenance manuals – these manuals shall describe the recommended maintenance, all design parameters and the designations, part numbers and commercial sources of spare parts. Manual format and numbers shall be in accordance with Authority requirements. As a minimum three copies shall be provided.
11. Manufacturer recommendations for handling and long term storage of any spare equipment.
12. Equipment loads and footing reactions for supporting steelwork.
13. Details of the brake to be provided (if a brake is required).
14. Dimensioned general arrangement and interface Shop Drawing of the fans.
15. Measured sound power spectrum for all duty points to ISO 3744.
16. Galvanizing and/or painting regime.
17. Completed equipment schedule as per Table 15889-1.

H. The fan pressures in Table 15889-1 are to be confirmed by the Contractor prior to manufacture of the fans. The Contractor shall submit calculations of the expected fan pressures to the Engineer prior to manufacture of the fans. This will require coordination with other Authority Contracts.

I. Equipment requirements are listed in Table 15889-1 of this Section and are shown on the Contract Drawings. The items in Table 15889-1 of this Section listed as "By Contractor" shall be completed by the Contractor as required by the Submittals of this Section. Equipment information and/or data sheets shall be submitted with the completed Table 15889-1.

J. The estimated motor size is to be confirmed by the Contractor. Motor sizes shall be based on an air temperature of 32°F.

TABLE 15889-1 Tunnel Ventilation Fan Schedule

Equipment Number	GW-TVF-01	NS-TVF-01	NS-TVF-03

	GW-TVF-02	NS-TVF-02	NS-TVF-04
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type	Reversible Axial Direct drive	Reversible Axial Direct drive	Reversible Axial Direct drive
Max Air Flow (kcfm)	159	159	159
Max Total Pressure (in wg) TBC	9.4 (supply)	4.4 (exhaust)	5.9 (exhaust)
Speed (rpm)	By Contractor	By Contractor	By Contractor
Shaft Power (HP)	By Contractor	By Contractor	By Contractor
Fan Diameter (in) – max	80	84	84
Hub Diameter (in)	By Contractor	By Contractor	By Contractor
No. of Blades	By Contractor	By Contractor	By Contractor
Pitch Angle (degrees)	By Contractor	By Contractor	By Contractor
Estimated Motor Size (HP) TBC	400	200	250
Type	By Contractor	By Contractor	By Contractor
Frame Size	By Contractor	By Contractor	By Contractor
Input (HP)	By Contractor	By Contractor	By Contractor
Voltage/Hz/pH	By Contractor	By Contractor	By Contractor
FLA (amps)	By Contractor	By Contractor	By Contractor
Thermistor	By Contractor	By Contractor	By Contractor
Elevated Temperature	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Variable Speed Drive	Yes	Yes	Yes
Duty Points (Total Pressure) (TBC)	kcfm @ in wg	kcfm @ in wg	kcfm @ in wg
1.	159 @ 9.4 (supply)	159 @ 4.4 (exhaust)	159 @ 5.9 (exhaust)
2.	159 @ 8.4 (exhaust)	159 @ 3.2 (supply)	159 @ 4.2 (exhaust)
Reverse Operations	Yes	Yes	Yes
Sound Power (dB)			
Emergency Operations	Outlet Inlet	Outlet Inlet	Outlet Inlet
63	By Contractor	By Contractor	By Contractor
125	By Contractor	By Contractor	By Contractor
250	By Contractor	By Contractor	By Contractor
500	By Contractor	By Contractor	By Contractor
1000	By Contractor	By Contractor	By Contractor
2000	By Contractor	By Contractor	By Contractor
4000	By Contractor	By Contractor	By Contractor
8000	By Contractor	By Contractor	By Contractor

dBA @ 10 ft	By Contractor		By Contractor		By Contractor	
Normal Operations	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet
63	By Contractor		By Contractor		By Contractor	
125	By Contractor		By Contractor		By Contractor	
250	By Contractor		By Contractor		By Contractor	
500	By Contractor		By Contractor		By Contractor	
1000	By Contractor		By Contractor		By Contractor	
2000	By Contractor		By Contractor		By Contractor	
4000	By Contractor		By Contractor		By Contractor	
8000	By Contractor		By Contractor		By Contractor	
dBA @ 10 ft	By Contractor		By Contractor		By Contractor	

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Design Life
   1. Fans shall be designed for an operating life of 20 years unless noted otherwise.

B. Serviceability of Electrical and Mechanical Equipment
   1. Serviceability of elements shall be considered in the detailed design and shall be clearly identified in the Shop Drawings.
   2. Lifting eyes shall be provided at the top of the fan above the center of mass and at two points approximately 60° around the fan casing either side of the first point.
   3. Fans shall be readily removable from the ductwork.
   4. Equipment shall be accessible and serviced safely to the satisfaction of the Engineer.
   5. Lifting beams and monorail trolleys of appropriate capacity shall be provided to enable usage of the access hatches and roller doors. These shall remain in place after installation.

C. Equipment Identification
   1. Fans and control devices shall be permanently labeled after installation. All labels shall be of a uniform format. This format shall identify and provide information regarding fan type, fan function, flow direction and other such data as appropriate. Identification shall include the equipment designator given on the Contract Drawings or in Table 15889-1. Naming and numbering shall be in accordance with any Authority requirements and shall be coordinated with Authority.
   2. The manufacturer's model number, the design duty point(s) and the motor power shall also be suitably recorded on the fan casing.

D. Equipment Location
   1. The Contract Drawings show the intended locations of the tunnel ventilation fans.

2.02 FANS

A. General
   1. Fans shall conform to the requirements of NFPA 130.
   2. The tunnel ventilation fans shall be direct drive axial flow fully reversible fans. Aerodynamic efficiency in the forward direction shall be not less than 65%. Aerodynamic efficiency in the reverse direction shall be not less than 90% of the efficiency in the forward direction. The required fans are given designations in the Contract Drawings.
   3. All the tunnel ventilation fans shall, as far as possible, be the same make and model, in order to maintain commonality of spares.

B. Fan Performance
   1. Design duty points (forward, reverse, etc) and the maximum duty points must be achievable when operating continuously and as described in this Section.

C. Fan Flowrate Performance
   1. The design fan flowrates, based on predicted project ventilation requirements, are given in Article 15889-2.02 E and in Table 15889-1 of this Section.
   2. The fans are to be adjustable pitch. While the fans should be selected for efficiency at the nominated design duty, allowance shall be made in the fan selection and motor sizing for pitch adjustment to give higher or lower flowrates. The maximum performance to be provided for is also given in Article 2.02 E of this Section.

D. Fan Pressure Performance
   1. The fans shall be installed complete with inlet and outlet transition ducts (evases), dampers and noise attenuators. Each of these items will have associated pressure losses. In both flow directions, the fans draw air from a plenum on one side and discharge air to a second plenum. The Contractor shall note that the fan pressure performance given in this Section is the required pressure for the system including an estimate of pressure loss for the evase, damper, attenuator assembly, as well as connecting ducts. The component of pressure which was estimated has been provided in this Section. In selecting a fan, the Contractor shall ensure the estimated allowance for the pressure losses in all elements of the fan, damper, attenuator, evase assembly is adequate given the other assembly equipment selected by the Contractor. This shall be coordinated by the Contractor with any fan supplier and other fan assembly equipment Supplier.
   2. Information submittals shall include the fan pressure curves to ISO 5801 (or BS 848 Part 1) and the pressure loss allowances made for each element at the design flowrates. The performance curves shall include contours of fan shaft power. If the data are different for the forward and reverse direction, they shall be given for both directions. All data shall be based on an air density of $0.075 lb/ft^3$. Estimates of the duty point pressures are given in Article 2.02 E of this Section.

E. Fan Performance Data
   1. Duty Point 1
      a. Flowrate: per fan at $0.075 lb/ft^3$ air density.

b. Fan total pressure:
   1) Gateway Station — 9.4 in wg @ 159 kcfm (supply) (TBC)
   2) North Side Station (East) — 4.4 in wg @ 159 kcfm (exhaust) (TBC)
   3) North Side Station (West) — 5.9 in wg @ 159 kcfm (exhaust) (TBC)

2. Duty Point 2
   a. Flowrate: per fan at 0.075lb/ft^3 air density.
   b. Fan total pressure:
      1) Gateway Station — 8.4 in wg @ 159 kcfm (exhaust) (TBC)
      2) North Side Station (East) — 3.2 in wg @ 159 kcfm (supply) (TBC)
      3) North Side Station (West) — 4.2 in wg @ 159 kcfm (supply) (TBC)

3. Nozzle Duty
   a. The fans at Gateway Station (GW-TVF-01 and GW-TVF-02) are used to provide flow to the Saccardo Nozzle at the northern end. Nozzle performance requirements are listed in Table 15889-2. Only one fan in operation needs to provide the performance requirements listed in Table 15889-2.
   b. The supply pressure duty points for Gateway Station are based on the nozzle operation. In order to define the nozzle performance a quantity called the pressure head increase (H) is used. Pressure head increase is defined as the pressure rise generated by the nozzle divided by the air density:

      $$H = \frac{\Delta P}{\rho} \quad (\text{sqft/s}^2)$$

   c. The Contractor shall analyze the nozzle installation to ensure the fans selected have a duty that provides the required pressure head increase.

TABLE 15889-2 Nozzle Performance Requirements

TV Fan Equipment Number	Total H (Nozzle) (sqft/s^2)	Design Tunnel Velocity – V_T (fpm)	Tunnel Area A_T (sqft)
GW-TVF-01	690	285	296
GW-TVF-02	690	285	296

F. Performance Characteristics and Stall
   1. The performance characteristic for all fans shall be such that the fan pressure rise increases continuously from the full flow/zero pressure point to the maximum pressure rise that the fans could be subjected to when operating. The fan design shall include any anti-stall devices required to protect the fan against the transient backpressure. Some of the fan, attenuator, damper assemblies are to operate as pairs in parallel and shall operate without damage at all possible timing combinations of the two fans starting and stopping.

G. Reversal
   1. Where required to be reversible, tunnel ventilation fans shall be capable of reversing from full forward flow to full reverse flow, or vice versa, with a de-energized period not exceeding 30 seconds between reversals. The period to reach

full capacity flow after de-energization shall not exceed 30 seconds. Three reversals shall be possible during a 20 minute, period where a reversal is defined as one change from forward mode operation to reverse mode operation or vice versa.

2. The requirement for short turnaround reversals may require a fan brake. If included, the brake shall incorporate limit switches to facilitate interlocks in the motor control center (MCC) to prevent the motor being energized until the brake is off and to prevent the brake being applied while the motor is energized. Both the interlock connections and the brake status signals shall also be available to the control system. Fan braking can be performed by the use of variable speed drives.

H. Tunnel Ventilation Variable Speed Drives
1. Multiple speed operation of the tunnel ventilation fans shall be achieved by the use of variable speed drive units installed in the MCCs.
2. VSDs shall be capable of running at least two preset speeds, selected remotely by volt free contacts (1 pair for each speed) hard wired into the VSD unit. Closing any of these contacts shall override any programmable logic controller (PLC) command present.
3. VSDs shall comply with NEMA MG-1 Part 31.

I. High Temperature Performance
1. Fans shall be designed to continue to operate for at least one hour while moving air at a temperature of 482°F.

J. Balancing
1. Each fan shall be balanced statically and dynamically in accordance with ISO 1940 (or BS 6861).

K. Impeller and Blades
1. It shall be possible to adjust the pitch angle of all fan blades with the fan stationary and in its installed location. The design of the pitch adjustment method shall ensure that blades will not 'freeze up' with time. Provision shall be made to accurately measure and set the blade pitch.
2. Impellers and blades shall be made of materials suitable for the specified temperature, pressure and pollution conditions and speeds, dynamic loads and fatigue loads.
3. Impellers shall be designed so that the bearings do not suffer permanent damage when the fans are stationary, over the design life of the fan.
4. All fan blades and the hubs shall be inspected by x-ray, or other non-intrusive means, and results provided to demonstrate freedom from cracks and imperfections, to the approval of the Engineer.
5. The first critical speed (natural frequency) of the shaft impeller motor assembly shall be at least 50% higher than the design maximum operating speed.
6. The assembly shall be able to withstand stresses and load created by over speed testing to 125% of the maximum operating speed.

L. Fan Casings
   1. Fan casings shall be made of welded mild steel with a minimum thickness of ¼ inch and with continuously welded flanged ends for connection to flexible couplings. The casings shall be fully protected from corrosion over the design life of the fan.
   2. Provision shall be made for fan performance to be checked, using an anemometer or pitot-static probe device in the annulus and mounted through a bushing in the fan casing. All fans of each type and size shall be furnished with a similar bushing (normally closed by a plug) located in an identical location on each fan housing.
   3. If fan blade pitch adjustment is not readily possible through transition duct access hatches then the fan casing shall include access hatches to facilitate pitch setting.

M. Anti-vibration Mountings and Flexible Connections
   1. Each fan shall be mounted on spring plus waffle pad anti-vibration mountings.
   2. Flexible connections shall be provided between the flanges of each fan and its transition ducts, so that no axial or transverse forces are transmitted between the two. The flexible connections shall be of the minimum length consistent with allowing for any vibration movement and thermal expansion. The flexible connections shall not be used to take up any misalignment between fan and duct flanges.
   3. The flexible connections and anti-vibration mountings shall be capable of the same high temperature performance as the fans, without failure. Density of flexible connections shall be suitable for the pressure and temperature duty expected. Flexible connection flanges shall be hot dipped galvanized.

N. Bearing Life
   1. The L_{10} design life of the fan motor bearings shall be 50,000 hours (minimum). The Contractor shall advise the maximum bearing life possible.
   2. Lubrication lines and nipples shall be provided to enable greasing of the bearings from outside the fan casing.

O. Fan Power
   1. Power supply shall be 480V 3ph 3 wire 60Hz. Fans should be capable of operating to designed performance within normal voltage and frequency tolerances.

P. Motors
   1. Tunnel ventilation fan motors shall be suitable for use in a tunnel environment, direct on line (DOL) (across-the-line) starting, totally enclosed air over (TEAO) and be capable of at least 6 starts per hour. Motors shall be suitable for VSD control.
   2. Motors shall be capable of run up and reversal in accordance with Article 2.02G of this Section.

Q. Other

1. Site measurement
    a. The particular fans required are designated on the Contract Drawings. The Contractor shall site measure all locations to be fitted with fans and shall be responsible for correct manufacture.
2. Fixtures
    a. Fans shall be supplied complete with all fixtures (nuts, bolts, spacers, washers, seals, packers etc) such that fans and components supplied with the fans can be completely assembled. Fixtures to enable the mounting of fans to ductwork shall be provided by the Contractor unless noted otherwise on the Contract Drawings.
3. Equipment surface corrosion protection
    a. Unless specified, appropriate anti-corrosion provisions shall be made by the Contractor for all components based on SSPC standards suitable for installation conditions. The Contractor shall provide information regarding material selections, galvanizing schemes and painting schemes.

2.03 FAN MOUNTING FRAMES

A. General
1. Fans shall be mounted on steelwork frames to support the fans off the floor as shown on the Contract Drawings.
2. Where mounted on the floor, fan support frames shall be placed on reinforced concrete equipment pads/plinths. Minimum pad/plinth height shall be 4 inches. The work shall be coordinated with other Authority Contracts as necessary.
3. Fans shall be provided by the Contractor complete with mounting frames to enable mounting in the orientation shown on the Contract Drawings. The Contractor shall design and supply steel framing to enable mounting of the fans to pads/plinths.
4. Fans shall not be suspended from the ceiling.
5. All support steelwork shall conform to Section 05120, "Structural Steel" and Section 05520, "Miscellaneous Metal Work".

B. Other
1. Site measurement
    a. The particular fan mounting frames required are designated on the Contract Drawings. The Contractor shall site measure all locations to be fitted with fan mountings and shall be responsible for correct manufacture.
2. Fixtures
    a. Mounting frames shall be supplied complete with all fixtures (nuts, bolts, spacers, washers, seals, packers etc) such that mounting frames and components supplied with the fans can be completely assembled.
3. Equipment surface corrosion protection
    a. Unless specified, appropriate anti-corrosion provisions shall be made by the Contractor for all components based on SSPC standards suitable for installation conditions. The Contractor shall provide information regarding material selections, galvanizing schemes and painting schemes.

2.04 EVASES

A. Evases are required to transition between the tunnel ventilation fans and the tunnel ventilation noise attenuators.

B. Evases shall be provided as part of the tunnel ventilation fan assemblies and shall be included in this Section of the work.

C. Evases shall be made from fully welded mild steel of minimum ¼ inch thickness. Bolted, airtight, flanged joints shall be provided at the ends and as otherwise necessary such that no single piece is greater than 6 feet long. The ducts shall be designed and stiffened (externally) as necessary to prevent any vibration or resonance.

D. The included angle of the transition ducts shall not exceed 30 degrees without the approval of the Engineer.

E. Bolted access panels shall be included in each transition duct to allow visual inspection of each side of the fan (and if required, adjustment of blade pitch) through openings 2 feet square or larger.

F. Lifting lugs are to be provided at the top and both sides of each transition duct section to facilitate maintenance.

G. Evases shall be supplied as part of the fan assembly in accordance with Section 15889, "Tunnel Ventilation Fans".

2.05 DUCTWORK

A. All ductwork, supports, mounts, expansion joints, turning vanes and insulation associated with the fan assemblies and other interconnecting ductwork associated with the system as identified on the Contract Drawings shall be supplied as part of this Section.

B. Unless specified, appropriate anti-corrosion provisions shall be made by the Contractor for all ductwork components based on SSPC standards suitable for installation conditions. The Contractor shall provide information regarding material selections, galvanizing schemes and painting schemes.

2.06 INSTRUMENTATION

A. Passive type dry contact flow switches shall be provided with each fan to provide positive indication of airflow (in each direction).

B. Each fan shall be supplied complete with permanent equipment to measure and report out of balance vibration from the impeller, motor and bearings. This equipment shall monitor the fan continuously while it is running, and shall generate an alarm signal available to the control system if the vibration exceeds a preset limit (defined by the fan manufacturer).

C. Each fan motor shall be fitted with motor bearing RTDs and motor winding RTDs connected to separate terminal boxes on the fan casing. These sensors shall generate an alarm condition (not shut the fan off) available to the control system via an approved motor protection relay, when bearing or winding over-temperature is detected.

D. Each set of ventilation fans shall be fitted with an air flow temperature sensor and transmitter. These transmitters shall provide a 4-20 mA output signal which shall be connected into the PLC.

E. All instrumentation and leads within the air stream shall continue to operate in the same high temperature conditions required of the fans.

F. The manufacturer shall supply appropriate anemometer equipment (e.g. pitot-static probe) required for the fans to allow airflow measurements to be undertaken. A written procedure for testing the fans in the field with these instruments shall be included as part of the operation and maintenance instructions. The procedure shall be based on ISO 5802 (or BS 848 Part 3).

G. General Electrical Requirements
   1. Additional electrical requirements are given in Section 16890, "Tunnel Services Electrical Requirements for Mechanical Equipment"

2.07 SPARES

A. The Contractor shall provide a spare tunnel ventilation fan and associated equipment of each type installed.

B. The spares shall be suitably packed for handling and for long term storage in accordance with manufacturer recommendations that have been approved by the Engineer and coordinated with Authority. Clear identification of the equipment shall be provided on the packaging. The Contractor shall be responsible for the transport and off-loading of any spares to a site nominated by Authority.

ARTICLE 3 EXECUTION

3.01 SHOP TESTING

A. Testing procedures shall be submitted to the Engineer for review and approval.

B. The fan manufacturer shall undertake shop performance tests as follows on one tunnel ventilation fan of each duty specified.
   1. ISO 5801 (or BS 848 Part 1 type C) performance tests giving fan pressures as a function of air flowrate with efficiency contours. Tests shall be carried out for a

range of blade pitch angles to cover the required range of operation. Similar plots shall also be prepared giving fan total pressure as a function of air flowrate.
2. As part of 1, carry out noise tests to ISO 5136 (or BS 848 Part 2). In-duct sound power levels are to be recorded both upstream and downstream. Noise measurements shall be made at the nominal duty point and at the highest pressure which is required at the maximum flowrate.
3. As part of 1, record the motor voltage and currents for each operating point.
4. Prove the airflow reversing cycle.
5. Prove the operation of instrumentation.
6. Prove operation at 482°F for 1 hour and verify resistance to thermal shock from 68°F to 482°F in 20 seconds. This will require elevated temperature tests on at least one fan unit of each type.

C. The fan manufacturer shall undertake the following tests on all fans:
   1. Run at 100% and 125% of maximum rated speed for 3 minutes each, with no damage, excessive vibration or adverse behavior.

D. All fan testing shall be shown as a witness point in the manufacturing schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Shop testing carried out without sufficient notice will be deemed to have not been done and those fans will be re-tested when the Engineer can be in attendance.

3.02 SITE TESTING AND COMMISSIONING

A. Site testing and commissioning shall be in accordance with Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

B. The Contractor shall carry out tests on completion. The tests shall be carried out once all elements of the tunnel structure which affect the ventilation system represent adequately the final operating conditions. The performance tests shall be carried out to demonstrate to the Engineer that the fans are operating correctly.

C. Tests shall include both aerodynamic, vibration and noise tests.

D. All testing shall be shown as a witness point in the Contractor's Project Schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Site testing carried out without sufficient notice will be deemed to have not been done and those fans will be re-tested when the Engineer can be in attendance.

3.03 SYSTEM COMMISSIONING

A. The tunnel ventilation fans form part of the overall ventilation system.

B. System commissioning shall be completed as part of Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 15889.001 – Tunnel Ventilation Fans and all Associated Equipment shall be measured as a lump sum unit, complete in place.

B. Item 15889.002 – Evases and all Associated Equipment shall be measured as a lump sum unit, complete in place.

C. Item 15889.003 – Spare Tunnel Ventilation Fans and all Associated Equipment shall be measured as a lump sum unit, complete in place.

D. Item 15889.004 – High Temperature Testing of Tunnel Ventilation Fans and all Associated Equipment shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 15889.001 – Tunnel Ventilation Fans and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

B. Item 15889.002 – Evases and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

C. Item 15889.003 – Spare Tunnel Ventilation Fans and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

D. Item 15889.004 – High Temperature Testing of Tunnel Ventilation Fans and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 15890

TUNNEL VENTILATION JET FANS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for tunnel ventilation jet fans, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design detailing, manufacture detailing, supply, delivery, off-loading, storage, furnish, install, testing and commissioning of the new jet fans and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the jet fans portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 01785, "Construction Surveying"

B. Section 01910, "Operations, Maintenance and Repair Data"

C. Section 05120, "Structural Steel"

D. Section 05520, "Miscellaneous Metal Work"

E. Section 01911, "Operations, Maintenance and Repair Database"

F. Section 15400, "Tunnel Services Scope of Work"

G. Section 15887, "Tunnel Ventilation and Balancing Dampers"

H. Section 15888, "Tunnel Ventilation Noise Attenuators"

I. Section 15889, "Tunnel Ventilation Fans"

J. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

K. Section 16889, "Tunnel Services Electrical Testing and Commissioning"

L. Section 16890, "Tunnel Services Electrical Requirements for Mechanical Equipment"

M. Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center"

1.03 REFERENCE STANDARDS

A. Anti-friction Bearing Manufacturer's Association (AFBMA)

B. AMCA

C. ANSI

D. ASHRAE

E. ASTM

F. AWS

G. British Standards (BS)

H. IEEE

I. ISO

J. NEMA

K. NFPA

L. SSPC

M. UL

1.04 SUBMITTALS

A. All drawing, calculation and design submittals shall be sealed by a Professional Engineer.

B. Jet fan clearance waiver
   1. The jet fans in the Liberty Avenue tunnel between Wood St Station and Gateway Station are the subject of a waiver for interference with the clearance (LRV and pantograph) envelope. The status of this shall be confirmed by the Contractor prior to shipment of the jet fans or components to the Worksite.
   2. A construction survey shall be completed by the Contractor in accordance with Section 01785, "Construction Surveying". This shall be used by the Contractor as a basis to develop a CAD drawing of the cross sections where the Liberty Avenue jet fans are to be installed. The cross section shall include the clearance envelope (LRV and pantograph) and the proposed jet fans including attenuators, fully detailed mountings and all other auxiliary equipment required for a fully functional jet fan assembly in accordance with the Contract Documents. The cross

section shall be dimensioned to show the interference of the jet fan assembly with the clearance envelope. Supporting documentation regarding the proposed jet fan dimensions and mounting detail shall be submitted to the Engineer for approval prior to procurement of the jet fans

3. It shall be the Contractor's responsibility to ensure that the as built jet fan assemblies conform to the requirements of the jet fan waiver. The Contractor shall inform the Engineer of any discrepancies between the Contractor's drawings and the as-built jet fan assembly.

C. Certified results from the required shop testing shall be provided prior to shipment of the jet fans or components to the Worksite.

D. Shop Drawings
   1. Submit Shop Drawings of the tunnel ventilation jet fans showing layout, location, size of system components, installation conditions, mounting details, the clearance envelope (LRV and pantograph) relative to the jet fan assembly and any other relevant information. These shall be submitted to the Engineer for approval prior to procurement and installation of any components of the tunnel ventilation jet fans.

E. As Built Drawings
   1. Submit As Built Drawings for tunnel ventilation jet fans showing layout, location, size of system components, installation conditions, mounting details, the clearance envelope (LRV and pantograph) relative to the jet fan assembly and any other relevant information. These shall be submitted to the Engineer for approval upon Substantial Completion of the tunnel ventilation jet fans portion of the Work.

F. The documentation provided shall include key manufacturing quality assurance reports, including particularly the testing procedures carried out for material quality and structural integrity and the results in terms of defects noted.

G. High temperature testing procedures shall be submitted to the Engineer for review and approval prior to any high temperature testing activities.

H. The Contractor shall submit the following manufacturing certificates and details within 60 days of Notice to Proceed.
   1. Catalogue cuts shall be provided of the proposed jet fans.
   2. Predicted thrust data for the jet fans and certified thrust data from testing similar jet fans if available.
   3. Verification documents that the jet fans can withstand a working gas temperature of 482°F for one hour and resist thermal shock (recent tests on comparable jet fans of the same manufacture and components may be acceptable with agreement from the Engineer).
   4. Evidence that the materials selected and the assembled product will have a service life expectancy of not less than 20 years with reasonable maintenance. This shall include details of corrosion protection.

5. Evidence that the materials selected and the assembled product can withstand the stresses caused by a pressure transient of ± 4 in. wg occurring 500 times per day.
6. Schedule of at least 3 locations where comparable jet fans and drive systems have been in satisfactory operation for a minimum period of 5 years.
7. Factory quality control plan and manufacturing schedule.
8. Estimated mean time between failure (MTBF).
9. Estimated mean time between service failure (MTBSF).
10. Mean time to repair (MTTR).
11. Recommended planned maintenance schedule.
12. Manufacturer recommendations for handling and long term storage of any spare equipment.
13. Equipment loads for supporting steelwork.
14. Dimensioned general arrangement and interface Shop Drawing of the jet fans and mountings.
15. Anticipated sound power spectrum to ISO 3744.
16. Proposed galvanizing and/or painting regime.
17. Completed equipment schedule as per Table 15890-1 of this Section.

I. The Contractor shall submit manufacturer certificates and details below prior to delivery to the Worksite. The documentation delivery Schedule shall be proposed by the Contractor in the Project Schedule and submitted to the Engineer for approval.
   1. Certified thrust data from testing the jet fans.
   2. Test reports to show that the jet fans can withstand a working gas temperature of 482°F for one hour and resist thermal shock. This shall require testing of each type of fan to be supplied.
   3. Evidence that the materials selected and the assembled product will have a service life expectancy of not less than 20 years with reasonable maintenance. This shall include details of corrosion protection.
   4. Evidence that the materials selected and the assembled product can withstand the stresses caused by a pressure transient of ± 4 in. wg occurring 500 times per day.
   5. Factory quality control records, inspection checklists and test reports.
   6. Estimated mean time between failure (MTBF).
   7. Estimated mean time between service failure (MTBSF).
   8. Mean time to repair (MTTR).
   9. Operation and maintenance manuals – these manuals shall describe the recommended maintenance, all design parameters and the designations, part numbers and commercial sources of spare parts. Manual format and numbers shall be in accordance with Authority requirements. As a minimum three copies shall be provided.
   10. Manufacturer recommendations for handling and long term storage of any spare equipment.
   11. Measured sound power spectrum under tests in accordance with ISO 3744.
   12. Equipment loads for supporting steelwork.
   13. Dimensioned general arrangement and interface Shop Drawing of the jet fans and mountings.

14. Galvanizing and/or painting regime.
15. Completed equipment schedule as per Table 15890-1 of this Section.

J. Equipment requirements are scheduled in Table 15890-1 of this Section and are shown on the Contract Drawings. The items in Table 15890-1 of this Section listed as "By Contractor" shall be completed by the Contractor as required by the Submittals of this Section. Equipment information and/or data sheets shall be submitted with the completed Table 15890-1.

TABLE 15890-1 Jet Fan Schedule

Equipment Number	GW-TJF- 101 to 104	NS-TJF- 201 to 206	NS-TJF- 207 to 210
Make	By Contractor	By Contractor	By Contractor
Model	By Contractor	By Contractor	By Contractor
Type	Reversible	Reversible	Uni-directional
Thrust (lbf) (TBC)	Table 15890-2	Table 15890-2	Table 15890-2
Exit Velocity (fpm)	By Contractor	By Contractor	By Contractor
Speed (rpm)	By Contractor	By Contractor	By Contractor
Shaft Power (HP)	By Contractor	By Contractor	By Contractor
Max Fan Diameter (in)	25	40	63
Hub Diameter (in)	By Contractor	By Contractor	By Contractor
No. of Blades	By Contractor	By Contractor	By Contractor
Pitch Angle (degrees)	By Contractor	By Contractor	By Contractor
Estimated Motor Size (HP) (TBC)	30	60	100
Type	By Contractor	By Contractor	By Contractor
Frame Size	By Contractor	By Contractor	By Contractor
Input (HP)	By Contractor	By Contractor	By Contractor
Voltage/Hz/pH	By Contractor	By Contractor	By Contractor
FLA (amps)	By Contractor	By Contractor	By Contractor
Thermistor	By Contractor	By Contractor	By Contractor
Elevated Temperature	482°F for 1 hour	482°F for 1 hour	482°F for 1 hour
Variable Speed Drive	No	No	No
Direct on Line	Yes	Yes	Yes
Sound Power (dB)	Outlet Inlet	Outlet Inlet	Outlet Inlet
63	By Contractor	By Contractor	By Contractor
125	By Contractor	By Contractor	By Contractor
250	By Contractor	By Contractor	By Contractor
500	By Contractor	By Contractor	By Contractor
1000	By Contractor	By Contractor	By Contractor
2000	By Contractor	By Contractor	By Contractor
4000	By Contractor	By Contractor	By Contractor
8000	By Contractor	By Contractor	By Contractor

dBA @ 10 ft	By Contractor	By Contractor	By Contractor
Attenuator Length	2D	2D	2D

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Materials
1. The Contractor shall provide all manufactured items, materials, labor, cartage, tools, plant, appliances and fixings necessary for the proper execution of the work, together with all the minor and incidental works.
2. Should the Contractor propose any deviation from the specified requirements, such variations shall be submitted in writing to the Engineer for approval.
3. This Section shall be read in conjunction with the relevant Contract Drawings.

B. Design Life
1. Jet fans shall be designed for an operating life of 20 years unless noted otherwise.

C. Serviceability of Electrical and Mechanical Equipment
1. Serviceability of elements shall be considered in the detailed design and shall be clearly identified in the Shop Drawings.
2. Lifting eyes shall be provided at the top of the fan above the center of mass and at two points approximately 60° around the fan casing either side of the first point. The lifting points shall be suitable for lifting an entire fan unit including attenuators.
3. Jet fans shall be readily removable from the mounting steelwork.
4. Equipment must be accessible and serviced safely to the satisfaction of the Engineer.

D. Equipment Identification
1. Jet fans and control devices shall be permanently labeled after installation. All labels shall be of a uniform format. This format shall identify and provide information regarding fan type, fan function, flow direction and other such data as appropriate. Identification shall include the equipment designator given on the Contract Drawings or in schedules. Naming and numbering shall be in accordance with any Authority requirements and shall be coordinated with the Authority.
2. The manufacturer's model number and the motor power shall also be suitably recorded on the fan casing.

E. Equipment Location
1. The Contract Drawings show the intended locations of the jet fans.

2.02 JET FANS

A. General

1. The tunnel ventilation jet fans shall be direct drive axial flow fans. Depending on the installation position, jet fans may or may not be fully reversible. This is quantified in Table 15890-1 of this Section. Aerodynamic efficiency in the forward direction shall be not less than 70%. If required to be reversible, the performance requirements (thrust) shall be attainable in both directions. The efficiency in the reverse direction shall be not less than 90% of the efficiency in the forward direction
2. All tunnel ventilation jet fans of a given size shall be the same. In the selection of jet fans, interchangeability of parts shall be considered. All jet fans of a given size shall be from a single manufacturer.

B. Fan Performance

1. The nominal fan performance requirements are given in Table 15890-2. Listed thrust values are based on a jet fan discharge velocity of 6900fpm. For discharge velocities outside of this range, jet fan thrusts will need to be re-assessed (Note: values listed include installation and elevated temperature factors as required). Listed thrust values are per fan for the number of jet fans as shown on the Contract Drawings and listed in Table 15890-2 of this Section.

TABLE 15890-2 Fan Performance Requirements

Jet Fan Equipment Number	Total H (Jet Fans) ($sqft/s^2$)	Design Tunnel Velocity - V_T (fpm)	Tunnel Area - A_T (sqft)	Reversible	Nominal Jet Fan Thrust per fan (lbf)
GW-TJF-101 GW-TJF-102 GW-TJF-103 GW-TJF-104	221	500	420	Yes	93 (Allows for 4 jet fans operating)
NS-TJF-201 NS-TJF-203 NS-TJF-205	321	364	312	Yes	236 (Allows for 2 jet fans operating)
NS-TJF-202 NS-TJF-204 NS-TJF-206	321	364	312	Yes	236 (Allows for 2 jet fans operating)
NS-TJF-207 NS-TJF-209	576	246	323	No	562 (Allows for 1 jet fan operating)
NS-TJF-208 NS-TJF-210	576	246	323	No	562 (Allows for 1 jet fan operating)

2. The nominal jet fan thrust per fan given in Table 15890-2 is based on a certain number of jet fans operating at once. This is indicated in Table 15890-2 and

allows for redundancy in the system. Any variation in the number of jet fans operating will require the nominal jet fan thrust per fan to be reassessed.

3. In order to define the jet fan thrusts, a quantity called the pressure head increase (H) is used. The nominal thrust is that achieved when the fan is operating in a free field of otherwise still air at a density of $0.075 lb/ft^3$. Pressure head increase is defined as the pressure rise generated by jet fans divided by the air density:

$$H = \frac{\Delta P}{\rho} \quad (sqft/s^2)$$

4. The Contractor shall select and analyze the jet fan installation designs to ensure they will provide the required pressure head increases.

C. Reversal

1. Reversible tunnel jet fans shall be capable of reversing from full forward flow to full reverse flow, or vice versa, with a de-energized period not exceeding 30 seconds between reversals. The period to reach full capacity flow after de-energization shall not exceed 30 seconds. Three reversals shall be possible during a 20 minute period, where a reversal is defined as one change from forward mode operation to reverse mode operation or vice versa.

D. High Temperature Performance

1. Jet fans, attenuators and mounting systems shall be designed to continue to operate and maintain structural integrity for at least one hour while moving air at a temperature of 482°F.

E. Noise (Attenuators)

1. The jet fans shall be supplied complete with attenuators such that when the jet fans are mounted according to the Contract Drawings and all operating together, the noise level 5 feet above any part of the tunnel walkway does not exceed 85dBA. Supplier data shall be submitted to the Engineer for review prior to the Contractor procuring the fans.
2. Attenuators shall be of the cylindrical type and conform to the same elevated temperature requirements as the fans. Attenuators shall be self draining. The attenuators shall be fully protected from corrosion over the design life of the fan.
3. Supports for attenuators may also be required.

F. Screens
   1. Screens shall be provided on the inlet side of each attenuator supplied as part of the jet fan assembly.
   2. Screens shall be supplied by the jet fan manufacturer as part of the attenuator.
   3. Screens shall have the maximum open area possible and shall not be less than 95% open.
   4. The Contractor shall ensure that the screens do not adversely affect the jet fan performance or the high temperature requirements of NFPA 130.

G. Balancing
   1. Each fan shall be balanced statically and dynamically in accordance with the appropriate level in AMCA204.

H. Impeller and Blades
   1. Fan rotors shall consist of manually adjustable blades. Unidirectional jet fan blades shall be of true aerofoil section. Reversible jet fan blades shall be symmetrical for efficiency in both directions.
   2. Impellers and blades shall be made of materials suitable for the specified temperature, pressure and pollution conditions and speeds, dynamic loads and fatigue loads.
   3. Impellers shall be designed so that the bearings do not suffer permanent damage when the fans are stationary, over the design life of the fan.
   4. All fan blades and the hubs shall be inspected by x-ray, or other non-intrusive means, and results provided to demonstrate freedom from cracks and imperfections, to the approval of the Engineer.
   5. The first critical speed (natural frequency) of the shaft impeller motor assembly shall be at least 50% higher than the design maximum operating speed.
   6. The assembly shall be able to withstand stresses and loads created by overspeed testing to 125% of the nominal operating speed.

I. Fan Casing
   1. Fan casings shall be made of welded mild steel with a minimum thickness of ¼ inch and with continuously welded flanged ends. The casings shall be fully protected from corrosion over the design life of the fan.
   2. Access points shall be provided in the fan casing for access to blade locking devices for field adjustment of blade pitch.

J. Installation Cradle
   1. Jet fan supply shall include one installation cradle designed to facilitate the installation and maintenance of the jet fans using a scissor lift or similar platform. The cradle shall suit all jet fans supplied as part of the Section.
   2. The installation cradle and any associated equipment shall remain the property of Authority after the installation of the jet fans. The Contractor shall be responsible for the transport and off-loading of the cradles to a site nominated by Authority.

K. Fan Power

1. Power supply shall be 480V 3 ph 4 wire 60Hz. Jet fans shall be capable of operating to designed performance within normal voltage and frequency tolerances.

L. Motors

1. Jet fan motors shall be suitable for use in a tunnel environment, single speed, Direct On Line (DOL) (across-the-line) starting, totally enclosed air over (TEAO) and be capable of at least 6 starts per hour. They shall also be capable of being run in an inclined position (up to 15 degrees from the horizontal).
2. Motors must comply to applicable ANSI, IEEE and NEMA or approved equivalent ISO standards and be of NEMA Design B.
3. Motors shall be capable of run up and reversal in accordance with Article 2.02C of this Section.
4. Motors shall be fitted with anti-condensation heaters.

M. Bearing Life

1. The L_{10} design life of the fan motor bearings shall be 50,000 hours (minimum). The Contractor shall advise the maximum bearing life possible.

N. Other

1. Site Measurement
   a. The particular jet fans required are designated on the Contract Drawings. The Contractor shall site measure all builder's work to be fitted with jet fans assemblies and be responsible for correct installation to the tunnel walls.
2. Fixtures
   a. Jet fans shall be supplied complete with all fixtures (nuts, bolts, spacers, washers, seals, packers etc) such that jet fans and components supplied with the jet fans can be completely assembled.
3. Equipment surface corrosion protection
   a. Unless specified, appropriate anti-corrosion provisions shall be made by the Contractor for all components based on SSPC standards suitable for installation conditions. The Contractor shall provide information regarding material selections and galvanizing and painting schemes.

2.03 JET FAN MOUNTING FRAMES

A. General

1. Depending on the location, jet fans are to be mounted in configurations from tunnel ceilings and/or walls. The mountings to the tunnel wall or ceiling shall be able to sustain the full weight of the jet fan assembly without failure. The Contractor shall coordinate with other Authority Contracts to ensure that the mountings will not adversely affect the structural works or lead to failure of a structural section. Mounting fixtures shall be provided by the Contractor unless noted otherwise on the Contract Drawings.
2. Jet fans shall be provided complete with mounting frames or points to enable mounting in the orientation as shown on Contract Drawings. The Contractor shall

design and supply steel frames to enable mounting of jet fans to mounting fixtures.

3. All support steelwork shall conform to Section 05120, "Structural Steel" and Section 05520, "Miscellaneous Metal Work".

B. High Temperature Performance

1. Jet fan mounting systems shall be designed to continue to operate and maintain structural integrity for at least one hour while moving air at a temperature of 482°F.

C. Anti-vibration Mountings

1. Jet fans shall be supplied with suitable mounting frames to facilitate mounting to the tunnel roof and/or tunnel walls.
2. Each jet fan shall be mounted on spring anti-vibration mountings to attenuate vibrations reaching the structural connection to the tunnel roof or walls. The mounting shall be designed so that the complete failure of the anti-vibration element does not allow the fan to fall. These shall be provided by the Contractor. Coordination with the jet fan supplier may be required with respect to the selection of mountings.
3. The anti-vibration mountings shall be capable of the same high temperature performance as the jet fans, without failure.
4. The support system shall be adequately braced to ensure stability during unit start up, operation and shut down.

D. Other

1. Site Measurement
    a. The particular jet fan mountings required are designated on the Contract Drawings. The Contractor shall site measure all builder's work to be fitted with jet fans assemblies and be responsible for correct installation to the tunnel walls.
2. Fixtures
    a. Jet fan mountings shall be supplied complete with all fixtures (nuts, bolts, spacers, washers, seals, packers etc) such that jet fan mountings can be completely assembled. Fixtures to enable the mounting of jet fans in the tunnels shall be provided by the Contractor unless noted otherwise on the Contract Drawings.
3. Equipment surface corrosion protection
    a. Unless specified, appropriate anti-corrosion provisions shall be made by the Contractor for all components based on SSPC standards suitable for installation conditions. The Contractor shall provide information regarding material selections and galvanizing and painting schemes.

2.04 INSTRUMENTATION AND CABLING

A. Passive type dry contact flow switches shall be provided with each fan to provide positive indication of airflow (in each direction for reversible fans).

B. Each fan shall be supplied complete with permanent equipment to measure and report out of balance vibration from the impeller, motor and bearings. This equipment shall monitor the fan continuously while it is running, and shall generate an alarm signal available to the control system if the vibration exceeds a preset limit (defined by the fan manufacturer).

C. Each set of jet fans shall be fitted with an air flow temperature sensor and transmitter. These transmitters shall provide a 4-20mA output signal which shall be connected into the PLC.

D. Each fan motor shall be fitted with motor bearing RTDs and motor winding RTDs connected to separate terminal boxes on the fan casing. These sensors shall generate an alarm condition (not shut down fans) available to the control system via an approved motor protection relay, when bearing or winding over-temperature is detected.

E. All instrumentation and leads within the air stream shall continue to operate in the same high temperature conditions required of the jet fans.

F. General Electrical Requirements
   1. Additional electrical requirements are given in Section 16890, "Electrical Requirements for Mechanical Equipment for Fire Life Safety Systems".

2.05 SPARES

A. The Contractor shall provide a spare jet fan assembly and associated equipment for each type of jet fan installed.

B. The spares shall be suitably packed for handling and for long term storage in accordance with manufacturer recommendations that have been approved by the Engineer and coordinated with Authority. Clear identification of the equipment shall be provided on the packaging. The Contractor shall be responsible for the transport and off-loading of any spares to a site nominated by Authority.

ARTICLE 3 EXECUTION

3.01 SHOP TESTING

A. Testing procedures shall be submitted to the Engineer for review and approval.

B. The fan manufacturer shall undertake shop performance tests as follows on one jet fan of each type.

1. ISO 5801 (or BS 848 Part 1 type C) performance tests to determine volume flowrates and exit velocity. The fan assembly complete with attenuators shall be tested for thrust performance. Measurement of developed thrust shall be in accordance with the requirements of ISO 13350 (BS 848-10). Testing shall be in the forward and reverse (where applicable) direction to determine thrust developed, airflow, exit velocity and input power.
2. As part of 1, carry out noise tests to ISO 3744. In view of the size of the jet fans, these are to be free field tests above a reflecting plane. Sound power levels are to be recorded both upstream and downstream.
3. As part of 1, record the motor voltage and currents.
4. Prove the reversing cycle.
5. Prove the operation of instrumentation.
6. Prove operation at 482°F for 1 hour and verify resistance to thermal shock from 68°F to 482°F in 20 seconds. This shall require elevated temperature tests on at least one fan unit of each type supplied.

C. The fan manufacturer shall undertake the following tests on all jet fans:
   1. Run at 100% and 125% of maximum rated speed for 3 minutes each, with no damage, excessive vibration or adverse behavior.

D. All fan testing shall be shown as a witness point in the manufacturing schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Shop testing carried out without sufficient notice will be deemed to have not been done and those jet fans will be re-tested when the Engineer can be in attendance.

3.02 SITE TESTING AND COMMISSIONING

A. Site testing and commissioning shall be in accordance with Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

B. The Contractor shall carry out tests on completion. The tests shall be carried out once all elements of the tunnel structure which affect the ventilation system represent adequately the final operating conditions. The performance tests shall be carried out to demonstrate to the Engineer that jet fans are operating correctly.

C. Tests shall include both aerodynamic, vibration and noise tests.

D. All testing shall be shown as a witness point in the Contractor's Project Schedule. At least 2 weeks notice of testing shall be given and the Contractor shall facilitate the attendance at the tests of the Engineer. Site testing carried out without sufficient notice will be deemed to have not been done and those fans will be re-tested when the Engineer can be in attendance.

3.03 SYSTEM COMMISSIONING

A. The tunnel ventilation jet fans are part of the overall ventilation system and shall be included in the ventilation system commissioning.

B. System commissioning shall be completed as part of Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 15890.001 – Tunnel Ventilation Jet Fans and all Associated Equipment shall be measured as a lump sum unit, complete in place.

B. Item 15890.002 – Spare Tunnel Ventilation Jet Fans and all Associated Equipment shall be measured as a lump sum unit, complete in place.

C. Item 15890.003 – High Temperature Testing of Tunnel Ventilation Jet Fans and all Associated Equipment shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 15890.001 – Tunnel Ventilation Jet Fans and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

B. Item 15890.002 – Spare Tunnel Ventilation Jet Fans and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

C. Item 15890.003 – High Temperature Testing of Tunnel Ventilation Jet Fans and all Associated Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 15891

TUNNEL SERVICES MECHANICAL TESTING AND COMMISSIONING

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for mechanical testing and commissioning for tunnel services systems, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Shop Testing - Shop testing of tunnel services equipment as required by the Related Sections.
   2. Equipment Commissioning - Verification that individual equipment and sub-assemblies are installed in accordance with the Contract Documents, as well as in accordance with their respective manufacturer's recommendations for optimal performance and/or good practice. This activity shall include installation, pre-commissioning and equipment commissioning stages.
   3. System Commissioning - Verification that all systems are performing according to the Related Sections and other Contract Documents, with correct settings to ensure that the tunnel services system behavior reflects the design analysis or intent for all tunnel services modes of operation.

C. The tunnel services equipment to be tested and commissioned include, but are not limited to, the following:
   1. Tunnel ventilation noise attenuators
   2. Tunnel ventilation fans
   3. Tunnel ventilation jet fans
   4. Tunnel ventilation dampers
   5. Tunnel ventilation balancing dampers
   6. Tunnel fire extinguishers
   7. Tunnel dry standpipes
   8. Tunnel sump pumps (mechanical drainage)
   9. Tunnel sump level detection (mechanical drainage)

D. The tunnel services systems to be tested and commissioned as complete systems operating in various modal configurations include, but are not limited to, the following:
   1. Tunnel ventilation system for normal, congested and emergency operations.
   2. Tunnel fire protection system (dry standpipe system).
   3. Tunnel mechanical drainage system.

E. This Section outlines the minimal requirements for commissioning. Commissioning of other equipment and systems not listed above or described in this Section is described in Related Sections.

1.02 RELATED SECTIONS

A. Section 15400, "Tunnel Services Scope of Work"

B. Section 15445, "Tunnel Mechanical Drainage Systems"

C. Section 15884, "Tunnel Fire Extinguishers and Cabinets"

D. Section 15885, "Tunnel Dry Standpipe Systems"

E. Section 15887, "Tunnel Ventilation and Balancing Dampers"

F. Section 15888, "Tunnel Ventilation Noise Attenuators"

G. Section 15889, "Tunnel Ventilation Fans"

H. Section 15890, "Tunnel Ventilation Jet Fans"

I. Section 16889, "Tunnel Services Electrical Testing and Commissioning"

J. Section 16890, "Tunnel Services Electrical Requirements of Mechanical Equipment"

K. Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center"

L. Section 16892, "Tunnel Services Uninterruptible Power Supply"

M. Section 16893, "Tunnel Services Power Factor Correction"

N. Section 16894, "Tunnel Emergency Rail Lighting and Lighting Receptacles"

O. Section 16895, "Tunnel Services Low Voltage AC Variable Speed Drive"

1.03 REFERENCE STANDARDS

A. AMCA

B. ANSI

C. Anti-Friction Bearing Manufacturer's Association (AFBMA)

D. ASHRAE

E. ASME

F. ASTM

G. AWS

H. BOCA

I. British Standards (BS)

J. IEEE

K. ISO

L. NEC

M. NEMA

N. NFPA

O. Port Authority of Allegheny County, North Shore Connector Manual of Design Criteria.

P. SMACNA

Q. SSPC

R. UL

1.04 DEFINITIONS

A. Normal Operations: Conditions where trains are moving through the tunnels generally to timetable, stopping only at stations.

B. Congested Operations: Conditions when one train comes to a halt in a running tunnel between stations, either because of signaling problems, or traffic congestion, or other reasons, but where there is no immediate risk to people.

C. Emergency Operations: Conditions when a fire or other serious event has occurred underground, with possible risk to people and requiring use of the ventilation system.

D. Ventilation Mode: A preprogrammed ventilation response that involves the use of sets of fans to supply or exhaust air to a section of tunnel. This requires certain sets of dampers to open or close depending on the response required.

1.05 SUBMITTALS

A. All submittals shall be sealed by a Professional Engineer.

B. The Contractor shall submit a detailed commissioning plan to the Engineer for approval prior to all commissioning activities. The plan for system commissioning shall be submitted at least 6 weeks before the planned commencement of the system commissioning.

C. The commissioning plan shall provide details of all commissioning activities to be undertaken and the schedule for these to occur. This shall also outline the coordination required with other Authority Contracts to complete the work.

D. The Contractor shall submit all test procedures to the Engineer for approval prior to any commissioning activities.

E. The Contractor shall submit valid calibration certificates for all test equipment to the Engineer prior to commencing any testing and/or commissioning activities. The Contractor shall submit valid calibration certificates for any equipment that are listed in test plans and associated test reports.

F. The Contractor shall submit as part of the commissioning plan details of all proposed measuring techniques (i.e. procedures for measuring in-tunnel airflows, damper airflows, water flows etc).

G. The Contractor shall submit all testing and commissioning results as required by this Section and Related Sections.

ARTICLE 2 PRODUCTS

A. NOT USED

ARTICLE 3 EXECUTION

3.01 GENERAL

A. All commissioning is to be carried out in a safe manner in accordance to Authority Occupational Health and Safety guidelines.

B. The Contractor shall coordinate or complete all interfaces with other Authority Contracts to ensure that full functionality of tunnel services systems is achieved prior to commissioning.

C. The Contractor shall carry out the testing, setting to work and commissioning of all mechanical tunnel services systems.

D. The Contractor shall ensure that individual systems meet Design Criteria specified in the related Sections.

E. The Contractor shall check and correct all interface systems and commission the system as a whole.

F. The Contractor shall ensure that the system performance as a whole complies fully with the design intent to the satisfaction and approval of the Engineer.

G. The Contractor shall ensure that all apparatus, material used and completed equipment shall withstand satisfactorily such tests as are specified herein and any additional tests customary in the manufacture and installation of the types of equipment included in the Contract Documents, or which may reasonably be required by the Contractor to prove compliance with this Section and Related Sections.

3.02 TEST INSTRUMENTS

A. All test equipment to enable the tests specified herein to be performed shall be provided by the Contractor. Equipment required includes, but is not limited to, the following:
   1. Anemometers (rotating vane and hot wire)
   2. Vibration monitoring equipment
   3. Sound level meters
   4. Tachometers
   5. Non-contact temperature measuring equipment

B. Incidentals and associated equipment shall be provided by the Contractor as required to complete all testing and commissioning of mechanical tunnel services systems.

C. The Contractor shall check the condition of the testing equipment at the time of the test and issue a report on its condition to the Engineer.

3.03 WITNESSING OF TESTS

A. All tests shall be carried out in the presence of the Engineer and test certificates are to be submitted to the Engineer for approval within seven days thereafter.

B. All testing and commissioning shall be shown as a witness point in the manufacturer's and/or Contractor's Project Schedule. At least 2 weeks notice shall be given and the Contractor shall facilitate the attendance of the Engineer. Any testing or commissioning carried out without sufficient notice will be deemed to have not been done and will be required to be redone when the Engineer can be in attendance.

3.04 SHOP TESTING

A. The Contractor shall submit all shop tests including, but not limited to, that described in the related Sections for each type of equipment required for this portion of the Work.

B. All relevant test results and documentation produced during the factory tests shall be submitted to the Engineer for approval before delivery to Worksite.

3.05 EQUIPMENT COMMISSIONING

A. The Contractor shall complete all testing and commissioning including, but not limited to, that required in the Related Sections.

B. Installation Stage - This stage focuses on compliance with drawings, specification and equipment schedules by the Contractor. Details such as correct orientation and clearances specified by the drawings, specifications or manufacturer's manuals shall be documented. Correct identification labeling of all equipment and control devices shall also be verified at this stage. The Contractor shall perform and document all necessary checks during the installation process according to any items outlined in this Section, Related Sections and the Contractor's standard installation procedures and practice.

C. Pre-Commissioning Stage - This stage shall commence after the Installation stage has been completed and approved by the Engineer. Electrical power needs be available to the equipment. The focus of this stage is performing start-up tests and checking basic operability of the equipment and sub-assemblies. This includes, but is not limited to, bump testing of all fans and pumps and basic operation checks on all dampers. The Contractor shall perform and document all necessary tests according to items outlined in this Section, Related Sections and the Contractor's standard pre-commissioning procedures and practices.

D. Equipment Commissioning Stage - This stage shall commence after the Pre-Commissioning stage has been completed and approved by the Engineer. The ability to control equipment remotely (if applicable) from the OCC shall be available at this stage. The focus of this stage is the functional operability of individual items of equipment and sub-assemblies (both local and remote controlled), and compliance with the performance requirements outlined in the Related Sections and shown on the Contract Drawings. Measurements that are required to demonstrate compliance with the relevant performance requirements shall be fully documented and submitted to the Engineer for review. These tests/measurements shall include, but not be limited to:

1. Tests shall be carried out on each of the tunnel ventilation fans in accordance with BS848 Part1 Section 3 (ISO 5801). The purpose of the tests shall be to determine volume flow rate, power input and total pressure across the fan under actual operating conditions (i.e. confirm that the required air volume performance is attained). The tests shall also be used to provide an actual value of the flow resistance in the airways and volume flow into the tunnels. Some adjustment of

fan blade pitch etc may occur during this stage. These tests shall be in addition to the System Testing and Commissioning required by this Section. The volume flow rates shall also be measured at tunnel inlet and outlet points to confirm that airflows developed at the fans are achieved at the required inlet/outlet points (i.e. duct leakage is minimal). The airflow requirements are detailed in the Related Sections and in the mode table included in the Contract Documents.

2. Tests shall also include balancing and testing of each exhaust ductwork system that requires air balancing. Airflow would be regulated through setting balancing dampers and modulating dampers as required to meet the design intent.
3. Run tests of tunnel ventilation jet fans can also be undertaken at this stage, however performance testing of these will not be achieved until System Commissioning is complete.
4. Tests shall be carried out on each of the sump pumps to confirm flow rate requirements are achieved. The Contractor shall obtain the required water for this test.
5. Testing of the dry standpipe system shall be in accordance with NFPA 14.

3.06 SYSTEM TESTING AND COMMISSIONING

A. These tests shall be completed after the SCADA programming is complete and the system is capable of operating in the modes described in the mode table in the Contract Documents.

B. Some of these tests will require possession of large parts of the tunnel network (possibly after hours) and involve close coordination with all other Authority Contracts and Authority to set up and carry out the tests and then return the railway to its previous operational status. The use of Authority rolling stock will be required. The Contractor shall allow for the coordination of this and all associated costs involved.

C. Final adjustment of equipment (e.g. fan blade angles, balancing dampers, etc) shall be carried out at this stage as necessary to meet the system performance requirements.

D. The Contractor shall confirm that the selected modes are operating equipment in accordance with the system mode table. For example, for each mode the correct dampers are opening and closing as required and the correct ventilation fans and jet fans are operating.

E. Normal Operations
1. Cold air-flows at the station and in the running tunnels shall be measured to demonstrate compliance with the performance requirements and the design intent.
2. These tests shall include, but are not limited to, those scheduled in Table 15891-1.
3. Some of these tests require running trains through the system.
4. Station airflows must achieve values provided in the mode tables on the Contract Drawings (MC-400 to MC-404). For cases where the flows given are duct flows

and the duct inlets are balancing dampers, it must be demonstrated that the total flow to be achieved is balanced. The air flow rate through any individual balancing damper must not vary by more than 10% from the mean flow rate per exhaust inlet along that run of duct.

5. Air velocity at station entrances must be measured. Average and peak values are to be recorded.
6. Air velocity at three (3) equi-spaced stations along each platform shall be measured. Average and peak values shall to be recorded.
7. All test results shall be submitted to the Engineer for approval. The test results shall record all relevant information to the satisfaction of the Engineer. Tests that are not adequately documented will be deemed to not have happened and will be repeated by the Contractor at no extra expense to Authority.

Table 15891-1 Normal Operation Commissioning

Case	Description	Train Operations	Ventilation Zone	Ventilation Mode	Air Flow Measurements
1	Gateway Station Airflow: Balance Case	NA	3, 4	1	Mode table flows. Station entrance flows.
2	Gateway Station Airflow: Operating Case	Operate Station at Peak Hour Headway	3, 4	1	Station entrance flows. Flow along platform
3	North Side Station Airflow: Balance Case	NA	8	5	Mode table flows. Station entrance flows.
4	North Side Station Airflow: Operating Case	Operate Station at Peak Hour Headway	8	5	Entrance flows. Flow along platform

F. Congested and Emergency Operations

1. Cold air-flows at the station and in the running tunnels shall be measured to demonstrate compliance with the performance requirements and the design intent.
2. These tests shall include, but are not limited to, those scheduled in Table 15891-2 and Table 15891-3.
3. Some of these tests require locating trains at specific positions at stations and in tunnels.
4. Station airflows must achieve values provided in the mode tables on the Contract Drawings (MC-400 to MC-404). For cases where the flows given are duct flows and the duct inlets are balancing dampers, it must be demonstrated that the total

flow to be achieved is balanced. The air flow rate through any individual balancing damper must not vary by more than 10% from the mean flow rate per exhaust inlet along that run of duct.

5. All test results shall be submitted to the Engineer for approval. The test results shall record all relevant information to the satisfaction of the Engineer. Tests that are not adequately documented will be deemed to not have happened and will be repeated by the Contractor at no extra expense to Authority.

Table 15891-2 Congested and Emergency Tunnel Commissioning

Case	Description	Incident Track	Stationing (Front of Train) or General Position of Train	Vent Zone	Vent Mode	Tunnel Flow Required Across Train (kcfm)
1	Bored tunnel between Gateway and North Side Stations: Ventilation via Gateway Nozzle towards North Side Station.	Right	6017+00	5	26	168
2	Bored tunnel between North Side and Gateway Stations: Ventilation via jet fans towards Gateway Station.	Left	6038+00	6	28	158
3	Cut and Cover tunnel between portal and North Side Station: Ventilation via jet fans towards North Side Station.	Left	6047+00	10	35	177
4	Existing Liberty Avenue Tunnel: Ventilation via jet fans towards Gateway Station.	Left and Right	4 trains equally spaced in Liberty Avenue Tunnel	Existing Zone H	17	235
5	Existing Liberty Avenue Tunnel: Ventilation via jet fans towards North Side Station.	Left and Right	4 trains equally spaced in Liberty Avenue	Existing Zone H	18	230

			Tunnel			

Table 15891-3 Congested and Emergency Station Commissioning

Case	Description	Incident Track	Stationing (Front of Train) or General Position of Train	Vent Zone	Vent Mode	Tunnel Flow Required Across Train (kcfm)
1	Gateway Station, East Platform – Station Exhaust	Right	Train not required	3	20	Mode table flows
2	Gateway Station, West Platform – Station Exhaust	Left	Train not required	4	21	Mode table flows
3	Gateway Station, North-East Platform – Station Exhaust	Right	Train not required	3a	22	Mode table flows
4	Gateway Station, South-East Platform – Station Exhaust	Right	Train not required	3b	23	Mode table flows
5	Gateway Station, North-West Platform – Station Exhaust	Left	Train not required	4a	24	Mode table flows
6	Gateway Station, North-East Platform – Station Exhaust	Left	Train not required	4b	25	Mode table flows
7	North Side Station Platform – Station Exhaust	Left and Right	Train not required	8	31	Mode table flows

G. Noise Requirements
1. The Contractor shall measure and confirm that the noise levels are in accordance with the requirements of the Related Sections.
2. Noise levels shall be recorded and submitted to the Engineer and Authority for approval.

H. Dry Standpipe System
1. Operation of the dry standpipe system shall have been proven in the previous commissioning activity. The Contractor shall obtain the required water for this test.

I. Mechanical Drainage

1. The mechanical drainage system shall be tested to demonstrate that fully automatic operation is attained to the satisfaction of the Engineer.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 15891.001 – Mechanical Testing and Commissioning for Tunnel Services shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 15891.001 – Mechanical Testing and Commissioning for Tunnel Services will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16050

BASIC ELECTRICAL REQUIREMENTS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for Basic Electrical Requirements in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Electrical conduits
   2. Fittings
   3. Wires
   4. Cables
   5. Associated accessories
   6. Power distribution equipment

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data."

B. Section 16111, "Conduit."

1.03 REFERENCE STANDARDS

A. National Electrical Code (NEC) – National Fire Protection Association (NFPA 70)

B. National Electrical Safety Code (NESC)

C. Illuminating Engineering Society of North America (IESNA)

D. American National Standards Institute (ANSI)

E. National Electrical Manufacturers Association (NEMA)

F. Institute of Electrical and Electronic Engineers (IEEE)

G. Insulated Cable Engineers Association (ICEA)

H. Underwriters Laboratories, Inc. (UL)

I. National Electrical Contractors Association (NECA)

J. Electrical Codes of the Local Jurisdiction

K. American Society for Testing and Materials (ASTM)

L. Occupational Safety and Health Administration (OSHA)

M. Association of Edison Illuminating Companies (AEIC)

N. Life Safety Code – NFPA 101

O. Uniform Building Code (UBC)

P. Building Officials and Code Administrators (BOCA) Building Code

Q. Americans With Disabilities Act (ADA)

R. National Fire Alarm Code – NFPA 72

S. Instrumentation Society of America (ISA)

T. International Electrical Testing Association (NETA) Acceptance Testing Specifications (ATS) for Electrical Power Distribution Equipment and Systems

1.04 SUBMITTALS

A. Submittals for each manufactured item shall include manufacturer's descriptive literature, equipment drawings, diagrams, performance and characteristic curves, and catalogs cuts. Each submittal shall include the manufacturer's name, trade name, catalog model or number, nameplate data and rating, size, layout dimensions, capacity, specification reference, and information necessary to establish contract compliance.

B. Shop Drawings shall show types, sizes, accessories, elevations, plans, sectional views, installation details, elementary diagrams, and wiring diagrams. Wiring diagrams shall identify terminals and shall indicate the internal wiring for each item of equipment and the interconnection between the items. Shop Drawings for underground conduit installation shall show conduit routing, elevations and stub-up details.

C. Shop Drawings and manufacturer's data shall be submitted grouped to include in a complete single submittal of related systems, products, and accessories.

D. List of Materials: Prior to beginning the work of this Section, a list of materials and equipment proposed for use shall be submitted together with applicable standards. Provide the name of the manufacturer, the brand name, and the catalog number of each item.

E. Shop Drawings: Approved Shop Drawings shall be submitted showing the exact location and arrangements of conduits stubbed into equipment, cabinet, pull boxes and assigned spaces, conduit sleeves for exposed conduits, and for fabricated work. Submit such drawings before rough-in work, fabrication, and within ample time to prevent delays in the work. Include complete electrical wiring diagrams for equipment and equipment installation.

F. Operation and Maintenance Manuals shall be provided for major electrical equipment in accordance with Section 01910, "Operations, Maintenance and Repair Data." It shall include manufacturer's operation and maintenance instructions, wiring diagram, control and power elementary diagrams, list of spare parts, and recommended stock quantities for one-year routine maintenance and repair. A copy of approved Shop Drawing of equipment and other items where considered necessary shall be included.

G. Elementary and schematic wiring diagrams differentiating between manufacturer-installed and field-installed wiring shall be submitted.

H. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

I. Manufacturer's Certifications shall be signed showing certifying compliance with the Contract Document requirements. Upon request, submit evidence of experience.

J. Installers' Certificates shall be signed by the Contractor showing that the installers complied with the Contract Document requirements.

K. Field testing firm certificates shall be signed by Contractor showing that the firm complied with the Contract Document requirements.

L. Report of Field Tests: Certified copies of field tests shall be submitted.

M. The manufacturer shall provide a list of spare parts and equipment required to maintain the operation of the systems being placed in service

1.05 QUALITY ASSURANCE

A. Requirements of Regulatory Agencies: Comply with construction requirements of state, county, and such other local jurisdiction specifications as may exceed the requirements of the codes, standards, and approving bodies referenced herein.

B. Certificates: Upon completion of work, the Engineer shall be furnished formal certification of final inspections from authorities having jurisdiction.

C. Source Quality Control: Products used throughout shall be those of companies having established reputations in the manufacturing of the particular materials and equipment specified.

D. Inspection and Tests: The Contractor shall be furnished certification, through inspection and tests, that the equipment and systems provided and installed as part of the Contract shall satisfy the performance requirements of the Contract Documents.

These tests and inspections shall be performed before equipment is shipped to the site and during acceptance and startup testing at the site.

E. Inspection of the materials and equipment shall be made at the point of delivery and the manufacturing facility. Notify the Engineer when the materials and equipment are being fabricated or shipped to the site in order that the desired inspections can be made.

F. Products shall be provided that are free from defects that may impair performance, durability, or appearance and of the industrial quality best suited for the purpose indicated or specified herein.

G. New and high quality materials and equipment of the design, size, and rating indicated shall be furnished.

H. Test equipment suitability and calibration shall comply with NETA ATS "Suitability of Test Equipment" and "Test Instrument Calibration."

I. All systems shall be complete, tested, and fully operational prior to the acceptance by Authority.

1.06 PROJECT SITE CONDITIONS

A. Interferences
   1. The Contract Drawings are generally diagrammatic and indicative of the work. Install work in locations shown on the Contract Drawings, unless prevented by project conditions. Prepare Working Drawings showing proposed rearrangement of work to meet project conditions, including changes to work specified in other Sections. Obtain the Engineer's permission before proceeding.
   2. Electrical equipment shall be installed in a manner not to delay or interfere with other operations or project work.
   3. Prior to making electrical installations, electrical work shall be coordinated with the work of other trades, especially in congested areas.

B. All items of labor, materials, and equipment, not specified in detail or shown on drawings but necessary for completion of a fully operational system shall be furnished and installed.

C. Electrical work shall be installed in sequence with Project construction phasing.

1.07 COORDINATION WITH OTHER WORK

A. Drawings:
   1. For purposes of clarity, and legibility, Contract Drawings are essentially diagrammatic.
   2. Exact routing of wiring and locations of outlets, panels, etc., shall be governed by structural conditions, obstructions, and existing conditions.

3. Mounting heights of brackets, outlets, etc., shall be as required to suit equipment served.
4. Contract Drawings indicate, generally, routes of all branch circuits. All runs to panels are indicated as starting from nearest outlet, pointing in direction of panel. Continue all such circuits to panel as though routes were indicated in their entirety.

B. Coordination
   1. Coordinate all work conditions advance of installation. If necessary, and before work proceeds in restricted areas, prepare supplementary Working Drawings for the Engineer's review, showing all work in restricted area. Provide supplementary Working Drawings and additional work necessary to overcome restricted conditions.
   2. Coordinate electrical power and control wiring requirements of mechanical equipment with the Contract Documents.

C. Equipment Rough-In
   1. Rough-in locations shown on Contract Drawings for equipment furnished by Authority and for equipment furnished under other Sections are approximate only.

D. Obtain exact rough-in locations from following sources
   1. From Shop Drawings for Contractor-furnished and installed equipment.
   2. Coordinate installation of required supporting devices and set sleeves in cast-in-place concrete, masonry walls, and other structural components as they are constructed.
   3. Coordinate location of access panels and doors for electrical items that are behind finished surfaces or otherwise concealed.

1.08 DELIVERY, STORAGE AND HANDLING

A. Store and protect products in accordance with manufacturers' instructions, with seals and labels intact and legible.
   1. One copy of these instructions shall be included with the equipment at time of shipment.

B. Cover products subject to deterioration with impervious sheet covering. Provide ventilation where required to avoid condensation or potential degradation of product.

C. Provide equipment and personnel to store products by methods to prevent soiling, disfigurement, or damage.

D. Arrange storage of products to permit access for inspection. Periodically inspect to verify products are undamaged and are maintained in acceptable condition.

E. Each unit or component shall be shipped securely packaged and labeled for safe handling in shipment and to avoid damage or distortion.

F. Maintain protective coverings until installation is complete.

G. Equipment and material damaged during transportation, installation, or operation shall be considered as totally damaged and shall be replaced with new.

H. Protect from loss or damage.

ARTICLE 2 PRODUCTS

2.01 MATERIALS AND EQUIPMENT

A. Furnished by manufacturers regularly engaged in the production of such products of equal material, design, and workmanship.

2.02 MATERIALS FURNISHED

A. Provide Equipment of one manufacturer, alike in appearance and function.
   1. For equipment specified by manufacturer's number, include all accessories, controls, etc., listed in catalogue as standard with equipment. Furnish optional or additional accessories as specified.

B. Where no specific make of material or equipment is mentioned, use product of approved manufacturer, which conforms to requirements of the Contract Documents.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Contract Drawings are symbolic and diagrammatic in nature and are intended to show approximate location of equipment. The locations shown on the Contract Drawings are subject to modification due to conditions arising as construction progresses. Check locations shown prior to installation.

B. Work shall be installed in a first-class, neat and workmanlike manner. Firmly support all materials and equipment.

3.02 FIELD QUALITY CONTROL

A. Electrical Systems Test
   1. Perform tests in the presence of the Engineer, and furnish statements of the tests made and the results to the Engineer
   2. Testing: Test materials and assemblies in conformance with currently approved method for the particular type and class of work, and, where applicable, in accordance with International Electrical Testing Association (NETA) Acceptance Testing Specifications (ATS) for Electrical Power Distribution Equipment and Systems.

3. Render the entire installation free from short circuits and improper grounds. Test each individual power circuit at the panel with the power equipment connected for proper operation.
4. Perform electrical system tests using insulation resistance testers prior to placing electrical systems into complete operation. In no case, shall the insulation resistance be less than one hundred thousand ohms.
5. Correct failures in a manner satisfactory to the Engineer.
6. After other work is accomplished, clean exposed conduit, panels, fixtures, and equipment and leave in satisfactory condition.

3.03 INSTALLATION

A. Install electrical materials, equipment, and accessories in locations as indicated, rigid, and secure, plumb, and level, and in alignment with related and adjoining work to provide a complete and operable system.

B. Do not weld electrical materials for attachment or support.

C. Provide anchor bolts and anchorage items as required, and field check to ensure proper alignment and location.

D. Provide templates, layout drawings, and supervision at the job site to ensure correct placing of anchorage items in concrete. Check embedded items for correctness of location and detail before concrete is placed.

E. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, and angles as required to set and connect the work rigidly. Conform to UBC requirements for Seismic Zone 1 location. Control erection tolerance requirements so as not to impair the strength, safety, serviceability, or appearance of the installations.

F. Determine exact locations of conduit and indicate such on the Working Drawings. The trade size, type, and general routing and location of conduits, raceways, and boxes shall be coordinated in the field.

G. Install equipment to facilitate service, maintenance, and repair or replacement of components of both electrical equipment and other nearby installations. Connect as to facilitate future disconnecting with minimum interference with other items in the vicinity.

H. Accurately set and level equipment with supports neatly placed and properly fastened as shown and specified.

I. Provide means of moving and installing equipment in place inside building.

J. Mount electrical equipment away from walls and ceilings. A minimum clearance of three-quarters of an inch shall be maintained.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16060

GROUNDING AND BONDING

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for grounding and bonding, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Excavation
   2. Ground rod
   3. Bonding
   4. Testing
   5. Backfilling
   6. Grounding conductor
   7. Equipment grounding conductors
   8. Bonding and grounding of metal conduits and walkways, crossovers, ladders, stairs and handrails.

C. Contractor shall provide grounding and bonding for all OCS facilities including:
   1. Catenary poles and portal cross-beams installed on aerial structures and all direct fixation areas shall be bonded and grounded to the grounded bridge deck rebar, as shown on the Contract Drawings.
   2. Surge arresters shall be grounded in accordance with the manufacturer's recommendations.
   3. Catenary tunnel supports.
   4. OCS Dead End supports.
   5. Metal conduits installed on Tunnel walls.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 05520, "Miscellaneous Metals"

C. Section 16050, "Basic Electrical Requirements."

D. Section 16130, "Raceways and Boxes."

E. Section 16200, "Traction Power Substation General Requirements."

F. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

G. Section 16360, "Traction Power Substation Testing."

H. Section 16602, "General Requirements Overhead Contact System."

1.03 REFERENCE STANDARDS

A. ANSI

B. ASTM:
1. B3 – Specification for Soft or Annealed Copper Wire
2. B187 – Specification for Copper, Bus Bar, Rod, and Shapes and General Purpose Rod, Bar, and Shapes

C. ICEA

D. IEEE:
1. 80 – IEEE Guide for Safety in AC Substation Grounding
2. 81 – IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
3. 142 – Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book)

E. NEMA:
1. GR-1 – Grounding Rod Electrodes and Grounding Rod Electrode Couplings

F. NETA:
1. Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems (ATS)

G. NFPA:
1. 70 – National Electricity Code (NEC)

H. NICET

I. UL:
1. 467 – Grounding and Bonding Equipment

J. City of Pittsburgh Building Code

K. City of Pittsburgh Electrical Code

1.04 SUBMITTALS

A. Product Data: Provide data for grounding electrodes, conductors, rods, and connections, bushings and fittings, and stones for surface application.

B. Test Reports: Indicate overall resistance to ground and resistance of each electrode.

C. Manufacturer's Instructions: Include instructions for storage, handling, protection, examination, preparation, and installation of exothermic connectors.

D. Product Certification: Signed by manufacturer of equipment certifying that products comply with the Specifications requirements.

E. Manufacturer's Qualifications as described in Article 1.05 of this Section.

F. Submit Shop Drawings and as-built drawings accurately recording locations of ground rods, grounding conductors, and ground grids.

G. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

H. Additional Submittals for Substation Grounding and Bonding:
   1. Submit substation grounding system test plan and procedures for review and approval prior to testing. Test procedures submitted for approval shall include test report format and proposed probe placement and spacing intervals relative to the ground grid being tested.
   2. Contractor shall perform fall-of-potential tests in at least two (2) different directions (two traverses), resulting in at least two (2) test data plots.
   3. Grounding system test reports shall include the following, as a minimum:
      a. Sketch of grounding system being tested showing locations of test probes relative to the ground grid under test.
      b. Make, model and calibration date of test instruments.
      c. Weather conditions at time of test.
   4. Plotted "S" curves resulting from the fall-of-potential tests. Shape of curves shall be satisfactory as determined by the Engineer, demonstrating adequate probe spacing evidenced by a distinct horizontal section in the middle of the curve (refer to IEEE Std. 81). Unsatisfactory test data plots shall be rejected and re-testing shall be required.

I. Submit grounding plan details for the approved layout of walkways, crossovers, ladders, stairs and handrails. Submittal shall include connection hardware for grounding and isolation of the different walkway sections.

1.05 QUALITY ASSURANCE

A. Manufacturer: Company specializing in manufacturing Products specified in this Section with minimum ten (10) years documented experience.

B. The equipment shall be standard equipment of proven performance as manufactured by reputable concerns. Equipment shall be designed, and constructed; and operate satisfactorily when installed as shown in the Contract Drawings.

C. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

1.06 DELIVERY, STORAGE AND HANDLING

A. Equipment shall be handled and stored in accordance with manufacturer's instructions. One copy of these instructions shall be included with the equipment at time of shipment.

ARTICLE 2 PRODUCTS

2.01 MATERIALS

A. General
   1. Furnish Products listed and classified by Underwriters Laboratories, Inc. as suitable for purpose specified and shown.
   2. The equipment shall be standard equipment of proven performance as manufactured by reputable concerns. Equipment shall be designed, and constructed; and operate satisfactorily when installed as shown in the Contract Drawings.

2.02 GROUNDING ELECTRODE SYSTEM

A. Metal underground water pipe

B. Metal frame of the building

C. Concrete-encased electrode

D. Rod Electrode

E. Underground Loop/Grid System

F. Catenary Support Structures

G. Metal Pilings

H. Additional Requirements for Substation Grounding and Bonding:
   1. Grounding Conductors:
      a. Bare conductors: Class B stranded, annealed, soft-drawn copper cable conforming to ASTM B3.
      b. Size: As indicated on the Contract Drawings.
   2. Ground Rods:
      a. UL-listed copper-clad steel rods, 1 inch diameter, nominal 10 foot sections complying with NEMA GR-1.
      b. Carbon steel core and tip, with plated copper cladding of at least 10 mils thickness.
      c. Use bronze ground rod couplers, threaded type, if required to provide the total rod lengths indicated on the Contract Drawings.

3. Fittings:
    a. All connections below ground (i.e. buried) shall be exothermic weld type connections.
    b. All above-ground connections shall be bolted type.
    c. All fittings shall be UL-listed.
4. Substation Interior Ground Bus:
    a. Minimum ¼ by 2 inch copper bus bar mounted on stand-off insulators of sufficient length to permit bolted bus connections.
    b. Connect to substation ground grid at two locations using 500 kcmil cable and NEMA 2-hole lug cable connectors.

I. Walkways, crossovers, ladders, stairs and handrails shall be grounded using #2/0 AWG bare wire.

2.03 PERFORMANCE REQUIRMENTS

A. Grounding system resistance: 2 ohms for substation grounding and 5 ohms for other applications

2.04 ROD ELECTRODE

A. Manufacturers:
1. Copperweld
2. Heary Bros.
3. Erico.
4. Or Approved Equal

B. Material (For applications other than for substation grounding):
1. Copper

C. Diameter (For applications other than for substation grounding):
1. Three quarters of an inch

D. Length:
1. Ten feet minimum

2.05 EXOTHERMIC CONNECTIONS

A. Manufacturers:
1. Cadweld
2. Thermoweld
3. Erico
4. Or Approved Equal

2.06 WIRE

A. Material: Stranded copper.

B. Grounding Electrode conductor: Size to meet NFPA 70 requirements, and as indicated on Contract Drawings.

2.07 FITTINGS

A. All fittings shall be corrosion resistant copper.

B. Ground rod and all bonded joints shall be free of nonconductive coatings, such as paint or enamel.

ARTICLE 3 EXECUTION

3.01 EXAMINATION:

A. Verify that final backfill and compaction has been completed before driving rod electrodes.

3.02 INSTALLATION

A. Install Products in accordance with manufacturer's instructions and as indicated on Contract Drawings.

B. Ground grid shall be installed within Authority right-of-way easement.

C. Install additional ground rods to achieve required resistance to ground.

D. Provide grounding well pipe with cover at each rod location. Install well pipe top flush with finished grade.

E. Install #4/0 AWG or #500 kcmil bare copper wire in foundation/invert slabs where indicated.

F. Provide bonding to meet regulatory requirements and the NEC.

G. Bond metal siding not attached to grounded structure to grounding system. Bond rebar, pipes, and other metallic objects to grounding system.

H. Equipment Grounding Conductor: Provide separate, insulated conductor within each feeder and branch circuit raceway. Terminate each end on suitable lug, bus, or bushing.

I. Install conduits to electrical equipment to make a continuous ground, or as directed.

J. Ground new equipment and existing equipment where work has been performed. In no case, shall the grounding or bonding conductors be smaller than required by the National Electrical Code.

K. Attach copper wire to ground rods. In enclosures, where structural steel is available and where the ohmic resistance to earth is not excessive, grounding may be accomplished by attaching the copper wire or copper strip to the structural steel in an approved manner.

L. Ground rods shall be at least 10 feet in length and at least three-quarters of an inch in diameter. Ground rods shall be of such length, over the minimum, and so driven as to ensure that the lower 2 feet of the rod will be in permanently moist soil. Ohmic resistance between the equipment and the earth shall not exceed 5 ohms. If, after the installation of the ground, it is found that the ohmic resistance between the equipment and the earth is excessive, another rod or rods shall be installed in multiple with the first rod, until results satisfactory to the Engineer have been obtained. Rods connected in multiple shall be spaced a minimum distance of 6 feet apart.

M. Provide grounding stubs-up located not to create a hazard to passing personnel.

N. Do not permit ground connection to the track rails.

O. Ground all electrical equipment.

P. Each isolated section of the walkways, crossovers, ladders, stairs, handrails and wall mounted metal conduits shall be grounded with #2/0 ground wire connected to the aerial ground wire.

Q. Ground the electrical service at the service entrance.

R. All bonding connections shall be exothermic weld process in strict accordance with manufacturer's instructions unless otherwise noted on Contract documents. Test all completed exothermic welds by striking with a 2-pound hammer. If cracks develop after striking, replace weld at no additional expense to Authority.

S. Substation Ground Loop System
   1. All connections to the substation ground system, except for lightning protection down conductors, shall be made via the enclosure ground bus; direct connections from equipment inside the enclosure to the ground grid will not be permitted.
   2. Trenching, excavating and backfilling for installation of underground grounding conductors. Stone shall be kept clean and free of contaminants.
   3. Bond the rebar in all foundation footings and slabs to the substation ground grid using approved exothermic weld fittings intended for this application. Coat these welds with bitumastic before encasing them with concrete.
   4. Drive ground rods vertically into the earth using approved driving sleeves until top of rod is at least one foot below final grade. If obstructions are encountered during driving, re-drive rod at a 30 degree angle from vertical. If the full length of the rod still cannot be driven entirely into the earth, Contractor shall note the rod location(s) and continue installing the remaining rods shown on the Contract Drawings. Before backfilling over the grid, Contractor shall advise the Engineer

of the locations at which rods could not be driven to the prescribed depth. Contractor shall then complete rod installation as approved by the Engineer.

5. Duquesne Light Company utility equipment grounds and supply cable neutrals shall not be connected to Authority substation ground grids.
6. Substation enclosure steelwork and all electrical equipment, enclosures (except rectifier enclosure and dc switchgear enclosure), and metallic conduits, cable trays, fittings and fixtures shall be bonded to the substation ground grid.
7. The ground system shall be connected to each primary service feeder's shield. The ground cable shall be a minimum #4/0 AWG bare copper conductor. Sufficient connections to the structural steel and the main metallic water pipe system and rebar embedded in concrete shall be provided to ensure a maximum ground impedance of 2 ohms. Each switchgear and power transformer shall be connected to the ground loop at two points at opposite ends of the equipment. All gates and doors shall be bonded to the ground loop system.

3.03 FIELD QUALITY CONTROL

A. Inspect grounding and bonding system conductors and connections for tightness and proper installation.

B. Use suitable test instrument which has been calibrated to measure resistance to ground of system. Perform testing in accordance with NETA recommendations.

C. Additional tests for substation grounding and bonding:
1. Before connecting the substation ground bus to the substation ground grid, test the resistance of the completely installed substation ground grids in accordance with IEEE Std. 81, using the fall-of-potential method. Tests shall be made in the presence of the Engineer.
2. Testing shall be performed by a NICET or NETA-certified test technician with demonstrated experience in the resistance testing of power substation ground grids. Test frequencies shall be selected to minimize potential interference from 60 Hz induced voltages and harmonics thereof, and stray 60 Hz ac and dc currents.
3. Test reports shall include graphically plotted results of the fall-of-potential tests taken from at least two traverses. Data points and resulting plots shall be made with care and are subject to the Engineer's review and approval.
4. If tests indicate that the resistance of the ground grids exceeds two (2) ohms, the Engineer shall be immediately notified. The Contractor shall install several additional 20 foot sectional ground rods to the substation ground grid to decrease grid resistance, and the substation grid resistance re-tested. This process shall be repeated if necessary until substation ground grid resistance is two (2) ohms or less.

3.04 OCS FIELD TESTING

A. Field testing shall be thorough, complete and performed throughout the installation. Fully document the following as a minimum:
   1. Electrical resistance tests shall be made for each ground system installation to verify continuity and compliance with specified resistances.
   2. Measure, record and report the resistance to earth of each portion of the grounding system as soon as possible after installation so that corrective measures, if required, may be made with minimum disruption of construction. All required ground resistances shall be equal to or less than the following values:
      a. OCS poles and portal cross-beam mounted on aerial structures: 10 ohms or less.
      b. Surge Arrestors: 5 ohms or less or as recommended by the arrestor manufacturer.
      c. Overhead bridge girders and metal barriers crossing over OCS wires and ROW: 25 ohms or less.
      d. Tunnel Supports: 10 ohms or less.
   3. Measure, record, and report the ground resistance at each location where a grounding system is installed and any special conditions.

B. Resistance-to-earth tests shall be witnessed by the Engineer and the written results of these tests shall be submitted to the Engineer for evaluation and instructions regarding any corrective action which may be deemed necessary.
   1. Ground resistance tests shall be made using the three-probe method described in IEEE Standard 81

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16060.001 – Grounding and Bonding shall be measured as a lump sum unit, complete in place.

B. No separate measurement shall be made for the OCS work of this Section.

4.02 PAYMENT

A. Item 16060.001 – Grounding and Bonding will be paid at the lump sum price and shall include the cost of all work specified in the Section.

B. No separate payment will be made for the OCS work of this Section. Payment for the OCS work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16075

ELECTRICAL IDENTIFICATION

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for electrical identification, in accordance with the Contract Documents.

1.02 RELATED SECTIONS

A. Section 16205, "Circuit Breaker Room And Tie-Breaker Station."

1.03 REFERENCE STANDARDS

A. ANSI

B. City of Pittsburgh Electrical Code

1.04 SUBMITTALS

A. Submit the following as specified for each:
   1. Samples:
      a. Two sample nameplates complete with 8 attaching screws.
   2. Identification List:
      a. Submit complete listing of nameplate identification system for approval.
   3. Material list showing composition of nameplate elements.

1.05 QUALITY ASSURANCE

A. The following Codes, Regulations, Reference Standards and Specifications apply to work included in this Section:
   1. Codes and regulations of jurisdictional authorities.
   2. Codes and Standards:
      a. ANSI.

ARTICLE 2 PRODUCTS

2.01 MATERIALS

A. Nameplates
      a. Provide nameplates consisting of three-ply, laminated phenolic plates, approximately 1/8-inch thick with beveled edges, engraved through white

face to black core and attached by stainless steel rivets, drive screws, or sheet metal screws.

b. For letter size of nameplates conform to ANSI requirements.
c. Provide vertical gothic lettering using round or square cutter. V-shape groove is not acceptable.
d. Provide nameplates 1-inch high by 3-inches wide or as shown.
e. Where equipment nomenclature requires additional space, provide nameplates of such size as required.
f. Standard abbreviations may be used as required.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Place nameplates on each panelboard, individual circuit breakers and switches in switchgear, switchboards, transformers, cabinets, battery unit, push button station, alarm bell, and control device.

B. Install in accordance with nameplate manufacturer's instructions.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16081

ELECTRICAL TESTING AC SYSTEMS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for electrical testing AC systems, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Electrical testing on alternating current (AC) systems in traction power systems, and facility power systems.

1.02 RELATED SECTIONS

A. Section 16050, "Basic Electrical Requirements."

1.03 REFERENCE STANDARDS

A. International Electrical Testing Association (NETA) Acceptance Testing Specifications (ATS) for Electrical Power Distribution Equipment and Systems

B. The City of Pittsburgh Building Code

1.04 SUBMITTALS

A. Submit all documentation and certifications of tests performed.

B. Submit testing company's NETA certification

ARTICLE 2 PRODUCTS

NOT USED

ARTICLE 3 EXECUTION

3.01 FIELD QUALITY CONTROL

A. Tests shall be performed in conformance with the standard test codes of the applicable industry organizations and be witnessed by the Engineer. Testing procedures will be based, as a minimum, on the NETA ATS and be performed by a certified NETA testing company.

B. Measuring instruments shall be of the precision type and be calibrated. All instruments and ancillary equipment/devices, including labor for the tests, shall be provided by the testing entity. The Engineer reserves the right to check the Contractor's instruments. Contractor shall furnish all electrical energy required to perform the tests.

C. Field tests shall be made on individual components of the AC systems material, equipment, apparatus and protective devices and controls. In addition, field tests shall be made on system assemblies completed in the field to demonstrate the soundness and suitability of the assembled materials, and the adequacy of the craftsmanship of the installation work. After completion of individual system, equipment, and assembly tests, performance tests shall be made on the plant as a whole, upon its major subdivisions in conformity with the standard test codes of the applicable standards and industry associations.

D. Provide necessary testing apparatus, calibrated electrical meters, gauges, fittings, thermometers, etc. The foregoing apparatus supplied by the Contractor for these tests shall remain their property and be removed by them after the tests.

E. Test procedures, showing in complete detail, the manner in which the tests will be performed, the constraints, if any, of the tests, shall be submitted to the Engineer for approval prior to scheduling the tests. The test procedures shall also set forth the acceptance and rejection criteria.

F. Defects in the new systems shall be corrected to the satisfaction of the Engineer. All equipment and systems shall be retested after the correction of defects.

G. Insulation resistance and ground tests of all wiring shall be made prior to connection to equipment and in the presence of the Engineer.

H. Apparatus such as circuit breakers, contactors, motor starters, push button stations, etc., shall be checked for free movement and alignment of parts and contacts.

I. Ground fault protection system shall be performance tested, as required by the National Electrical Code (NEC) and other applicable codes and standards.

J. Grounding system shall be tested and verified with accepted methods and standards by actual measurements in the field. The proposed method of measurement shall be submitted to the Engineer for approval. Unless otherwise specified grounding resistance shall not exceed 5 ohms. A certified test report of the resistance values and the soil conditions at the time measurements were made, along with location of any ground rod shall be submitted to the Engineer.

K. Performance test shall be made to verify proper electrical operation of all power and control circuits and electrical apparatus.

L. After installation, performance tests shall be made on the plant as a whole, upon its major subdivisions and required by the Engineer. The tests shall be performed with all rated loads connected.

M. Similar tests shall be performed on the emergency equipment with all rated emergency loads connected.

N. Motors shall be checked for proper rotation, and for balancing of the currents in all three phases.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section.

END OF SECTION

SECTION 16111

CONDUIT

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for conduit, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Excavation.
   2. Conduit installation.
   3. Connection to existing conduits.
   4. Bedding.
   5. Concrete encasement.
   6. Detectable warning tape.
   7. Backfill and compaction.

1.02 RELATED SECTIONS

A. Section 02320, “Backfill.”

B. Section 03305, “Cast-in-Place Concrete and Cement Concrete Structures.”

C. Section 13574, “Wayside Signal Equipment.”

D. Section 13585, “Installation Requirements.”

E. Section 16210, “Traction Power Basic Electrical Materials and Methods.”

F. Section 16700, “Communications.”

G. Section 16650, “OCS Basic Electrical Materials and Methods.”

H. Section 01900, “Train Clearance Testing.”

1.03 REFERENCE STANDARDS

A. National Electrical Manufacturers Association (NEMA):
   1. Standard Publication 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
   2. TC-2 – Electrical Plastic Tubing (EPT) and Conduit (EPC-40 and EPC-80)
   3. TC-3 - PVC Fittings for use with Rigid PVC Conduit and Tubing
   4. TC 6 – PVC Plastic Utilities Duct for Underground Installation.
   5. TC 8 – PVC and ABS Plastic Utilities Duct for Underground Installation

6. TC 9 – Fittings for ABS and PVC Plastic Utilities Duct for Underground Installation.

B. NFPA 70, National Electrical Code (NEC).

C. PENNDOT, Publication 408.

D. NECA "Standard of Installation"..

E. American Society for Testing & Materials (ASTM):
   1. A123 – Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
   2. . B633 – Standard Specifications for Electrodeposited Coatings of Zinc on Iron or Steel
   3. D149 – Tests for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
   4. D638 – Test for Tensile Properties of Plastics
   5. D695 – Test for Compressive Properties of Rigid Plastics
   6. D790 – Test for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

F. NESC – C2 – National Electric Safety Code.

G. City of Pittsburgh Building Code.

H. Duquesne Light Company.

I. PENNDOT Publications 148

J. FS

K. American National Standards Institute (ANSI):
   1. C80.1 – Specifications for Rigid Steel Conduit, Zinc-Coated

L. Underwriters Laboratories, Inc. (UL):
   1. 6 – Rigid Metal Conduit

1.04 SUBMITTALS

A. Provide manufacturer's standard catalog data for all items described in this specification indicating conformance and compliance with standards and criteria indicated.

B. Manufacturer's description, shop drawings, installation and operational instructions.

C. Certified test data.

D. Installation drawing showing conduit arrangement attachment detail, grounding, and offset from running rail that meets clearance requirements as specified for this contract.

ARTICLE 2 PRODUCTS

2.01 MATERIALS

A. Rigid Steel Conduit:
1. Rigid steel conduit shall be in accordance with Federal Specification WW-C-581d, ANSI C80.1, UL No. 6, NEMA RN1-1980, and NEC.
2. The conduit shall be hot-dipped galvanized, including threads and pipe interior (threads shall be galvanized after cutting).
3. Conduit Fittings and Accessories shall be galvanized steel and meet the requirements of FS, W-F-408.
4. Couplings, entrance elbows, sweeps and all other steel conduit fittings and hardware shall be cast malleable iron, hot-dipped galvanized in accordance with these specifications. All exposed conduit ends shall be protected. Liquid tight connectors shall be used where a cable or wire exits a conduit end.
5. Conduit Hubs: Watertight, with neoprene gasket, nylon insulated throat and case-hardened locknut.
6. Grounding: Nylon insulated metal bushing.
7. Conduit sealing bushings: O-Z/Gedney type KR, or approved equal.
8. Conduit Straps, Clamps, Back and Spacers - Hot-dip galvanized malleable iron

B. Conduit Expansion Fittings:
1. The end couplings shall be of the same material as those of the conduits to be coupled.
2. Neoprene sleeves attached to the end couplings by stainless steel bands shall accommodate an axial expansion or contraction from normal of 3/4 inch minimum in either direction, parallel misalignment of the axis of coupled conduit runs, in any direction, parallel misalignment of the axis of coupled conduit runs, in any direction, of 3/4 inch minimum, and an angular misalignment of the axis of coupled conduit runs, in any direction, of 30 degrees minimum.
3. A tinned flexible copper braided bonding jumper, integral with the expansion fitting, shall be attached to the end couplings to provide electrical continuity for all metal conduits.

C. PVC Conduit:
1. Conduits shall be UL listed and rated for use with 194° Fahrenheit conductors.
2. Schedule 40 and Schedule 80 PVC conduits shall comply with NEMA TC-2 and UL 651, and have the following minimum properties:
3. Tensile Strength: ASTM D638, 5,000-6,500 psi, at 73.4° F.
4. Flexural Strength: ASTM D790, 12,500 to 14,700 psi.
5. Compressive Strength: ASTM D695, 9,000 psi.
6. Dielectric Strength: ASTM D149, 1,100 Volts, per mil.

7. Conduit Cement: As recommended by conduit manufacturer.
8. Fittings: In accordance with NEMA TC-3 and UL 514B.
9. Duct Spacers: Plastic, interlocking type for use with PVC conduit.

D. Liquid-Tight Flexible Metallic Conduit and Fittings:
   1. The Contractor shall furnish conduit consisting of a core of flexible galvanized steel with an extruded liquid-tight neoprene jack overall. Use where applicable, such as switch machines to junction boxes.
   2. The Contractor shall furnish conduits of 1.25 inches diameter and smaller with a continuous copper bonding conductor spiral wound between the convolutions.
   3. The Contractor shall provide fittings that are cadmium or zinc-coated and meet the requirements of UL Standard 514.

E. Detectable Warning Tape:
   1. Detectable warning tape shall be installed within all buried PVC conduits.

F. Class P Concrete in accordance with Section 03305, "Cast-in-Place Concrete and Cement Concrete Structures."

G. No. 57 Coarse Aggregate in accordance with Section 02320, "Backfill."

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Install according to manufacturer's recommendations, in accordance with NECA "Standard of Installation" and in accordance with PENNDOT 408, Sections 910.3 and 954.3.

B. Install no more than equivalent of three 90-degree bends throughout length of duct bank run.

C. Excavate the conduit trenches in accordance with the Contract Documents.

D. Backfill all conduit encasements in accordance with the Contract Documents.

E. Before excavating, stake or mark trench alignments which deviate from the indicated locations for inspection and acceptance by the Engineer.

F. All Metal Conduits installed on the tunnel walls shall include an insulating non-conductive bushing spaced apart as required to isolate sections of the conduit to a maximum length of 500 feet between bushings.

3.02 PROTECTION

A. All conduits must be sealed with an approved sealant to prevent damage due to flooding.

B. Repair field damage to any galvanized finishes by painting with two coats of Zinc Dust-Zinc Oxide Paint, in accordance with ASTM A 780, or with an acceptable equal.

C. Use suitable caps to protect installed conduit against entrance of dirt and moisture.

D. Contractor shall seal ends of partially installed conduit runs upon the temporary suspension of work.

3.03 CONNECTIONS TO EXISTING CONDUIT

A. Clean existing conduit ends prior to applying solvent cement. Follow manufacturer's instructions.

B. When required, conduit shall be square cut with all ends smooth and free of burrs and fins. Conduit ends shall be accurately tapered or finished to properly mate with couplings and fittings. A method for connecting to existing conduit must be submitted to and approved by the Engineer. All conduit joints shall be sealed with waterproof solvent cement as per the manufacturer's instructions.

3.04 CONCRETE ENCASEMENT

A. Encase all conduit located in roadway, parking lot and driveway areas with concrete 3 in. minimum thickness, in all directions surrounding the circumference of the conduit. Concrete shall be Class P concrete

B. Place detectable warning tape 1 ft. above concrete encased conduits.

3.05 DEPTH OF COVER

A. 5" PVC conduit shall have a minimum cover of 36" at all times.

B. The Contractor shall notify the Engineer when it is not possible to adhere to the conduit placement details and minimum cover requirements due to underground obstructions and in such cases, Contractor shall complete the installation as directed by the Engineer at no additional cost to Authority.

3.06 EMBEDDED CONDUIT

A. Reinforcing steel may be shifted to accommodate conduits.

B. Do not cut or remove reinforcing steel.

C. Conduits shall not be spaced closer than 3 diameters apart on center.

D. Embedded conduit in concrete structures shall be placed as indicated on the Contract Drawings.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16111.001 – 1" Direct Burial Conduit shall be measured per linear foot, complete in place.

B. Item 16111.003 – 2" Direct Burial Conduit shall be measured per linear foot, complete in place.

C. Item 16111.004 – 3" Direct Burial Conduit shall be measured per linear foot, complete in place.

D. No separate measurement shall be made for other work of this Section.

4.02 PAYMENT

A. Item 16111.001 – 1" Direct Burial Conduit will be paid at the unit price and shall include the cost of all related work specified in this Section.

B. Item 16111.003 – 2" Direct Burial Conduit will be paid at the unit price and shall include the cost of all related work specified in this Section.

C. Item 16111.004 – 3" Direct Burial Conduit will be paid at the unit price and shall include the cost of all related work specified in this Section.

D. No separate payment will be made for other work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16120

LOW VOLTAGE POWER CABLES

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for low voltage power cables, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to the design, coordination and implementation of the following activities:
   1. Contractor's design shall provide wire and cables as shown on the Contract Drawings and as specified herein.
   2. The work includes the installation of all necessary conduits to complete the cable installation as shown in the Contract Drawings.
   3. The work also includes the installation of all pull boxes, splice enclosures, slack enclosures cable ladder and other miscellaneous hardware required to provide a functional, reliable and maintainable system.
   4. Furnishing and installing cable and wires in tunnel conduit, pull boxes, splice enclosures, terminations, connectors and other miscellaneous hardware necessary to provide a reliable, maintainable system that meets the requirements of the Contract Documents.
   5. Cable sizing and conduit routing provided in the Contract Drawings are indicative only, and Contractor shall design, check, and verify cable sizing and lengths required.
   6. Testing of the cabling installation.
   7. Wire and cables rated 600V and less.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the low voltage cabling systems portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16050, "Basic Electrical Requirements."

B. Section 16060, "Grounding and Bonding."

C. Section 16075, "Electrical Identification."

D. Section 16081, "Electrical Testing AC Systems."

E. Section 16111, "Conduit"

F. Section 16130, “Raceways and Boxes”

G. Section 16702, “Copper Outside Plant”

H. Section 16890, “Tunnel Services Electrical Requirements of Mechanical Equipment”

1.03 REFERENCE STANDARDS

A. NFPA 70 - NEC

B. UL

C. ICEA

D. City of Pittsburgh Building Code

E. NEMA

F. International Electrical Testing Association (NETA) – Acceptance Testing Specifications (ATS) for Electrical Power Distribution Equipment and Systems

G. ASTM

H. IEEE

I. NESC

J. NFPA 130 – Standard for Fixed Guideway Transit and Passenger Rail Systems

1.04 SUBMITTALS

A. Product data for each product specified.

B. Submit the procedure for pulling all wires and cables through ducts and conduits to the Engineer for approval.

C. Product Certification: Signed by manufacturer of equipment certifying that products comply with the Contract Document requirements.

D. Report of Field Tests: Certified copies of field tests.

E. Manufacturers’ Test reports: Indicate procedures and values obtained.

F. Manufacturers’ Installation Instructions: Indicate application conditions and limitations of use stipulated by product testing agency.

G. Manufactures qualifications

1.05 QUALITY ASSURANCE

A. For the equipment specified herein, the manufacturer shall be International Organization for Standardization (ISO) 9001:2000 certified.

B. Equipment shall be designed, constructed, tested, and installed in accordance with the best practices of the industry, and operate satisfactorily when installed as shown on the Contract Drawings.

C. Manufacturers shall have a minimum of ten (10) years in the manufacture of this type of wire and cable.

1.06 PROJECT CONDITIONS

A. Verify measurements in field.

B. Wire and cable routing shown on Contract Drawings is approximate unless dimensioned. Route wire and cable as required to meet Project conditions.

C. Conductor sizes are based on copper.

D. Where wiring routing is not shown, and destination only is indicated, the Contractor shall determine the exact routing and lengths required.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Conductor packaging and reels: Plainly mark or tag with Manufacturer's name, AWG, size, voltage rating, insulation type, and date of manufacture.

B. Deliver all conductors to the site on their original cable reels or in their original unbroken packages.

C. Equipment shall be handled and stored in accordance with Manufacturer's instructions. One copy of these instructions shall be included with the equipment at time of shipment.

ARTICLE 2 PRODUCTS

2.01 MANUFACTURERS

A. Kerite

B. Okonite

C. Southwire

D. Rockbestos Surprenant

E. Or Approved Equal

2.02 WIRE AND CABLE

A. All station and tunnel life safety circuits wiring shall be Type RHW, 2-hour fire-rated, low smoke, zero halogen, as manufactured by Raychem or approved equal as required by NFPA 130.

B. All tunnel life safety control and communications circuits wiring shall be UL Listed Type XHHW-2, low smoke, zero halogen, Firewall LSZH as manufactured by Rockbestos-Surprenant or approved equal as required by NFPA 130.

C. All station and tunnel non-life safety circuits wiring shall be UL Listed Type XHHW-2, low smoke, zero halogen, Firewall LSZH as manufactured by Rockbestos-Surprenant or approved equal as required by NFPA 130.

D. All cable shall be copper.

E. Ground Wire(s) sized in accordance with the NEC

2.03 NFPA 130 WIRING REQUIREMENTS

A. All wiring materials within the station shall conform to the requirements of the NEC and, in addition, shall satisfy the requirements of NFPA 130, Sections 5.4.2 through 5.4.9.

B. All wiring materials within the trainway shall conform to the requirements of the NEC and, in addition, shall satisfy the requirements of NFPA 130, Sections 6.3.3.2.2 through 6.3.3.2.9.

2.04 CONDUITS AND PULL BOXES

A. Conduits and accessories shall comply with Section 16111, "Conduit" of the Contract Documents. All conduits for tunnel fire life safety equipment shall be rigid metal conduit and comply with NFPA 130.

B. Pull boxes shall comply with Section 16130, "Raceway and Boxes" of the Contract Documents.

2.05 IDENTIFICATION

A. In accordance with Section 16075, "Electrical Identification."

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Conduits shall be cleared by the use of proper tools. Before any cable is pulled into a conduit, a mandrel shall be pulled through said duct from one end to the other. Before installing cables, break away all projecting pieces of conduits which may cause damage to the cables. Clean ducts and install draglines before installing wires and cables.

B. Cables must not be installed until all supports and housings are in place, completely installed. Cables shall be prevented from touching or rubbing against walls, concrete surfaces or columns.
   1. Where more than one wire or cable is installed in any duct or conduit run, all such wires and cables shall be pulled in at the same time.
   2. Cable pulling compounds shall not damage the cable and shall be subject to approval by the Engineer.
   3. After the cable has been installed, the ends of the cable shall be immediately sealed as directed until such time as the cable is spliced or otherwise terminated.

C. Terminate the ends of all conduits by means of suitable bushings. Where cables emerge from ducts, they shall be effectively blocked by approved means to prevent access of rodents.

D. Where cables pass through walls and floors or enter compartments, without being enclosed in ducts or conduits, approved tubes shall be provided for these cables.

E. Pump water out of manholes and removal of mud, silt, and debris there from, if required, as determined.

F. All wire and cable lengths shall be continuous and without splices in conduits between the points of connections, and sufficient slack shall be provided for the proper make up of such connections. In handholes, splices shall be provided as required.
   1. New and existing cables shall be spliced or otherwise connected as indicated on the Contract Drawings.
   2. Splices shall be made in accordance with the cable manufacturer's recommendations.
   3. In general, avoid splicing in places where access for maintenance will be difficult.

G. Wiring to terminal blocks or to terminal connectors shall be neatly dressed, and there shall be no nicks in the conductors where the insulation has been stripped. All terminal connections shall be made up in such manner that no loose connections shall exist or develop when the wires or cables are put into service. Terminals and connectors found damaged or making improper contact after installation shall be removed and shall be replaced by new terminals.

H. Before cutting any existing cable, make sure the cable has been properly identified, deenergized, and grounded or otherwise made safe. The ends of cables that are cut made idle and left in place shall be sealed in an approved manner. Where necessary, existing cables will be tested before any work is done on them. Install products in accordance with manufacturer's instructions.

I. Use conductor not smaller than #12 AWG for power and lighting circuits.

J. Use conductor not smaller than #14 AWG for control circuits.

K. Pull all conductors into raceway at same time.

L. All conductors shall be copper.

M. Protect exposed cable from damage.

N. Neatly train and lace wiring inside boxes, equipment, and panelboards.

O. Use suitable cable fittings and connectors.

P. Clean conductor surface before installing lugs and connectors.

Q. Make splices, taps, and terminations to carry full ampacity of conductors with no perceptible temperature rise.

R. Multiple three-phase circuits shall not be combined in one conduit. Derating of conductor capacity shall not be permitted.

S. Individual ground conductors shall be run in all conduits. The conduit shall not be utilized as the sole grounding conductor.

T. Wiring methods shall be in compliance with the NEC and NESC.

U. Feeder and branch circuits for power and lighting shall be balanced for all phases as closely as practicable.

V. The temperature rating associated with the ampacity of a conductor shall be selected as to not exceed the lowest temperature rating of any device or terminal.

W. Warning tape shall be installed above underground conduit distribution system.

X. Conductors in junction boxes, pull boxes, and wireways shall be tagged, indicating panelboard and circuit number.

Y. Minimum bending radius shall be in accordance with the NEC.

3.02 WIRING

A. Wire and cable shall be of the quantity, rating, type, and size indicated, on the Contract Drawings and in accordance with this Section. All wire and cable shall be continuous without splices between pull boxes and termination of runs. Sufficient slack shall be left in all boxes for splicing wires and making proper connections, as indicated on the Contract Drawings.

B. Wiring for systems rated nominal 600 volts shall not occupy the same conduit with wiring systems rated less than nominal 600 volts. A separate conduit or enclosure shall be used for each system, unless otherwise indicated on the Contract Drawings.

3.03 COORDINATION

A. Determine required separation between cable and other work.

B. Determine cable routing to avoid interference with other work.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16120.001 – Low Voltage Cables and all Associated Equipment for Fire/Life Safety Systems shall be measured as a lump sum unit, complete in place.

B. Item 16120.003 – AWG No. 10 Direct Burial Copper Cable, 1 Conductor shall be measured per linear foot, complete in place.

4.02 PAYMENT

A. Item 16120.001 - Low Voltage Cables and all Associated Equipment for Fire/Life Safety Systems will be paid at the lump sum price and shall include the cost of all work specified in this Section.

B. Item 16120.003 – AWG No. 10 Direct Burial Copper Cable, 1 Conductor will be paid at the unit price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 16123

MV TRANSFORMERS, LIQUID FILLED

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for MV transformers, liquid filled, in accordance with the Contract Documents to be installed at the Gateway and North Side Stations.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Furnish and install two (2) substation transformers at Gateway Station.
   2. Furnish and install two (2) substation transformers at North Side Station.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data."

B. Section 16050, "Basic Electrical Requirements."

C. Section 16060, "Grounding and Bonding."

D. Section 16075, "Electrical Identification."

E. Section 16081, "Electrical Testing AC Systems."

1.03 REFERENCE STANDARDS

A. The substation transformers shall be designed, manufactured and tested in accordance with NEMA and ANSI. NEMA 201, 210; IEEE 100, ANSI C57.

B. Factory Mutual (FM)

C. UL

D. NFPA - NEC

E. International Electrical Testing Association (NETA), Acceptance Testing Specifications (ATS) for Electrical Power Distribution Equipment and Systems

F. NEMA 201, 210

G. IEEE 100

H. ANSI C57

1.04 SUBMITTALS

A. The following information shall be submitted to the Engineer:
   1. Master drawing index
   2. Front view, side view, elevation and weight
   3. Plan view
   4. Schematic diagrams
   5. Nameplate diagram
   6. Component list
   7. Conduit entry/exit locations
   8. Ratings including:
      a. kVA
      b. Primary and secondary voltage
      c. Taps
      d. Primary and secondary continuous current
      e. Basic Impulse Level
      f. Impedance
      g. Insulation class and temperature rise
      h. Sound level
      i. Short circuit
   9. Cable terminal sizes
   10. Product data sheets

B. Where applicable, the following additional information shall be submitted to the Engineer:
   1. Busway connection

C. The following information shall be submitted for record purposes:
   1. Final as-built drawings and information for items listed in Article 1.04, and shall incorporate all changes made during the manufacturing process
   2. Wiring diagrams
   3. Certified production test reports
   4. Installation information
   5. Warranty Information
   6. Seismic certification as specified

D. Manufacturer's qualifications.

E. The Contractor shall provide three (3) copies of the manufacturer's representative's certification for equipment installation.

F. Operation and Maintenance Manual

G. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

1.05 QUALITY ASSURANCE

A. The manufacturer of the assembly shall be the manufacturer of the major components within the assembly.

B. For the equipment specified herein, the manufacturer shall be ISO 9001 or 9002 certified.

C. The manufacturer of this equipment shall have produced similar electrical equipment for a minimum period of ten (10) years. When requested by the Engineer, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with this requirement.

D. Provide Seismic tested equipment as follows:
   1. The equipment and major components shall be suitable for and certified to meet all applicable seismic requirements of the Uniform Building Code (UBC) for Zone 1 application. Guidelines for the installation consistent with these requirements shall be provided by the switchgear manufacturer and be based upon testing of representative equipment.
   2. The following minimum mounting and installation guidelines shall be met, unless specifically modified by the above referenced standards.
      a. The Contractor shall provide equipment anchorage details, coordinated with the equipment mounting provision, prepared and stamped by a licensed civil engineer in the state. Mounting recommendations shall be provided by the manufacturer based upon approved shake table tests used to verify the seismic design of the equipment.
      b. The equipment manufacturer shall certify that the equipment can withstand, that is, function following the seismic event, including both vertical and lateral required response spectra as specified in above codes.
      c. The equipment manufacturer shall document the requirements necessary for proper seismic mounting of the equipment. Seismic qualification shall be considered achieved when the capability of the equipment, meets or exceeds the specified response spectra.
   3. The record (as-built) drawings shall include the same drawings as the approval Working Drawings, and shall incorporate changes made during the manufacturing process.

1.06 DELIVERY, STORAGE AND HANDLING

A. Equipment shall be handled and stored in accordance with manufacturer's instructions. One (1) copy of these instructions shall be included with the equipment at time of shipment.

B. Deliver each transformer on individual shipping skids for ease of handling. Each transformer shall be wrapped for protection.

C. Inspect and report concealed damage to carrier within adequate time.

D. Maintain factory protection or cover with heavy canvas or plastic to keep out dirt, water, construction debris and traffic.

E. Transformer shall be equipped to be handled by a crane.

ARTICLE 2 PRODUCTS

2.01 LIQUID TRANSFORMER MANUFACTURERS

A. Eaton / Cutler-Hammer

B. General Electric

C. Cooper Power Systems

D. Square D

E. ABB

F. Niagara Transformers

G. Or Approved Equal

2.02 RATINGS

A. The ratings of the transformers shall be as follows:
   1. kVA Rating
      a. Gateway Station – 2000/OA
      b. Northside Station – 2500/OA
   2. Impedance: 5.75
   3. HV: 22.9 kV Delta
   4. HV BIL: 150 kV
   5. HV De-energized Taps: +/- 2 - 2-1/2% full capacity
   6. LV: 480/277 Volts Wye
   7. LV BIL: 30 kV

2.03 CONSTRUCTION

A. The unit shall be biodegradable electrical insulating fluid from high oleic vegetable oil sources filled and shall be in accordance with the latest edition of the NEC. High fire point fluids shall be Factory Mutual and UL listed.

B. The transformer shall carry its continuous rating with average winding temperature rise by resistance that shall not exceed 55 degrees C, based on average ambient of 30 degrees C over 24 hours with a maximum of 40 degrees C. The insulation system shall allow an additional 12% kVA output at 65 degrees C average winding temperature rise by resistance, on a continuous basis, without any decrease in normal transformer life.

C. Transformers will be lower into subterranean rooms.
Transformers must be able to be lowered through the following roof openings:
Gateway Station: 2000 KVA: opening 10'x12'
North Side Station: 2500 KVA : opening 7'x11' (room is 15' x 18' x 14' high)

- In order to fit the transformer into the North Side Station the transformer will have to be made tall and narrow. The transformer can be a Network type or a Unit Sub type or a hybrid of both.

D. The transformer shall be designed to carry short-time emergency overloads in accordance with ANSI C57.12.92 as applicable. Duration and magnitude of designed withstand capability shall be as outlined in ANSI C57.12.90 and the latest draft of the IEEE short-circuit test code.

E. The transformer shall be designed to meet the sound level standards for liquid transformers as defined in NEMA TR1. The measurement procedure shall be as specified in ANSI C.57.12.90.

F. High-voltage and low-voltage windings shall be cooper. Insulation between layers of the windings shall be by Insuldur paper or approved equal.

G. The main transformer tank and attached components shall be designed to withstand pressures 25% greater than the required operating design value without permanent deformation. Construction shall consist of carbon steel plate reinforced with external sidewall braces. All seams and joints shall be continuously welded.

H. If standard radiators are used, then each radiator assembly shall be individually welded and receive a quality control pressurized check for leaks. The entire tank assembly shall receive a similar leak test before core and coil are tanked. A final six-hour leak test shall be performed after the transformer is tanked, welded and completed to ensure that there are no leaks before shipment.

2.04 ACCESSORIES

A. Transformer features and accessories shall include:
1. De-energized tap changer with externally operated, padlockable handle
2. Combination drain and filter valve and sampling device
3. Manual gas pressure test connection
4. Filling plug and filter press connection in cover
5. Dial-type top liquid thermometer
6. Magnetic liquid level gauge

7. Provisions for lifting, provisions for jacking, base designed for skidding or rolling in two directions
8. Ground pad – stainless steel
9. Nameplate – stainless steel
10. Pressure vacuum gauge
11. Welded-on main tank cover and handhole in cover
12. Pressure relief device

2.05 FINISH

A. The paint shall be applied using an air spray with air dry acrylic topcoat system to a minimum of three mils average thickness. Outdoor liquid transformer units shall include suitable outdoor paint finish. Units shall be painted ANSI 61 for indoor service or outdoor service and shall match the primary and secondary equipment.

B. Paint scratched or marred exterior surfaces to match original finish.

2.06 TERMINAL COMPARTMENTS/FLANGE CONNECTIONS

A. The transformer unit supplied shall include a HV cable terminal compartment and a busway flange. The HV cable compartment and cable lugs shall be sized by manufacturer to accommodate one (1) each 25 kV 4/o AWG copper conductor per phase. The LV compartment shall be sized by manufacturer to accommodate busway rated 2500A – Gateway Station and 3000A – North Side Station, three (3) phase four (4) wire, copper, with three (3) phases, internal ground, and neutral bars.

ARTICLE 3 EXECUTION

3.01 FACTORY TESTING

A. The following standard factory tests shall be performed on all equipment provided under this section. All tests shall be in accordance with the latest version of ANSI and NEMA standards.
   1. Resistance measurements of all windings on the rated voltage connection of each unit and at the tap extremes of one unit only of a given rating on this project
   2. Ratio tests on the rated voltage connection and on all tap connections
   3. Polarity and phase-relation tests on the rated voltage connections
   4. No-load loss at rated voltage on the rated voltage connection
   5. Exciting current at rated voltage on the rated voltage connection
   6. Impedance and load loss at rated current on the rated voltage connection of each unit and on the tap extremes of one unit only of a given rating on this project
   7. Applied potential test
   8. Induced potential tests

B. The manufacturer shall provide three (3) certified copies of factory test reports.

3.02 MANUFACTURER'S CERTIFICATION

A. A qualified factory-trained manufacturer's representative shall certify in writing that the equipment has been installed, adjusted and tested in accordance with the manufacturer's recommendations.

3.03 INSTALLATION

A. The Contractors shall install all equipment per the manufacturer's recommendations and the Contract Drawings.

B. All necessary hardware to secure the assembly in place shall be provided by the Contractor.

C. Transformer enclosure shall be grounded to the station ground grid in two places using the ground pads supplied with the transformer.

3.04 FIELD ADJUSTMENTS

A. Adjust taps to deliver appropriate secondary voltage.

3.05 FIELD TESTING

A. Measure primary and secondary voltages for proper tap settings.

B. Megger primary and secondary windings

C. Liquid transformers – Test oil for dielectric strength.

D. Perform field acceptance tests in accordance with NETA ATS and manufacturer's recommendations.

E. Inspect installed transformers for anchoring, alignment, grounding and physical damage.

F. Check tightness of all accessible mechanical and electrical connections with calibrated torque wrench in accordance with minimum acceptable values as specified in manufacturer's instructions.

G. The Contractor shall provide the Engineer three (3) copies of the start-up report tabulating and recording the results of the tests described in this Specification and those suggested by the manufacturer.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16123.001 – MV Transformer shall be measured per each, complete in place.

4.02 PAYMENT

A. Item 16123.001 – MV Transformer will be paid at the unit price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16124

MEDIUM VOLTAGE CABLES, 25 KV

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for medium voltage cables, 25kv, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Furnish and install 25 KV Cables from handhole to station transformers at Gateway Station.
   2. Furnish and install 25 KV Cables from North Side Substation to transformers at North Side Station.
   3. Conduit from North Side Substation to Interface Point with NSC-006. Conduit from interface point to North Side Station by others.
   4. Conduit from handhole to Gateway Station Electrical Room Pullbox.
   5. Cable terminations and accessories.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data

B. Section 16050, "Basic Electrical Requirements."

C. Section 16060, "Grounding and Bonding."

D. Section 16111, "Conduit."

E. Section 16075, "Electrical Identification."

F. Section 16081, "Electrical Testing AC Systems."

1.03 REFERENCE STANDARDS

A. NFPA - NEC

B. ICEA

C. IEEE

D. NEMA

E. ASTM

F. UL

G. CFR

H. International Electrical Testing Association (NETA) Acceptance Testing Specification (ATS) for Electrical Power Distribution Equipment and Systems

I. City of Pittsburgh Building Code

1.04 SUBMITTALS

A. Product Data: For each type of cable indicated, include terminations for cables and cable accessories.

B. Submit test procedure for approval.

C. Schematic cable connections, wire, conduit and trough schedules, duct assignment, conduit and trough layouts, cable layout and detailed Working Drawings for approval thirty (30) days prior to start of any work. Submit manhole Working Drawings showing the existing and new cables for approval thirty (30) days prior to start of work.

D. Installers' Certificates: Signed by the Contractor, certifying that the installers comply with the requirements of this Section.

E. Report of Field Tests: Certified copies of field tests.

F. Field testing organization certificates, signed by the Contractor, certifying that the testing organization complies with the requirements of this Section.

G. Maintenance data for materials and products for inclusion in Operating and Maintenance Manual.

H. Certified flame retardancy test reports and data for tests performed not more than 12 months prior to submittal for materials which are identical to those of the furnished cable.

I. Submit smoke density test reports and data from tests performed not more than 12 months prior to the submittal for materials that are identical to those of the furnished cable.

J. Certified test reports demonstrating that cable complies with specified requirements and those of referenced ICEA and NEMA Standards.

K. Certificates from manufacturer and the Underwriters Laboratories Inc. verifying that products conform to requirements of this Section. Include certificates with submittal of Working Drawings and with each cable shipment.

L. Submit Testing Agency and Testing Agency's Field Supervisor Qualifications.

M. Submit Manufacturer's qualifications as listed in Article 1.05.F and G of this Section.

N. Submit the procedure for pulling all wires and cables through ducts and conduits to the Engineer for approval.

O. Submit wire and cable samples not less than 24-inches in length and ten copies of the notarized certified test reports of each type and size of wire and cable to be furnished for the approval of the Engineer prior to delivery.

P. Cable pulling calculations shall be submitted to the Engineer for approval.

1.05 QUALITY ASSURANCE

A. Engage a cable terminator, trained and certified by terminator material manufacturer, to install, and terminate medium voltage cables.

B. Testing Agency Qualifications: Testing agency as defined by OSHA in 29 CFR or a member company of the International Electrical Testing Association and that is acceptable to authorities having jurisdiction.
   1. Testing Agency's Field Supervisor: Person currently certified by the International Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise testing specified in Article 3 of this Section.

C. Source Limitations: Obtain cables and accessories through one source from a single manufacturer.

D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70 and marked for intended use.

E. Cable shall be standard equipment of proven performance as manufactured by reputable concerns. Cable shall be designed, constructed, and installed in accordance with the best practices of the trade, and operate satisfactorily when installed as shown on the Contract Drawings.

F. Cable manufacturer shall be ISO 9001:2000 certified.

G. The manufacturer of the cables shall have produced similar electrical equipment for a minimum period of 10 years. Provide an acceptable list of installations with similar cables demonstrating compliance with this Section.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Ship each unit securely packaged and labeled for safe handling and shipment.

B. Store products in a dry and secure facility.

C. Cables shall be handled and stored in accordance with manufacturer's instructions. One copy of these instructions shall be included with the cables at time of shipment.

D. NFPA 130 Wiring Requirements
   1. All wiring materials within the station shall be in accordance with NEC and NFPA 130, Sections 5.4.2 through 5.4.9.
   2. All wiring materials within the trainway shall be in accordance with NEC and NFPA 130, Sections 6.3.3.2.2 through 6.3.3.2.9.

ARTICLE 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers:
   1. Cables:
      a. Kerite
      b. Southwire
      c. Okonite
      d. Or approved equal
   2. Cable Terminating Products and Accessories:
      a. G&W Electric
      b. Raychem
      c. Thomas & Betts
      d. Or approved equal

2.02 CABLES

A. Cable Type: MV-105 three (3) conductor

B. Voltage Rating: 25 kV.
   1. Insulation Thickness: 133 percent insulation level.

C. Conductor: Annealed uncoated Copper, Class B soft

D. Conductor Size: #4/0 AWG.

E. Strand Filling: Conductor interstices are filled with impermeable compound.

F. Conductor Insulation: Low smoke, halogen free, low toxicity Ethylene-Propylene Rubber (EPR), ICEA Type II, and have the following properties:
   1. The low smoke, halogen free, low toxicity EPR insulation shall be capable of withstanding operating copper conductor temperature of 105°C continuous. The insulation shall be highly moisture resistant, shall be free-stripping and leave the surface of the conductor clean. An opaque mylar separator may be used between the conductor and the insulation to ease stripping. Any additional tapes (e.g., flame-retardant fiberglass over the tinned copper tape, etc.) deemed necessary by the manufacturer shall be clearly noted.

G. ICEA S-93-639, pg. 15 Conductor Temperatures Shield: Tape shall be free from burrs and shall be applied in such a manner that electrical continuity or contiguity will not be distorted or disrupted during normal installation bending.

H. Nonmetallic Jacket for Single Conductor Cable:
   1. Properties tested in accordance with ASTM, ICEA, UL, IEEE, and MIL specifications. Jacket material shall be low smoke, halogen free, low toxicity, fire retardant. Bond jacket to insulation to prevent moisture pockets between the jacket and insulation.
   2. Mark each single conductor cable to show UL Listing, size, voltage, manufacturer, etc. in accordance with NEC, ICEA/NEMA, and UL requirements.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Install cables in accordance with industry standards and practices.

B. Install cable continuous, without splices, between terminations, except as otherwise noted.

C. Minimum bending radius shall be in accordance with the NEC.

D. Pull Conductors: Do not exceed manufacturer's recommended maximum pulling tensions and sidewall pressure values.
   1. Where necessary, use manufacturer-approved pulling compound or lubricant that will not deteriorate conductor or insulation.
   2. Use pulling means, including fish tape, cable, rope, and basket weave cable grips that will not damage cables and raceways. Do not use rope hitches for pulling attachment to cable.

E. Install exposed cables parallel and perpendicular to surfaces of exposed structural members and follow surface contours where possible.

F. Support cables in accordance with recommended manufacturers procedures and the NEC.

G. In manholes, handholes, pull boxes, junction boxes, and cable vaults, train cables around walls by the longest route from entry to exit and support cables at intervals adequate to prevent sag.

H. Install cable terminators at ends of conductors.

I. Arc Proofing: Unless otherwise indicated, arc proof medium voltage cables at locations not protected by conduit, cable tray, direct burial, or termination materials. In addition to arc proofing tape manufacturer's written instructions, apply arc proofing as follows:

1. Clean cable sheath.
2. Wrap metallic cable components with 10-mil (250-micrometer) pipe-wrapping tape.
3. Smooth surface contours with electrical insulation putty.
4. Apply arc proofing tape in one half lapped layer with coated side toward cable.
5. Band arc proofing tape with 1-inch (25-millimeter) wide bands of half lapped, adhesive, glass cloth tape 2-inches (50-millimeter) on center.

J. Seal around cables passing through fire rated elements.

K. Ground shields of shielded cable at terminations, splices, and separable insulated connectors. Ground metal bodies of terminators, splices, cable, and separable insulated-connector fittings and hardware.

L. Identify cables in accordance with Section 16075, "Electrical Identification."

M. Submit the procedure for pulling all wires and cables through ducts and conduits to the Engineer for approval. Include in this procedure the manufacturer recommended pulling force for each wire and cable, and product Data for lubricants and equipment. Indicate pulling points on Working Drawings.
1. Cable reels shall be set upon jacks in such position that the cable can be fed from them freely, without distorting or injury, into the ducts or conduits through an approved type bell or shield. Extreme care must be used in installing cable so as to avoid twisting, kinking, or in any way injuring the cable or its sheath.
2. Cables must not be installed until all supports and housings are in place, completely installed.
3. Where more than one wire or cable is installed in any one duct or conduit run, all such wires and cables shall be pulled in at the same time.
4. Cable pulling compounds shall have no deleterious effect on the cable and shall be subject to the approval of the Engineer.
5. After the cable has been installed, the ends of the cable shall be immediately sealed until such time as the cable is spliced or otherwise terminated.

N. Cables entering at the top of vertical conduits shall be held rigidly in place by the use of 0-Z type cable wedges or approved equal, oakum and insulating compound, or other approved means. Horizontal runs and bottoms of vertical conduits shall be packed with oakum only. The ends of all conduits shall be terminated by means of suitable bushings. Where cables emerge from ducts, said ducts shall be effectively blocked by approved means to prevent access of rodents.

O. Pump water out of handholes and remove mud, silt and debris, if required, before installation of any cables and splice assemblies.

P. In manholes and vaults, all steel cable racks, hangers, straps, supporting members and other hardware used in connection with the installation of wires and cables shall be protected by hot dip galvanizing after fabrication.

Q. Wire and cable lengths shall be continuous and without splices in conduits between the points of connections, and sufficient slack shall be provided for the proper makeup of such connections. In duct manholes, splices shall be provided as required. Where cables are installed in ducts or conduits from manholes to other manholes or enclosures, splices in manholes shall be centrally located, except where otherwise specified.

1. Splices shall not be made in any wires or cables unless approved by the Engineer. Every splice shall have a conductivity of at least equal to that of the wire or cable.
2. If the splice cannot be completed within the period of the normal working day, the incomplete splice shall be covered with a rubber bandage to prevent moisture or dirt from contaminating the open wires.
3. Before cutting any existing cable, make sure the cable has been properly identified, deenergized and grounded or otherwise made safe. The ends of cables that are cut, made idle and left in place shall be

3.02 CABLE PULLING CALCULATIONS

A. Perform pulling calculations in accordance with the cable manufacturer's recommendations, and this Section. The calculations shall be sealed by a Professional Engineer (Electrical).

B. Cable pulling calculations shall be submitted to the Engineer for approval. Cable shall not be installed until the Contractor receives approval from the Engineer for the pulling calculations and cable installation.

3.03 FIELD QUALITY CONTROL

A. The Contractor shall engage the services of a qualified testing agency to perform the following field quality control testing:

1. After installing the medium voltage cables and prior to energizing the electrical circuit, test for compliance with requirements.
2. Perform each electrical test and visual and mechanical inspection stated in NETA ATS. Certify compliance with test parameters.

B. Remove malfunctioning cable and accessories, replace with new units, and retest as specified.

C. Provide equipment required to perform tests. Prior to insulation and high potential tests, disconnect instruments and equipment that might be damaged during such tests. Conduct tests in presence of the Engineer. Schedule all tests through the Engineer and provide a minimum 48 hours notice. All equipment and instruments requiring calibration shall be provided with documentation to certify that the required calibrations have been performed.

D. Submit test procedure for approval and perform approved tests. Do not perform tests without Engineer approved test procedure. Schedule all tests through the Engineer. Tests include but not limited to the following:
   1. 25 kV single conductor shielded cable:
      a. Test continuity of conductors using ohmmeter.
         1) Proof test insulation resistance to shield or to ground of the cable under test for a minimum of one minute using a 2,500 volt three terminal megger. Insulation resistance: 500 megohms, minimum, corrected to 15.6°C. Testing shall be done prior to termination of the cables at the two ends. Terminal lugs shall be installed prior to cable testing.
      b. Step voltage test:
         1) Make a second megger test at 1,000 volts dc for 1 minute and record end test reading on data sheet. If reading is less than 500 megohms, proceed with step (2), otherwise record new test reading on data sheet with comments depicting corrective action and proceed with testing next cable in the test plan.
         2) Increase the megger test voltage in increments of 500 volts starting at 1,500 volts dc up to 2500 volts dc and perform 1 minute insulation resistance measurement tests. Record end test readings on data sheet for each incremental test.
         3) Compare insulation test readings at all levels of test voltage. A decrease of insulation resistance from the 1,000 volts dc test voltage to the 2,500 volts dc test voltage indicates the cable insulation has incipient weakness and the cable shall be replaced at no cost to the Authority.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16124.001 – 25kV Cable from handhole to station transformers at Gateway Station shall be measured per linear foot, complete in place.

B. Item 16124.002 – 25kV Cable from North Side Substation to transformers at North Side Station shall be measured per linear foot, complete in place.

4.02 PAYMENT

A. Item 16124.001 – 25kV Cable from handhole to station transformers at Gateway Station will be paid at the unit price and shall include the cost of all work specified in this Section.

B. Item 16124.002 – 25kV Cable from North Side Substation to transformers at North Side Station will be paid at the unit price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16125

LOW VOLTAGE BUS DUCT

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for Gateway and North Side low voltage bus ducts, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Fabricated Bus Duct furnished and installed
   2. Fittings
   3. Hangers
   4. Accessories

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data

B. Section 16050, "Basic Electrical Requirements."

C. Section 16060, "Grounding and Bonding."

D. Section 16075, "Electrical Identification."

E. Section 16081, "Electrical Testing AC Systems."

1.03 REFERENCE STANDARDS

A. NEMA

B. UL

C. ANSI

D. IEEE

E. NFPA-70

F. International Electrical Testing Association (NETA) Acceptance Testing Specifications (ATS) for Electrical Power Distribution Equipment and Systems

1.04 SUBMITTALS

A. Shop Drawings and Product Data.
   1. Lengths of segments
   2. Fittings including support details
   3. Ratings of all sections and fittings
   4. Manufacturer's catalogue sheets indicating sheet metal enclosure gauges, finish, bracing and parts lists

B. Installation Shop Drawings showing method of constructions, support details, and routing of bus duct. Shop Drawings shall include plans, sections, and elevation of the bus duct.

C. Provide megger test report of completed bus assembly.

D. Equipment operation and maintenance manuals shall be provided with each assembly shipped, and shall include instruction leaflets and instruction bulletins for the complete assembly and each major component.

E. Manufacturer shall furnish the following Shop Drawings:
   1. Bus layout and arrangement (elevations and plan views)
   2. Bus enclosure cross sections, showing bus bars and supports
   3. Bus termination details
   4. Bus housing termination details (insulated from apparatus)

F. Manufacturer shall furnish instructions for the receipt, storage, handling, installation, test, and operation and maintenance of the bus duct assembly.

G. The following minimum mounting and installation guidelines shall be met, unless specifically modified by the above referenced standards.
   1. The Contractor shall provide equipment anchorage details, coordinated with the equipment mounting provision, prepared and stamped by a Professional Engineer. Mounting recommendations shall be provided by the manufacturer based upon approved shake table tests used to verify the seismic design of the equipment.
   2. The equipment manufacturer shall certify that the equipment can withstand, that is, function following the seismic event, including both vertical and lateral required response spectra as specified in above codes.
   3. The equipment manufacturer shall document the requirements necessary for proper seismic mounting of the equipment. Seismic qualification shall be considered achieved when the capability of the equipment, meets or exceeds the specified response spectra.

H. The following information shall be submitted for record purposes:
   1. Certified production test reports
   2. Installation information

3. Seismic certification and equipment anchorage details

I. Manufacturer's qualifications and ISO 9001:2000 certification.

J. Manufacturer's installation certification

1.05 QUALITY ASSURANCE

A. Equipment shall be standard of proven performance as manufactured by reputable concerns. Equipment shall be designed, constructed, and installed in accordance with the best practices of the trade, and operate satisfactorily.

B. Components of the bus duct shall be provided by one vendor, with sole responsibility of matching components and providing equipment that functions as a system.

C. Manufacturer shall be ISO 9001:2000 certified.

D. Manufacturer shall have produced similar electrical equipment for a minimum period of ten (10) years. Provide an acceptable list of installations with similar equipment demonstrating compliance with this Section.

E. The following minimum mounting and installation guidelines shall be met, unless specifically modified by these referenced standards.
   1. Provide equipment anchorage details, coordinated with the equipment mounting provision. Mounting recommendations shall be provided by the manufacturer.

F. A qualified factory trained manufacturer's representative shall certify in writing that the equipment has been installed, adjusted, and tested in accordance with the manufacturer's recommendations.

G. The bus duct shall have a UL label.

H. The equipment and major components shall be suitable for and certified to meet all applicable seismic requirements of the International Building Code (IBC) for Zone 1 application.

1.06 DELIVERY STORAGE AND HANDLING

A. Equipment shall be handled and stored in accordance with manufacturer's instructions. One copy of these instructions shall be included with the equipment at time of shipment.

B. Bus duct being stored prior to installation shall be stored so as to maintain the equipment in a clean and dry condition.

ARTICLE 2 PRODUCTS

2.01 MANUFACTURERS

A. Cutler-Hammer-Eaton

B. General Electric

C. Square D I-Line Class 5600

D. Or approved equal

2.02 MATERIALS

A. Six hundred (600 V) volt class AC bus duct, three-phase, four-wire, with 100% neutral and 50% internal ground, 2500 ampere rating (Gateway Station Substation); 3000 ampere rating (North Side Station Substation).

B. Bus duct shall consist of standard sections, with special length sections, offsets, and elbows provided to suit the installation. Bus duct shall be fabricated in as few pieces as possible to minimize field installation expense, consistent with convenience in handling on-site. Bus duct shall be manufactured and shipped in a manner which does not require field drilling or machining for unpacking or installation.

C. Bus duct housing shall be non-ventilated and capable of being mounted in any position without derating. Housing shall be painted with a protective finish of ANSI 61 light gray epoxy paint.

D. Bus bars shall be fabricated from high strength, copper, 98 percent conductivity, and silver-plated at all electrical joints and contact surfaces. Bus bars shall be insulated over the entire length, except at joints and contact surfaces, with an UL-listed insulating material consisting of epoxy powder applied by fluidized bed process. Tape or heat shrink sleeve insulation or any other method of insulation that can allow air gaps or insulation breakdown shall not be acceptable.

E. The bus duct and associated fittings shall consist of copper conductors totally enclosed in a steel and aluminum housing. The housing shall be bolted together using zinc-plated fasteners. The bus duct shall be capable of being mounted flat-wise, edgewise, or vertically without derating. The bus duct shall consist of standard ten (10) foot sections with special sections and fittings provided to suit the installation. Horizontal runs shall be suitable for hanging on ten (10) foot maximum centers. Vertical runs shall be suitable for mounting on sixteen (16) foot maximum centers.

F. Terminations

1. Bus duct manufacturer shall furnish materials, equipment, and instructions to terminate bus duct to the low voltage terminals on the MV transformers and LV switchgear.

G. Bus duct shall be designed and rated for the following symmetrical short circuits:
   1. Six hundred volt class bus duct: 200,000 RMS symmetrical amperes

H. Bus Duct shall be so designed and tested, that at its full rating, no part shall exceed a 55°C temperature rise for the conductor and 40°C for the enclosure based on a 40°C maximum ambient temperature.

I. Joints shall permit safe, practical testing of its tightness without de-energizing the run. Any one section of the duct shall be removable without disturbing adjacent sections. Joint covers shall be provided with captive hardware.

J. Bus duct shall be manufactured with two (2) sets of lifting eyes at the ends of sections to facilitate the hoisting and positioning of the bus duct during installation.

K. These feeders bus ducts shall be of the sandwich construction, meaning no air gap shall exist between bus bars except at terminations.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Expansion joints shall be provided in horizontal and vertical bus duct where the bus ducts traverse through building expansion joints.

B. Joint thru bolts shall be torqued as recommended by manufacturer.

C. At each joint, adjacent to torque bolt, a stamped or label shall be provided with the torque value as recommended by manufacturer.

D. The Contractor shall install all equipment per the manufacturer's recommendations and the Contract Drawings.

E. At Gateway, the Contractor shall remove the existing 2000 A bus duct from the LV lugs on the existing 1500 KVA transformer to the existing LV switchgear and connect the new 2500 A bus duct from the new 2000 KVA transformers to the new LV switchgear.

F. For bus duct penetration of fire rated walls and floors the Contractor shall provide fire stopping material.

G. For floor penetration Contractor shall install vertical hangers and floor flanges to support the bus duct. Floor flanges shall be installed both on top and on the underside of floor slab.

H. For wall penetration Contractor shall install two (2) wall flanges, one (1) on each side of wall.

3.02 FIELD TESTS

A. Prior to energization, the Contractor shall run a torque test on each joint and arrange for bus duct manufacturer's representative to conduct the following tests:
   1. Visual inspection of entire Bus Duct installation to confirm that installation is in accordance with manufacturer's printed recommendations.
   2. International Electrical Testing Association (NETA) Acceptance Testing Specifications (ATS) for Electrical Power Distribution Equipment and Systems and shall include:
      a. Insulation Resistance Tests: Insulation resistance of each bus run phase to phase and phase to ground for 1 minute shall be measured.
      b. Alternate or direct current overpotential tests shall be performed on each bus run phase to phase and phase to ground.
      c. Test Values
         1) Bus bolt torque values shall be in accordance with manufacturer's printed recommendations.
         2) Insulation resistance test voltage to be in accordance with ANSI. Resistance values shall be in accordance with manufacturer's values.
         3) Overpotential test voltages shall be applied in accordance with ANSI.

3.03 FACTORY TESTING

A. Standard factory tests shall be performed on the equipment provided under this section. All tests shall be in accordance with the latest version of ANSI and NEMA standards.

B. The manufacturer shall provide three (3) certified copies of factory test reports.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16125.001 – Bus Duct shall be measured per linear foot, complete in place.

4.02 PAYMENT

A. Item 16125.001 – Bus Duct will be paid at the unit price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16130

RACEWAYS AND BOXES

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for raceways and boxes, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Conduits,
   2. Pull boxes
   3. Fittings
   4. Grounding
   5. Cutting and patching

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data

B. Section 16050, "Basic Electrical Requirements."

C. Section 16060, "Grounding and Bonding."

D. Section 16120, "Low Voltage Power Cables"

1.03 REFERENCE STANDARDS

A. NFPA 70 - NEC

B. UL

C. NEMA

D. ASTM

E. City of Pittsburgh Building Code

F. American National Standards Institute (ANSI)

G. IEEE

H. International Electrical Testing Association (NETA) Acceptance Testing Specifications (ATS) for Electrical Power Distribution Equipment and Systems

I. NFPA 130 – Standard for Fixed Guideway Transit and Passenger Rail Systems

1.04 SUBMITTALS

A. Catalog cuts and other product data for each item. Samples as required by the Engineer.

B. Shop Drawings of conduits, boxes, and fittings indicating the exact location and manner of installation including dimensioned plans, sections, and elevations.

C. Maintenance data for materials and products, for inclusion in Operating and Maintenance Manual.

D. Field testing organization certificates: Signed by the Contractor, certifying that the organization complies with this Section.

E. Report of Field Tests: Certified copies from a NETA testing company of field tests including ground resistance tests.

F. Manufacturer's resume and ISO 9001:2000 certification

1.05 QUALITY ASSURANCE

A. The manufacturer of the assembly shall be the manufacturer of the major components within the assembly.

B. For the equipment specified herein, the manufacturer shall be International Organization for Standardization (ISO) 9001:2000 certified.

C. The manufacturer of this equipment shall have produced similar electrical equipment for a minimum period of 10 years. Provide an acceptable list of installations with similar equipment demonstrating compliance with this Section.

D. The equipment covered by this Section shall be standard equipment of proven performance as manufactured by the reputable firms. Equipment shall be designed, constructed, and installed in accordance with the best practices of the trade; and operate satisfactorily when installed as shown in the Contract Drawings.

E. Conduct field inspection to ensure proper installation in accordance with the best practices of the industry, and to insure that the installation is as shown on the Contract Drawing.

1.06 DELIVERY, STORAGE AND HANDLING

A. Equipment shall be handled and stored in accordance with manufacturer's instructions. Include instructions with the equipment at time of shipment.

1.07 NFPA 130 WIRING REQUIREMENTS

A. All wiring materials within the station shall conform to the requirements of the NEC and NFPA 130, Sections 5.4.2 through 5.4.9.

B. All wiring materials within the trainway shall conform to the requirements of the NEC and NFPA 130, Sections 6.3.3.2.2 through 6.3.3.2.9.

ARTICLE 2 PRODUCTS

2.01 RIGID CONDUITS

A. Rigid conduits shall be of the best grade standard weight steel piping, galvanized by the hot-dip process. Deliver rigid conduits to the Worksite in bundles of standard lengths, each length marked with the trademark of the manufacturer. Rigid conduits shall bend cold about a radius equal to 10 times the internal diameter of the conduit, without signs of flaw or fracture in either conduit or coating.

B. Required ferrous metal bonding bushings, couplings, sealing locknuts, hangers, clips, shall be protected per ASTM. Threaded rods, nuts, bolts, flat, and lock washers shall be protected against corrosion with a coating of zinc applied by the hot-dip process.

2.02 BOXES AND FITTINGS

A. Pull boxes for internal wiring shall be UL listed, and made of cast or malleable iron. Boxes and covers shall be protected inside and outside by a coating of zinc applied by the hot-dip process, have hubs for five full threads, where pendant fixtures are mounted on outlet boxes.

B. Pull boxes for installation of internal and external cables shall be UL listed, and made of galvanized sheet steel or aluminum. The pull boxes shall be provided with overlapping sheet steel or aluminum covers with integrated captivating screws to secure closure.

C. Fittings for rigid steel conduit shall be of cast or malleable iron, threaded, and protected by hot dip galvanizing. The use of split fittings or fittings, which are attached to the rigid steel conduit with a clamping action, shall not be permitted. Fittings shall be complete with gaskets, and approved blank or nipple covers, or composition outlet covers, as required, held in place with approved screws.

D. Pull boxes shall be sized in accordance with the NEC.
   1. Pull boxes shall be watertight and have ample size to permit pulling of cables without damage to the cable.

2.03 EXPANSION FITTINGS

A. Conduit expansion fittings shall consist of a hot-dipped galvanized malleable iron body and head, which permits a conduit to telescope back and forth within the body. The head shall provide a concrete-tight and weatherproof seal over the conduit.

2.04 FLEXIBLE CONDUITS

A. Flexible conduit where required shall be liquid tight flexible metallic type with an integrated PVC covering. Fittings shall be of approved type for use with the specific type of conduit that is provided.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Perform survey work required ascertaining the exact installation locations. Use the utmost care when drilling or cutting concrete.

B. Show the exact location of wire, cable, conduit, and related items on Shop Drawings to be approved. Any conduit that has been installed in such a manner that it creates a tripping hazard or interferes with the safety of the maintenance forces or interferes with a train operator's visibility of a signal shall be immediately relocated.

C. Bends or offsets may be made in the field with proper tools, but split, deformed, or damaged conduit shall not be used. Bends in rigid conduit shall be made on a radius of not less than ten times the internal diameter of the conduit, without signs of flaw or fracture in either conduit or coating. Conform conduit bends to all the applicable requirements of the City of Pittsburgh Building Code and NEC. Make conduit bends in accordance with the manufacturer's recommended procedure and in a manner as approved. Bends made by the manufacturer at the factory will be permitted. Conduit shall be kept clean, with inside surfaces smooth and free from obstructions liable to injure the wire or cable. Where conduits join any threaded couplings or fittings, the ends shall be reamed. Paint steel threads with approved thread sealing compound.

D. Unless otherwise indicated, fasten each conduit run to the structure by galvanized malleable iron clamps, of approved design, spaced in accordance with the NEC. Bolts shall be attached in concrete. Additional or special fastenings may be required, where necessary to provide a safe and permanent installation. Conduits shall be straight and neatly arranged.

E. Do not drill the steel structure to support conduits, boxes, or fittings. At certain locations, bolted clamps of an approved type, gripping the steel, may be used if approved. All parts of these supports and fastenings shall be galvanized except the machine screws, nuts, and bolts, which shall be made of stainless steel, and which shall have hexagonal heads and shall be provided with heavy lock washers, zinc plated as specified in the ASTM Specifications. Heavy-duty flat washers, zinc plated shall be provided with all screws and bolts.

F. Conduit straps and clamps shall be provided with approved base fittings or backplates, which shall maintain an air space of quarter inch between the conduit run and the wall or ceiling surface.

G. Conduits and conduit fittings shall be protected from the entrance of water or other foreign matter with hot-dip galvanized cast iron or malleable iron threaded (heavy duty) blank caps. This shall apply to all work left unfinished overnight or temporarily suspended.

H. Boxes and fittings shall be set square with the adjacent ceiling, floor, wall, or beam line; and all conduits shall enter squarely. No box shall be drilled for more conduits than actually enter it. Boxes shall be of ample size to receive, without crowding, all conduits entering them. Where construction permits, boxes and fittings shall be accessible.

I. No conduit smaller than three quarters of an inch shall be installed.

J. Exposed conduits shall be installed parallel to, or at right angles to, ceilings, walls, and partitions. Where direction changes of exposed conduits cannot be made with neat bends, such as required around beams or columns, suitable conduit fittings shall be used.

K. To secure surface mounted boxes firmly and permanently in place on the steel structure, approved hot dipped galvanized clamps and angle iron shall be utilized. Secure surface mounted boxes on encased columns and beams with stainless steel screw anchors, stainless steel machine screws, and washers.

3.02 EXPANSION FITTINGS

A. Use conduit expansion fittings to compensate for linear thermal expansion and contraction of conduits.

B. Conduit expansion fittings shall be installed as follows:
   1. A conduit expansion fitting shall be installed at every location where the conduit run crosses a structural expansion joint and at tube and tunnel portals.
   2. At locations deemed necessary to provide for expansion and contraction of the conduit.

3.03 CLEANING AND SNAKING

A. Conduits shall be cleaned before and after installation. Ends shall be free from burrs and inside surfaces shall be free from all imperfections likely to injure the wires or cables. Immediately before the wires are pulled into any conduit run, such completed conduit run shall be snaked with a steel band to which shall be attached an approved tube cleaner equipped with an approved spherical mandrel of a diameter not less than 85 percent of the nominal inside diameter of the conduit.

3.04 CONNECTION WITH EXISTING CONDUITS

A. Provide labor and material for additional conduits, exposed and concealed, and all necessary pull, outlet and bottomless boxes, and all supporting steel, and connect the conduits installed to an existing conduit system as indicated. Restore the surface of the structure where it has been damaged or removed to permit conduit connections necessary to make a complete and finished installation.

3.05 GROUNDING

A. Conduits and connections to electrical equipment shall be installed to make a continuous ground in accordance with Section 16060, "Grounding and Bonding".

3.06 CUTTING AND PATCHING

A. Where necessary cut away, or break through concrete or brick masonry, replace, and patch said masonry.

B. Drill and tap steel: The drilling of steel or the punching of steel will not be permitted without approval by the Engineer in each case. Burning of steel will not be permitted at any time. No stud welding will be permitted.

C. Where holes are left in the floors and walls by the removal of existing equipment and conduit and where the existing structure is cut away or broken through under this work, restore all openings or chases in floors, walls, or ceilings; and refinish all affected surfaces to match the existing, or as directed.

3.07 ANCHOR BOLTS

A. Holes for anchor bolts in concrete or masonry shall be drilled with their axis perpendicular to the surface of the concrete and shall be of a proper depth and diameter.

3.08 SLEEVES AND FERRULES

A. Install sleeves for conduit penetrations through walls and floors. Install fireproofing between the conduit and the sleeve. The fireproofing is to have the same rating as the enclosure. Fill in and waterproof openings between sleeve and wall or floor as directed. Submit Working Drawings showing method of installation.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16135

INTRUSION DETECTOR

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the procurement, installation and wiring of an intrusion detection system, in accordance with the Contract Documents.

B. The work of this section includes, but is not limited to, the following activities:
   1. Furnish and install an intrusion alarm detector in each signal, communication, motor control center, traction power, circuit breaker, tie breaker rooms and all emergency egress areas to detect unauthorized entrances.

1.02 RELATED SECTIONS

A. Section 16111 "Conduits"

B. Section 16120 "Low Voltage Power Cables"

C. Section 16130 "Raceways and Boxes"

D. Section 16280 "Traction Power Substation Enclosure"

E. Section 16205 "Circuit Breaker Room and Tie Breaker Station General Requirements"

F. Section 13570 "Signal System Requirements"

G. Section 16700 "Communications"

1.03 REFERENCE STANDARDS

A. NEMA

B. NEC

C. UL

D. ANSI

E. IEEE

F. NFPA-70

1.04 SUBMITTALS

A. Provide manufacturer's standard catalog data for all items described in this specification indicating conformance and compliance with standards with criteria indicated.

B. Manufacturer's description, shop drawings, installation and operational instructions.

C. Provide layout drawing for each area identifying all equipment.

ARTICLE 2 PRODUCTS

2.01 INTRUSION DETECTION

A. The intrusion detection device shall operate from a 24 VAC power input. There shall be two internal "intrusion" timers. These timers shall be used to provide an adequate amount of delay time before activation the alarm horn. One of the timers shall be used for the delay in entering while the other shall be used for the delay in exiting. Each timer shall have the capability of being adjusted from 15 seconds to 2 minutes. The design of the alarm system shall include spare contacts to provide for intrusion alarm indications to be reported to the Operation Control Center.

B. Intrusion Alarm Detection Circuits
   1. Intrusion alarm detection circuit shall be supervised (normally closed). If disable pushbutton is not pushed within 30 seconds of opening the door, alarm indication shall be provided to SCADA/PLC.

C. Alarm Annunciator Circuits
   1. Supervisory annunciators shall be arranged on separate class A circuits, supervised by the control panel.
   2. Indication of alarms from control panel to SCADA/PLC interface cabinet shall utilize supervised (normally closed) circuits.

D. Intrusion Alarm Control Unit

1. Functions
    a. The intrusion alarm control unit shall perform the following functions:
        1) Monitor normally closed contacts of magnetic door switch assembly.
        2) Control supervisory annunciator activation.
        3) Allow deactivation and activation if entering or leaving room by pushbutton or future keypad.
        4) Provide intrusion alarm indication to the SCADA/PLC interface cabinet.
        5) Provide for future installation of a 4 digit security code pad for activation or deactivation. A key shall be required to set the code.
2. Operation
    a. There shall be a 30 second nominal entry/exit time period.
    b. A low-level alert tone shall be activated when the magnetic switch is activated.
    c. If the alarm is deactivated by disable pushbutton or future 4 digit code pad within 30 second entry period, low level alert tone shall be deactivated, otherwise an alarm condition shall be detected.
    d. Alarm detection shall cause a silenced alarm output to the SCADA/PLC interface cabinet.
    e. The alarm shall be armed by an enable pushbutton or future 4 digit code pad. There shall then be a 30 second period for exiting without activating an alarm.
    f. If an incorrect or incomplete code is entered in future 4 digit control pad, it shall be cleared after 3 seconds. The operator may then reenter the code.
3. Enclosure
    a. The intrusion alarm control unit shall be housed in a NEMA-4 enclosure with locking cover.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Install magnetic switches at each door or hatch.

B. Install Intrusion Alarm panel and horn.

C. Install pushbuttons, with provisions for future keypad.

D. Wire and conduit between door switches, pushbutton and horn and alarm panel per contract drawings.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16135.001 Intrusion Detector shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16135.001 Intrusion Detector will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16200

TRACTION POWER SUBSTATION GENERAL REQUIREMENTS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for Traction Power Substation General Requirements, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. General requirements for the design, manufacture, furnishing, installing and testing of a new prefabricated-type outdoor traction power substation.
   2. System Support: The Contractor shall furnish, install and test one (1) new traction power substation and associated feeder circuits, and provide support materials and services such as operating and maintenance manuals, spare parts, training, training materials, and maintenance support as specified in these specifications.

C. The Contract Documents provide the performance parameters and design criteria to complete the Traction Power Substation General Requirements portion of the Work. The Contractor shall be responsible to provide a complete design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16360, "Traction Power Substation Testing."

1.03 REFERENCE STANDARDS

A. IEEE:
   1. 141 – Recommended Practice for Electric Power Distribution for Industrial Plants
   2. 242 – Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

B. NESC

C. UBC

1.04 DESIGN CRITERIA

A. The equipment furnished by the Contractor shall be designed to operate satisfactorily at full (100%) power under the following environmental conditions. The Contractor shall be responsible for verifying all local building code requirements.
   1. Elevation: 0 to 400'
   2. External humidity: 20 to 100%

3. Seismic withstand criteria: Zone 4, per latest addition of the Uniform Building Code (UBC)
4. Minimum snow load: 30 psf (Allegheny County requirement)
5. Design wind speed: 75 mph (Allegheny County requirement)
6. Design wind pressure: 14.4 psf (Allegheny County requirement)
7. Maximum external ambient temperature: 110° F
8. Minimum external ambient temperature: -10° F
9. Structure ice loading: NESC Heavy Loading District (1/2 inch ice)
10. Lightning isokeraunic level: 28

B. The normal substation enclosure HVAC controller setpoint range is expected to be 70 to 80° F. The maintained enclosure temperature for HVAC systems design purposes shall be 72° F.

C. The maximum noise level emitted by the substations shall be 45 dBA when measured 50 feet from the substation enclosure perimeter. Noise level measurement shall be in accordance with Section 16360, "Traction Power Substation Testing."

D. Substation Nominal Voltage: 23 kV.

E. Substation Available Three-Phase Short Circuit Currents: see Contract Drawing Single Line Diagrams. For calculating equipment interrupting duties, Contractor shall add 25% to the indicated available three-phase short circuit currents.

1.05 TRANSPORT AND DELIVERY

A. The Contractor shall be responsible for determining how to safely transport, deliver and unload the substation being installed under this Contract. As such, it will be the Contractor's responsibility to prepare suitable access from roads to the point of delivery of the substation. All costs associated with this requirement, including the obtaining of any necessary permits and weekend or nighttime working hours, will be borne by the Contractor.

1.06 TESTING

A. The Contractor shall obtain approval of the Test Plan for traction power equipment as set forth in Section 16360, "Traction Power Substation Testing," prior to developing and submitting the related Test Procedures.

B. The Contractor shall obtain approval of the Test Plan and Test Procedures for the traction power equipment, as set forth in Section 16360, "Traction Power Substation Testing," prior to commencing factory and field testing.

C. The Contractor shall perform all tests necessary to ensure that the new traction power substation performs according with the requirements of the Contract Documents.

1.07 WORK TO BE PERFORMED BY OTHERS

A. Duquesne Light Company will furnish and install the 23 kV cables, pad-mounted switchgear and pad-mounted switchgear bases that will be used to power the new traction power substation. The Contractor shall furnish and install the concrete-encased ductbanks for the Duquesne Light Company 23 kV cables, as indicated on the Contract Drawings. The Contractor shall coordinate the work of this Section with Duquesne Light Company, as required. An allowance has been provided in this Contract for work performed by Duquesne Light Company for service to the TPSS.

1.08 SHORT CIRCUIT AND PROTECTIVE DEVICE COORDINATION ANALYSIS

A. The Contractor will be required to provide a short circuit and protective device coordination analysis for the North Shore Traction Power Substation equipment that includes the effects of adjacent substations, and following requirements:
   1. In accordance with IEEE 141 and 242, for fault calculations and coordinated system protection.
   2. Include high voltage source, relays on high voltage switchgear, transformer-rectifier units and dc switchgear, and capability curves of rectifiers and rectifier transformers.
   3. Available short-circuit currents, based on a power company contribution of 22 kA, for 23 kV service, as referenced in Section 16220, "Traction Power Substation 27 kV AC Switchgear."
   4. Recommended settings and adjustment of protective devices.

1.09 ABBREVIATIONS

A. The following abbreviations augment those in the Contract Drawings and other sections of the Specifications:

AC	Alternating Current
Amp or A	Ampere
APCC	Auxiliary Power Control Cabinet
BF	Bid Form
CAT	Catenary
CDR	Critical Design Review
CSB	Contract Specification Book
dBA	A-Weighted Decibels
DC	Direct Current
EA	Each
EMF	Electro-Magnetic Field
ETC	Emergency Trip Control
ETS	Emergency Trip System
F	Fahrenheit
FO	Fiber Optic
FRE	Fiberglass Reinforced Epoxy
HH	Handhole
HDPE	High Density Polyethylene

HVAC	Heating, Ventilating, and Air Conditioning
HZ	Hertz
IBC	International Building Code
IFTC	Interface Terminal Cabinet (SCADA)
KCMIL	Thousand circular mils
KV	Kilovolt
KVA	Kilovolt-Amp
KW	Kilowatt
LRC	Light Rail Control
LRCI	Light Rail Control Interface
LS	Lump Sum
MA	Milliampere
MH	Manhole
MCM	Thousand Circular Mils
MNHR	Man hour
MO	Month
MPH	Miles per Hour
MTBF	Mean Time Between Failure
MW	Megawatt
MWA	Miscellaneous Work Allowance
NC	Normally Closed
NCE	Neat Construction Estimate (of Contract value)
NIC	Not In Contract
NO	Normally Open
NSC	North Shore Connector
NTP	Notice to Proceed
OCS	Overhead Contact System
O&M	Operation & Maintenance
PB	Pushbutton (on electrical diagrams)
PB	Parsons Brinckerhoff
PDR	Preliminary Design Review
PSI	Pounds per Square Inch
PSF	Pounds per Square Foot
PVC	Polyvinyl Chloride
ROW	Right Of Way
RMS	Root Mean Square
RS&I	Rules, Standards and Instructions
SCADA	Supervisory Control and Data Acquisition
SEC	Seconds
SPSS	Signal Power Supply Station
SUB	Substation
SW	Switch
TPSS	Traction Power Substation
UG	Underground
V	Volts

ARTICLE 2 PRODUCTS

[NOT USED]

ARTICLE 3 EXECUTION

3.01 FACTORY ASSEMBLY

A. Prior to shipment from the factory, the new substation shall be completely assembled in final field configuration and factory tested in accordance with Section 16360, "Traction Power Substation Testing."

B. Upon successful completion of factory testing, substation assemblies shall be disassembled as required to provide shipping packages of size and weight compatible with the transportation modes selected and for compliance with traffic regulations.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16205

CIRCUIT BREAKER ROOM AND TIE-BREAKER STATION
GENERAL REQUIREMENTS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for Allegheny Circuit Breaker Room and Gateway Tie Breaker Station General Requirements, in accordance with the Contract Documents.

B. Contractor shall prepare rooms by the proper demolition and removal of old equipment in the Gateway Tie Breaker Room.

C. The Contract Documents provide the performance parameters and design criteria to complete the Circuit Breaker Room and Tie Breaker Station portion of the work. The Contractor shall be responsible to provide a complete design for this portion of the Work.

D. System Support: The Contractor shall furnish, install and test each new Circuit Breaker Room and Tie-Breaker Station and associated feeder circuits, and provide support materials and services such as operating and maintenance manuals, spare parts, training, training materials, and maintenance support as specified in these specifications.

E. The work of this section also shall include:
1. The DC Switchgear, meters, protection devices, etc.
2. Battery, Battery Charger, DC Disconnect and DC Panel board
3. DC Breaker Test Cabinet
4. Annunciator Panel
5. All wiring, grounding, conduits, and miscellaneous hardware.
6. All 2 KV cable and RGS conduit from DC Tie breaker to Catenary connection point.
7. Floor and wall electrical insulation.

1.02 DESIGN CRITERIA

A. The equipment furnished by the Contractor shall be designed to operate satisfactorily at full (100%) power under the following environmental conditions. The Contractor shall be responsible for verifying all local building code requirements.
1. Elevation: -50' to 400'
2. External humidity: 20 to 100%

3. Seismic withstand criteria: Zone 1 per 2003 International Building Code (IBC)
4. Minimum snow load: 30 psf (Allegheny County requirement)
5. Design wind speed: 75 mph (Allegheny County requirement)
6. Design wind pressure: 14.4 psf (Allegheny County requirement)
7. Maximum external ambient temperature: 110 °F
8. Minimum external ambient temperature: -10 °F
9. Structure ice loading: NESC Heavy Loading District (1/2 inch ice)
10. Lightning isokeraunic level: 28

B. The normal HVAC controller setpoint range is expected to be 70 to 80° F. The maintained temperature for HVAC systems design purposes shall be 72° F.

C. Nominal Voltage: 650 VDC.

1.03 RELATED SECTION

A.	Section 16050	Basic Electric Requirements
B.	Section 16060	Grounding and Bonding
C.	Section 16111	Conduit (all paragraphs relating to rigid steel conduit)
D.	Section 16120	Low Voltage Power Cables
E.	Section 16130	Raceways and Boxes
F.	Section 16240	Metal-Enclosed DC Switchgear
G.	Section 16295	TP Substation Wire and Cable • Paragraph 2.05 2 KV DC Power Cable. • Paragraph 2.06 Cable Fittings and connectors
H.	Section 16310	Local Annunciator Panel
I.	Section 09900	Protective

1.04 REFERENCE STANDARDS

A. All equipment furnished under this Section shall be in accordance with the latest applicable standards of the IEEE, ANSI, NFPA, NEMA, ICEA, ASTM, UL, and National Electrical Code with regard to material, design, construction and testing.

1.05 SUBMITTALS

A. Submit shop drawings, technical data and certificates, and test procedures for all items of equipment under this section for approval:

1. Submit product data on the following:
    a. DC switchgear
    b. DC Battery, charger, DC Panel board
    c. AC Panel Board
    d. Intrusion Detector Panel
    e. Annunciator
    f. Room Equipment Layout
    g. Grounding Plan
2. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

1.06 QUALITY ASSURANCE

A. For codes, regulations, reference standards and specifications, refer to Article 1.04, above.

B. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

1.07 WORK TO BE PERFORMED BY OTHERS

A. Allegheny Circuit Breaker Room

1. Underground duct bank to Pier 11 by NSC-012 contract.
2. Outside perimeter ground grid by NSC-012 contract.
    a. Pig-tail ground cables from perimeter ground grid to inside circuit breaker room by NSC-012 contract.

ARTICLE 2 PRODUCTS

2.01 PRODUCTS

A. Refer to the following references for detail information for the major electrical equipment in each installation.

1. Intrusion Detection System – Section 16135
2. Auxiliary Power – Section 16235
    a. Paragraph 2.03 – Low Voltage AC Panel Boards
3. Metal-Enclosed DC Switchgear – Section 16240
    a. No spare breakers required.
    b. Only feeder breakers required.
    c. No cathode breakers
4. Negative Return Cabinet – Section 16250
    a. Dwg. TP302

5. 125VDC Battery System – Section 16270
6. SCADA System – Secttion16742
7. Provide insulation barriers per Contract Drawings and spec section 16210-2.22.
8. Provide insulated floor per Contract Drawing and specification Section 16210-2.23.
9. Provide and install grounds and ground bus around rooms per Contract Drawings.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Insulated floor and walls shall be done and approved before any equipment is installed.

B. All ground bus work shall be installed and all equipment grounded per contract drawing.

C. All equipment shall be bolted and secured per manufacturer's instructions.

D. All conduits entering or leaving the DC switchgear shall be PVC or RGS with a PVC transition of a minimum of one (1) foot.

E. All conduits shall be run horizontally and vertical in room in neat configuration.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16205.001 – Gateway Tie-Breaker Station shall be measured as a lump sum unit, complete in place.

B. Item 16205.002 – Allegheny Circuit Breaker Room shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16205.001 – Gateway Tie - Breaker Station will be paid at the lump sum price and shall include the cost of all work specified in this Section.

B. Item 16205.002 – Allegheny Circuit Breaker Room will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16210

TRACTION POWER SUBSTATION
BASIC ELECTRICAL MATERIALS AND METHODS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Traction Power Substation Basic Electrical Materials and Methods, in accordance with the Contract Documents.

B. The Contract Documents provide the performance parameters and design criteria to complete the Traction Power Substation Basic Electrical Materials and Methods portion of the Work. The Contractor shall be responsible to provide a complete design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16060, "Grounding and Bonding."

B. Section 16111, "Conduit."

C. Section 16200, "Traction Power Substation General Requirements."

1.03 REFERENCE STANDARDS

A. ANSI:
1. A14.1 – Ladders - Portable Wood, Safety Requirements for
2. C29.17 – Standard for Insulators - Composite-Line Post Type
3. C37.2 – Electric Power System Device Function Numbers
4. C37.90 – Relays and Relay Systems Associated with Electric Power Apparatus
5. C78.1 – Fluorescent Lamps - Rapid-Start Types - Dimensional and Electrical Characteristics
6. C80.1 – Specifications for Rigid Steel Conduit, Zinc-Coated
7. C82.1 – Electric Lamp Ballast - Line Frequency Fluorescent Lamp Ballast

B. ASTM:
1. A48 – Standard Specification for Gray Iron Castings
2. A123 – Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
3. A153 – Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
4. A167 – Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip

5. A575 – Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
6. A576 – Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
7. A1011 – Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
8. B3 – Soft or Annealed Copper Wire
9. B8 – Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
10. B117 – Standard Practice for Operating Salt Spray (Fog) Apparatus
11. B633 – Standard Specifications for Electrodeposited Coatings of Zinc on Iron or Steel
12. D149 – Tests for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
13. D257 – Standard Test Methods for DC Resistance or Conductance of Insulating Materials
14. D638 – Test for Tensile Properties of Plastics
15. D695 – Test for Compressive Properties of Rigid Plastics
16. D790 – Test for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
17. D1535 – Standard Practice for Specifying Color by the Munsell System
18. E84 – Standard Test Method for Surface Burning Characteristics of Building Materials

C. Duquesne Light Company (DLC) Specifications

D. EIA:
1. 443 – EIA/NARM Standard for Solid State Relay Service

E. ICEA (Insulated Cable Engineers Association)

F. IEEE:
1. C37.20.2 – Standard for Metal-Clad Switchgear
2. C37.20.3 – Standard for Metal-Enclosed Switchgear
3. C37.21 – IEEE Standard for Control Switchboards
4. C37.90.1 – Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric power Apparatus
5. C37.90.2 – Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers
6. 693 – Recommended Practice for Seismic Design of Substations

G. NEMA:
1. FG-1 – Fiberglass Cable Tray Systems
2. FU-1 – Low Voltage Cartridge Fuses
3. ICS-1 – Industrial Control Systems General Requirements

4. ICS-4 – Terminal Blocks
5. ICS-5 – Industrial Control Systems Control Circuit and Pilot Devices
6. ICS-6 – Industrial Control Systems: Enclosures
7. ICS-10 – AC Automatic Transfer Switches
8. 250 – Enclosures for Electrical Equipment (1,000 Volts Maximum)
9. RN-1 – Polyvinyl-Chloride Externally Coated Galvanized Rigid Steel Conduit
10. ST-20 – Dry-type Transformers for General Applications
11. TC-2 – Electrical Plastic Tubing (EPT) and Conduit (EPC-40 and EPC-80)
12. TC-3 – PVC Fittings for use with Rigid PVC Conduit and Tubing
13. VE-1 – Metal Cable Tray Systems
14. VE-2 – Metal Cable Tray Installation Guidelines
15. WC-57 – Standard for Control Cables
16. WC-70 – Standard for Non-Shielded Power Cables Rated 2,000 Volts or Less for the Distribution of Electrical Energy
17. WD-1 – General Purpose Wiring Devices
18. WD-6 – Wiring Devices - Dimensional Requirements

H. NFPA:
1. 70 – National Electrical Code (NEC)

I. UL:
1. 5 – Surface Metal Raceways and Fittings
2. 6 – Rigid Metal Conduit
3. 20 – General-Use Snap Switches
4. 83 – Thermoplastic-Insulated Wires and Cables
5. 94 – Tests of Flammability of Plastic Materials for Parts in Devices and Appliances
6. 224 – Extruded Insulating Tubing
7. 248 – Low-Voltage Fuses - Part 8: Class J Fuses
8. 467 – Grounding and Bonding Equipment
9. 512 – Standard for Fuseholders
10. 542 – Lampholders, Starters, and Starter Holders for Fluorescent Lamps
11. 651 – Schedule 40 and 80 Rigid PVC Conduit
12. 870 – Wireways, Auxiliary Gutters and Associated Fittings
13. 935 – Fluorescent - Lamp Ballasts
14. 1059 – Terminal Blocks
15. 1570 – Lighting Fixtures, Fluorescent

1.04 SUBMITTALS

A. Provide manufacturer's standard catalog data for all items described in this Section, indicating conformance and compliance with standards and criteria indicated.

B. Manufacturer's description, Shop Drawings, installation and operational instructions.

C. Certified test data.

D. Provide proof that similar units, presently being used on extra heavy rail transit systems, have developed a satisfactory operating history for a minimum of five (5) years.

E. Provide furniture catalog data for all items described in this Section.

F. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

1.05 QUALIFICATIONS

A. Design shall be that of a field proven product. No prototypes will be considered. A proven product is considered to be similar units presently being used on extra heavy rail transit systems and having developed a satisfactory operating history for a minimum of five (5) years.

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Materials furnished shall be standard products of manufacturers regularly engaged in the production of materials specified.

2.02 GALVANIZED RIGID STEEL CONDUIT

A. The material shall be in accordance with Section 16111, "Conduit".

2.03 PVC CONDUITS AND FITTINGS

A. The material shall be in accordance with Section 16111, "Conduit".

2.04 STEEL CABLE TRAYS

A. Steel trays shall be ladder type or ventilated solid-bottom type as required and shall be hot-dip galvanized after fabrication in accordance with ASTM A123.

B. Steel cable trays shall comply with the requirements of NEMA VE-1, and be designed and installed according to NEMA VE-2.

2.05 FIBERGLASS CABLE TRAYS

A. Fiberglass trays shall be ladder type, manufactured from fiberglass-reinforced polyester resin in compliance with NEMA FG-1, with the features noted below:
   1. Dimensions: Inside usable depth shall be four (4) inches, minimum. Outside depth shall be six (6) inches, maximum.
   2. Fitting Radius: 24 inches.

3. Rung Spacing: Maximum nine (9) inches between centers.
4. Working Load: 50 pound per linear foot, on a maximum span of eight (8) feet, with a safety factor of 1.5.
5. Fabrication: Straight section shall consist of rungs located between channel-shaped side rails.
6. Flame Spread Index: 25 maximum per ASTM E-84.
7. Smoke Density: 450 maximum per ASTM E-84.

B. All cable trays inside the substation shall have snap-on construction type covers.

2.06 METAL FRAMING AND WIREWAYS

A. Metal Framing (Continuous Slot Metal Channel System) - Comply with the following requirements:
1. Channel: Steel, ASTM A1011. Where used as a raceway and lighting fixture support, channel shall be listed by UL as complying with UL 5 for use as surface raceway and support for lighting fixtures with electric discharge lamps.
2. Configuration: Single channel or two single channels welded together. Channels shall accept spring-held steel nuts.
3. Single Channel Dimensions: 1-5/8 inch by 1-5/8 inch, 12-gauge.
4. Double Channel Dimensions: 1-5/8 inch by 3-1/4 inch, 12-gauge.
5. General Fittings Dimensions, for Flat, Angular and U Shapes: 1/4 inch thick by 1-5/8 inch wide, unless otherwise indicated.
6. Channel, Pipe Clamps, and General Fittings Finish: Hot-dip galvanized after fabrication, ASTM A123, as applicable.
7. Nuts, Bolts, and Screws Finish: Electrodeposited zinc coating conforming to ASTM B633, Class Fe/Zn 5, Type III.

B. Wireways: Galvanized sheet steel with screw covers, complying with UL 870.

2.07 HANGERS AND SUPPORTS

A. Hanger Rods:
1. Threaded, hot-rolled steel per ASTM A575 or ASTM A576.
2. Minimum ½ inch diameter with electro-deposited zinc coating conforming to ASTM B633, Fe/Zn 5, type III.

B. Trapeze, Multiple Conduit Hangers:
1. Fabricated of two (2) or more galvanized steel hanger rods, a steel channel horizontal member and U-bolts, clamps and other attachments necessary for securing hanger rods and conduits.
2. Horizontal Member: Continuous galvanized metal channel, single or double, as required.

2.08 OUTLET, JUNCTION AND PULL BOXES

A. In compliance with the NEC.

B. Surface Mounted Outlet and Switch Boxes: Cast iron alloy, hub-type with cover gasket in wet locations, complete with painted steel cover plates and complying with ASTM A48.

C. Pull and Junction Boxes:
   1. Dry Locations: Galvanized, 16 MSG minimum, sheet steel with welded seams and screw covers.
   2. Wet Locations: NEMA Type 4, hot-dip galvanized cast iron complying with ASTM A48 and A153.

2.09 GROUNDING AND BONDING MATERIALS

A. Furnish and install in accordance with Section 16060, "Grounding and Bonding".

2.10 INSULATED WIRE, CABLE AND ACCESSORIES

A. Low-Voltage Wire and Cable:
   1. UL listed for the intended purpose.
   2. Conductors: (Soft or annealed copper complying with ASTM B3).
      a. Power circuits shall be size No. 12 AWG, minimum with solid conductor. Size No. 10 AWG and larger shall be ASTM B8, Class B stranded.
      b. Control circuits shall be size No. 14 AWG, minimum, ASTM B8, Class B stranded.
      c. Fixture wiring shall be size No. 16 AWG, minimum, ASTM B8, Class C stranded.
   3. Insulation:
      a. Power Circuits: NEC Type XHHW or RHW conforming to NEMA WC-70.
      b. Control Circuits (except panel wiring): NEC Type THW, or Type RHW conforming to NEMA WC-90. Wiring in dc switchgear subjected to 750 Vdc nominal voltage shall have 2,000 V class insulation.
      c. Panel Wiring: NEC Type SIS. Comply with UL 83 flame retardant properties test. Wiring in dc switchgear compartments subjected to 750 Vdc nominal potential shall have 2,000V class insulation.

B. Terminations for 600 V Wire and Cable:
   1. Terminal connections shall be UL listed and have capacity and insulation voltage ratings of not less than the ratings of the wire or cable terminated.
   2. Terminals for No. 10 AWG and smaller wire: Vinyl insulated, electro-tin plated, electrolytic copper locking spade.
   3. Terminals for No. 8 to 3/0 AWG wire: Compression, tin-plated copper.
   4. Terminals for No. 4/0 AWG and larger wire: Long-barrel, tin-plated copper, compression-type, with two bolting holes in the pad.

5. Compression connectors shall be circumferential-type rather than indentation-type.

C. Substation Terminations for 2,000 Vdc cables:
1. Double U-bolt type variable terminal with NEMA two-hole lugs for connecting cables to flat bus bars.
2. High conductivity copper alloy with Everdur U-bolts, nuts and lockwashers.
3. Dossert-type UL, or approved equal.

D. Pole-Mounted Disconnect Switch Terminations for 2,000 Vdc cables:
1. Long barrel, ring-compression type terminal with NEMA two-hole lug.
2. High conductivity copper alloy.
3. Provide section of insulating/strain relief heat shrink tubing over the compression lug barrel and the first 12 inches of cable adjacent to the termination.

E. Feeder Cable Identification Markers:
1. Stainless steel tags mounted on stainless steel strips oriented parallel to (along) the cable. Strips shall be securely fastened to the cable with a minimum of two (2) heavy-duty cable ties.

F. Control Wire Identification Markers:
1. Heat shrinkable polyolefin sleeve type conforming to UL 224.
2. Fade, smudge, abrasion and chemical resistant print.

G. Wire Ties: Nylon strap with stainless steel locking barb and taper, black, ultraviolet ray resistant.

2.11 WIRING DEVICES

A. Terminal Blocks:
1. In compliance with NEMA ICS-4 and UL-1059, and the referenced standards associated with the equipment in which the terminal blocks are mounted. Terminal blocks shall be of the washerhead screw type. Base and inter-terminal barriers shall accommodate terminals for No. 8 AWG and smaller stranded copper wire connectors.
2. Terminal blocks shall be identified and provided with at least 25 percent spare terminals in additional to those required for circuit wiring for this contract. Terminal blocks shall be rack or rail mounted in vertical rows with permanent marker tags.

B. Switches:
1. In compliance with the NEC, UL-20 and NEMA WD-6.
2. Heavy duty, ac general use, snap type, toggle operated and rated 20A, 120/277 Vac.
3. Single-pole, double-pole, one-way or two-way, as determined by the application.

2.12 FUSES AND FUSEHOLDERS

A. Fuses and fuseholders shall be UL Listed.

B. Cartridge fuses: In compliance with NEMA FU-1 and UL-248.

C. Fuse Holders:
   1. In compliance with UL-512.
   2. Utilize "finger-safe" fuseholders wherever possible.

2.13 INDICATING LIGHTS

A. All indicating lights shall be light emitting diode (LED) panel indicator lamps and shall have the following features:
   1. Direct replacement for ET-16 incandescent lamp holders for individual switchboard-type indicating lights.
   2. Bright, large 0.9 inch diameter lens visible at great distance and at viewing angles to 180 degrees.
   3. 100,000 hour rated operating life.
   4. Diffused illumination - no hot spot.
   5. Rugged environmentally sealed encapsulated non-relampable assembly for increased reliability.
   6. Solid-state with high shock and vibration resistance.
   7. 20 mA operating current.

2.14 NAMEPLATES AND MARKINGS

A. Standard rating nameplates: Equipment rating nameplates shall comply with the requirements of the various references cited in this Section.

B. Special nameplates:
   1. Identification/designation nameplates shall be provided for each item of substation equipment, and associated control and metering devices. Contractor shall submit designation nameplate schedules for approval.
   2. Nameplate Material: opaque, white over black laminated melamine, not less than 3/32-inch thick, black engraved letters and shall comply with FS L-P-387A, Type NDP.
   3. Equipment Nameplates: 1-5/8 inch high plate with 7/8-inch high characters.
   4. Device Nameplates: 5/8-inch high plate with 1/4-inch high characters.
   5. Nameplates shall be fastened to the equipment or device compartment door with stainless steel machine screws. Attachment by adhesives will not be acceptable.

2.15 RELAYS

A. All relays shall be utility grade, and immune from inadvertent operation due to ambient radio frequency signals in accordance with IEEE C37.90.2. Relays shall be designed, constructed, and tested in accordance with the applicable provisions of ANSI C37.90, EIA 443 and NEMA ICS standards, and shall be UL recognized. Relay functional designations and circuits shall be as indicated. Relay contact ratings shall be not less than five (5) amps.

B. Protective relays shall be semi-flush mounted, draw-out style. For ac protective relays, test switches shall be provided for testing the relay in its case. The relays shall have dustproof cases finished in dull black. Protective relays shall be furnished with hand reset targets. Contacts and adjusting devices shall be readily visible, accessible, and adjustable from the relay front.

C. Lock-out Relays:
   1. 125 Vdc operating coil.
   2. Multi-deck, knife-type rotary contacts, 30 Amperes continuous and 10 amperes interrupting at 125 Vdc.
   3. Hand-reset type using oval handle.
   4. Mechanical targets: black for reset position, orange for trip position.
   5. Provide amber LED which illuminates when lockout relay has operated.
   6. Provide at least two (2) sets of normally-open and normally-closed spare contacts.

D. Auxiliary and General Purpose Relays:
   1. Provide as required to achieve specified functionality.
   2. Shall be easily accessible for removal or maintenance.
   3. Relay contacts shall be rated for the intended duty, but in no case shall be less than five (5) amperes at rated circuit voltage. Provide two (2) normally-open and two (2) normally-closed spare contacts per auxiliary relay.

E. SCADA Interposing Relays:
   1. Sealed plug-in style with stainless steel, hold-down spring clip.
   2. Provide socket bases with pressure plate terminals.
   3. Provide silver alloy contacts rated for 12 amperes at 24 Vdc.

2.16 METERS

A. Metering instruments shall be a UL approved, ANSI style analog switchboard type in 4-1/2 inch polycarbonate black cases. Lenses shall be contoured to minimize reflections.

B. Instruments shall be semi-flush, for panel mounting. Instruments shall have one (1) percent accuracy, 250-degree scale, with black lettering on white background. Instrument scales shall be calibrated to match the primary circuit current and voltage ranges.

C. Dielectric withstand rating: 2,300 Vac for one minute between circuit and case.

D. Contractor shall ensure that meter overshoot range will not be exceeded by both normal and abnormal load currents.

E. Ammeters and voltmeters shall be wired through suitable test switches.

2.17 SELECTOR SWITCHES

A. Control, selector, and instrument switches shall be of the rotary type. Switches shall have silver-to-silver contacts, rated 20 A, and cam action or similar positive means for actuating contacts. All contacts shall be enclosed within easily removable covers. All switches shall have escutcheon plates. Each controllable device shall have a separate control switch.

B. Breaker control switches shall have heavy-duty pistol-grip handles and operation targets. Switch positions shall be TRIP-CLOSE with spring return to normal. OPEN and CLOSED position indicating lights shall be furnished. All illuminated GREEN lights shall indicate breaker or switch in the OPEN position; RED shall indicate the CLOSED position.

C. Switchgear Device No. 43 selector switches shall have LOCAL-REMOTE positions, pistol-grip handles and shall be provided with white indicating lights. The white indicating light shall illuminate when the control selector switch is in the remote position. Two (2) independent spare contacts shall be furnished for each switch position.

D. Three-phase ac ammeter and voltmeter selector switches shall have OFF-1-2-3 positions.

2.18 ELECTRICAL WARNING SIGNS

A. Attach a minimum of one electrical warning sign to each of the four exterior walls of each substation; the signs on the side walls shall be located on the exterior of the entry doors.

B. Fabricate with ASTM A167, Type 304L, stainless steel plate with red background and engraved white lettering of two inches minimum height. Plate shall be 10 inches high by 14 inches wide and 1/8 inch thick minimum, machine drilled to accept six (6) stainless steel machine screws, included, for attachment to vertical surfaces.

C. Inscription shall read: “WARNING, HIGH VOLTAGE, KEEP OUT”.

2.19 LIGHTING FIXTURES

A. Substation Interior Fluorescent Lighting:
1. Luminaires for normal 120 Vac lighting system shall comply with UL-1570. Luminaires shall be standard suspended type industrial four-foot fluorescent lamp fixtures.

2. Lamp ballasts shall comply with ANSI C82.1 and UL-935 and shall be UL listed, Class P, with integral protection set to limit case temperature.
3. Fluorescent lamp shall be rapid start, cool white, and shall comply with ANSI C78.1.
4. Lampholders, starters, and starter holders shall be UL-542 listed.

B. Substation Exterior Lighting:
1. Outdoor lighting shall be provided by fixtures with unit photo-cell control and on/off automatic switch. These fixtures shall be installed in vandal-proof steel cages.
2. Lighting fixtures shall be mounted above each substation entry door as shown on the Contract Drawings.
3. The fixtures shall be weather-resistant, gasketed, industrial type with epoxy enameled cast iron or aluminum body, and clear heat resistant straight glass globe with guard secured to body by tamperproof stainless steel screws. Fixtures shall be UL 57 listed as suitable for wet locations.

C. Substation Alarm Lighting (Clear Light):
1. A substation alarm lighting fixture shall be mounted above each substation as shown on the Contract Drawings. The fixture shall be a clear or white LED.

2.20 EQUIPMENT FINISHES

A. Color: Light gray color No. 61 (Munsell notation 8.3 G6.10/0.54).

B. Paint Process for Ferrous Enclosures and Parts:
1. Electrostatically-applied polyester powder coat with average final thickness after baking of 2-4 mils, minimum.
2. Metal shall be prepared before painting with alkaline cleaning and phosphate rinse stages, followed by oven drying.
3. Finishes shall pass the coating (paint) qualification test described in Article 6.2.8 of IEEE Standards C37.20.2 and C37.20.3.

2.21 SUPERVISORY CONTROL (SCADA) INTERFACE EQUIPMENT

A. Status Indication and Annunciation Circuits:
1. Provide one normally open (a) and a normally closed (b) voltage-free contact rated 50 volts maximum, 2A resistive and 1A inductive load, suitably wired to interface cabinet.

B. Control Circuits:
1. Provide interposing relays with coils shall be designed for continuous operation from a 24 Vdc source with minimum pick-up of 18 Vdc, suitably wired to the interface cabinet. Contact arrangements and ratings at 125 Vdc nominal voltage shall be selected to suit equipment trip and close circuit requirements.

C. Transducers for Analog Indication Circuits:
   1. Provide transducers with 0-1 mA output for full-scale analog indication of ac voltages and currents, and dc voltages.
   2. Provide transducers with bidirectional +/- 1mA output for full-scale analog indication of dc currents.
   3. Transducers shall be average-sensing, 0.2 percent accuracy or better, and shall be selected by the Contractor to work with the electrical characteristics and burdens of the specific equipment purchased.
   4. Dielectric withstand rating: 2,500 Volts.
   5. Surge withstand capability: in accordance with IEEE C37.90.1.
   6. All transducers shall be sized to accommodate a 20 percent additional future burden.

2.22 GLASTIC INSULATION

A. UL recognized NEMA grade GPO-3 fiberglass reinforced thermoset polyester material with arc, electrical tracking and flame resistant properties.

B. Insulation resistance: 3.1×10^{12} ohms per ASTM D257 per ASTM D257.

C. Flame and Smoke Characteristics: low smoke V-0 per UL 94.

D. Track resistance: 1000 minutes per ASTM D2303 for 1/8 inch thick material.

2.23 INSULATED FLOOR TOPPING

A. Description: Insulated floor topping consisting of epoxy resin with filler. The floor topping will be placed under the rectifier and switchgear and extend to the walls up to five (5) feet around the equipment.

B. Epoxy Resistivity: Minimum 10^{12} ohm-cm.

C. Epoxy Manufacturer: Hallemite Grey Amazite, by Hallemite, 25 Holden Street, Providence, R.I. 02908; FX-70-6EE by Fox Industries, 3100 Falls Cliff Road, Baltimore, MD 21211, or approved equal.

D. Filler: Manufacturer's standard for this service.

2.24 FURNITURE

A. Work Bench: Heavy-duty, laminated maple top. Submit catalog for Engineer's approval.

B. Stool: Submit catalog for Engineer's approval.

C. Stepladder: Fiberglass, heavy-duty, eight (8) foot (ANSI A14.1, Type 1, Industrial). Submit catalog for Engineer's approval.

D. Drawing Hanger: For as-built drawings, submit catalog for Engineer's approval.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Exterior installation work shall be in accordance with applicable requirements of NFPA 70 (NEC). Interior work shall comply with the regulations of NEC and the UBC.

B. Materials and equipment shall be applied, installed, and connected as recommended by the manufacturer.

3.02 CONDUIT, FITTINGS AND ACCESSORIES

A. Install in accordance with Section 16111, "Conduit".

B. Exposed Conduits:
1. Exposed conduit shall be galvanized rigid steel.
2. Conduit runs shall be made with approved couplings and unions. Right angle bends, offsets, and change-in-direction bends shall be made with standard elbows, conduit fittings, pull boxes, or formed with a hickey or power bender. Conduit runs shall be straight and true; elbows, offsets, and bends shall be uniform and symmetrical. Bends shall be made without kinking or deforming the cross-sectional contour of the conduit.
3. Conduits entering outlet boxes, pull boxes, panelboard enclosures, terminal cabinets, and similar equipment enclosures shall be attached to the box or enclosure with a locknut outside and a locknut inside tightened against the box or enclosure. Conduit shall be provided with end bushings. Where required by NEC Code, conduit shall be provided with grounding bushings with copper jumper to the box or enclosure ground lug or bus. Conduits 1-1/4 inch trade size or larger shall be provided with insulating bushings.
4. To ensure ground continuity, unleaded, conductive anti-seize compound shall be applied to conduit threads, couplings, and hubs before assembly.
5. Trapeze hangers or wall mounted metal framing shall be used to support runs of conduit. Conduit clamps shall be used at the end of each run, at each elbow, and on each intermediate hanger to securely fasten each conduit in the group. The required strength of supports, and the size and type of anchors, shall be based on the combined weights of conduits, wires and supports, and stresses incurred during wire pulling.
6. Conduit runs shall be cleaned and swabbed to remove foreign matter prior to pulling in wire and cable.

3.03 CABLE TRAYS, METAL FRAMING AND WIREWAYS

A. Trays and wireways shall be supported by metal frame support or hangers of sufficient strength to carry combined weights of tray and cable and the dynamic loads imposed during cable pulling.

B. Electrical continuity shall be maintained between sections of steel tray by bolted copper braid and the steel tray connected to local grounding system.

C. Ac and dc cables shall be installed in separate raceways. All dc power cables shall be installed in non-metallic raceways.

3.04 OUTLET, JUNCTION AND PULL BOXES

A. Install junction and pull boxes so that covers are accessible after completion of the installation.

3.05 INSULATED WIRE, CABLE AND ACCESSORIES

A. General:
   1. Wire and cable shall be installed by means of equipment, devices, and methods recommended by the manufacturer. High-voltage cable terminations shall be performed by qualified personnel.
   2. Substation interior wiring and cabling shall be provided at the shop in accordance with approved Shop Drawings.
   3. Wiring and cabling shall be terminated and connected by means of connectors, lugs, and other methods specified.

B. Power Cabling:
   1. Ac and dc circuits consisting of multiple single conductors shall be grouped and pulled in separate designated raceway. Conductors shall be continuous from end to end without splices. Adequate slack shall be provided at terminations and in pull boxes.
   2. Traction power positive cables from the dc feeder breaker connections and negative cables from the bus connections shall be run in appropriate separate raceways, such as nonmetallic trays, or non-metallic conduit, or on racks if required to run within the substation. Raceways shall provide adequate cross-sectional area to permit a neat alignment of the cables and to avoid crossing or twisting.
   3. On racks, porcelain or fiberglass cable-support insulators designed for this purpose shall be used. Such supporting racks shall be spaced to avoid excessive weight or pressures on the cable insulation. The cables shall be arranged in not more than two layers. Positive and negative cables shall be run in separate raceways.

4. Bundle circuit conductors neatly and securely to cable trays with specified strap. Cables entering equipment panels and cubicles shall be spaced and tied to supports provided.
5. Cables shall be identified by individual tags at both ends of each circuit and at any intermediate pull box by specified markers.

C. Control Wiring:
1. Multi-conductor control wiring between equipment panels and cubicles shall be installed in designated conduits and raceways separate from those used for power cables. Multi-conductor cables installed in the same conduit shall be pulled together.
2. Control wiring shall be run from end to end without splices. Each multi-conductor cable shall be identified at each end, and at any intermediate pull box, by specified markers.
3. Control cable shall be neatly laid and grouped in cable tray and secured by specified strap. Cable entering equipment panels or cubicles shall be supported and secured to prevent tension on terminations. Adequate slack cable shall be provided and each wire terminated shall be double looped.
4. Interconnecting circuit between equipment panels and cubicles shall be terminated at terminal blocks. Substation interior wiring across shipping sections shall be neatly coiled and secured before shipment, and each wire shall be identified by specified marker.
5. Equipment panel and cubicle wiring shall be run in wireways and each conductor shall be continuous without splices or taps from terminal to terminal.
6. Wiring within dc switchgear and disconnecting switch compartments and cubicles shall be shielded from primary current conductors by flame-resistant insulating barriers.
7. Wiring within high-voltage ac equipment compartments shall be properly shielded.
8. Interior wiring within equipment panels and cubicles shall be identified at each termination with the equipment manufacturer's wire number by a marker with imprinted identification.

3.06 WIRING DEVICES

A. Device Mounting: Convenience power receptacles and lighting switches shall be rigidly attached to outlet boxes by two machine screws.

B. Wire Termination: Power wiring shall be terminated with approved connectors. Provide adequate slack wire, one loop minimum, to prevent strain on termination.

3.07 METERING CABINET

A. Duquesne Light Company furnished metering cabinet shall be installed outside the substation in accordance with Duquesne Light Company's instructions. A 2 inch diameter conduit shall be run from utility metering cabinet to each incoming line switchgear compartments. Wiring to the Metering cabinet will be provided by the Utility.

3.08 FIELD TOUCH-UP

A. Galvanized Metal Surfaces: Coat damaged surfaces, to the strength and finish of the original coating, with polystyrene organic rich compound containing not less than 91 percent by weight metallic zinc powder in dried film.

B. Painted Metal Surfaces: Clean, treat, and coat damaged surfaces with required rust inhibiting undercoating and finish coat paint system in accordance with manufacturer's instructions.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16220

TRACTION POWER SUBSTATION 27 KV AC SWITCHGEAR

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Traction Power Substation 27 kV AC Switchgear, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Furnish and install medium-voltage, metal-clad ac power switchgear assemblies for installation in new prefabricated-type traction power substation.
      a. The ac switchgear assemblies shall consist of indoor, single-height, self-supporting units rated for operation on a nominal 23 kV, three-phase, 60 Hz service provided by the Duquesne Light Company.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data."

B. Section 16200, "Traction Power Substation General Requirements."

C. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

D. Section 16270, "Traction Power Substation 125 VDC Battery System."

E. Section 16360, "Traction Power Substation Testing."

1.03 REFERENCE STANDARDS

A. ANSI:
   1. C29.1 – Test Methods for Electrical Insulators
   2. C29.9 – Wet-process Porcelain Insulators (Apparatus, Post-type)
   3. C29.10 – Wet-process Porcelain Insulators – Indoor Apparatus Type
   4. C37.06 – AC High-Voltage Circuit Breakers Rated on A Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities
   5. C12.1 – Code for Electricity Metering

B. ASTM

C. Duquesne Light Company (DLC) Specifications

D. ICEA

E. IEEE:
   1. C37.04 – Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
   2. C37.09 – IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
   3. C37.11 – IEEE Standard Requirements for Electrical Control for AC High-Voltage Circuit Breakers
   4. C37.20.2 – IEEE Standard for Metal-Clad Switchgear
   5. C37.21 – IEEE Standard for Control Switchboards
   6. C37.90.1 – Surge Withstand Capability for Relay Systems
   7. C57.13 – IEEE Standard Requirements for Instrument Transformers
   8. C62.11 – IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits
   9. C62.22 – IEEE Guide for the Application of Metal-Oxide Type Surge Arresters for Alternating Current Power Circuits
   10. 693 – Recommended Practice for Seismic Design of Substations

F. NEC

G. NEMA:
   1. EI-21.1 – Instrument Transformers for Revenue Metering
   2. SG 4 – AC High-Voltage Circuit Breakers
   3. SG 6 – Power Switching Equipment
   4. WC 57 – Standard for Control Cables

H. NFPA

I. UL

1.04 SUBMITTALS

A. The following information shall be submitted for approval:
   1. Manufacturer's descriptive literature, catalog data and other pertinent information sufficient to clearly demonstrate compliance with the Contract Documents.
   2. Detail Shop Drawings for each type of switchgear assembly. These drawings shall include dimensional outline drawings of all major equipment and devices indicating their location relative to other equipment. Dimensioned floor plans and front, rear, top, and section views shall be included.
   3. One line relay and metering diagrams, three line diagrams, and schematic wiring and internal connection diagrams showing all power and auxiliary circuits, protective devices, transducers, contact development, and current, potential and auxiliary transformers.
   4. Bills of Material and nameplate schedules keyed to the Shop Drawings.
   5. Tabulated equipment trip and lockout schedules.
   6. Complete descriptions of all protective devices, including coordination curves, setting procedures and instruction manuals.

7. After approval of schematic diagrams, submit interconnection and wiring diagrams for approval.
8. The manufacturer shall provide three (3) certified copies of factory test reports and test certificates.
9. Production test schedule, certified test reports, and test certificates.
10. Submit six (6) sets of the following to the Engineer for Duquesne Light Company approval:
    a. Shop Drawings showing utility supply cable termination details.
    b. 23 kV service Outdoor high voltage metering enclosures. The drawing shall include mounting details for metering current and potential transformers.
    c. Provide CT and PT catalog showing performance characteristics.
    d. Incoming line relay ranges and style numbers.
11. Submit short-circuit calculations and protective relay coordination study for system protection and selective overcurrent coordination to the Engineer for approval sixty (60) days after NTP, as follows:
    a. In accordance with ANSI/IEEE 141 and ANSI/IEEE 242 for fault calculations and coordinated system protection.
    b. Include high voltage source, relays on high voltage switchgear, transformer-rectifier units and dc switchgear, and capability curves of rectifiers and rectifier transformers.
    c. Available short-circuit currents, based on a power company contribution of 20 kA for 23 kV service.
    d. Recommended settings and adjustment of protective devices.
12. Provide proof that similar equipment, presently being used on extra heavy rail transit systems, have developed a satisfactory operating history for a minimum of five (5) years.
13. Provide proof that the proposed switchgear and circuit breaker shall have prior ANSI and NEMA certification.

1.05 QUALITY CONTROL

A. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

B. The short circuit and relay coordination study shall be performed by a Professional Engineer.

1.06 QUALIFICATIONS

A. The manufacturer must be regularly engaged in production of similar switchgear and has demonstrated a successful record of providing equipment of similar type and rating on extra heavy rail transit systems for at least five (5) similar projects.

B. The proposed switchgear and circuit breaker shall have prior ANSI and NEMA certification.

ARTICLE 2 PRODUCTS

2.01 27 KV SWITCHGEAR ASSEMBLIES

A. Switchgear assemblies shall consist of integrated lineups of metal-clad switchgear and associated control and metering equipment.

B. Arrange each assembly for supply from two (2) 23 kV, three (3) phase, 60 Hertz incoming feeders suitable for cable entrance and exit through the bottom. The service entrance units shall meet all Duquesne Light Company requirements prior to commencement of manufacturing.

C. The switchgear assemblies shall be rated as follows:
   1. Nominal voltage – 23 kV
   2. Maximum voltage – 27 kV
   3. Frequency – 60 Hz
   4. Insulation level, 60 Hz withstand – 60 kV
   5. Insulation level, impulse withstand – 125 kV
   6. Main bus continuous current – 1,200 A
   7. Nominal MVA class – 1,000 MVA
   8. Maximum symmetrical interrupting capability – 22 kA
   9. Closing and latching capability (Momentary) – 60 kA Crest
   10. Rated short-time withstand current – per IEEE C37.20.2
   11. Rated momentary withstand current – per IEEE C37.20.2

D. Construction:
   1. Stationary Structure:
      a. The switchgear assemblies shall consist of rigid, self-supporting and self-contained, electrically-welded steel structure units. Individual units shall be enclosed with not less than 11-gauge formed steel sheets. Each unit shall be bolted to each other to form a continuous, free standing switchgear assembly. The enclosures shall be sufficiently rigid to support equipment under normal loads and short-circuit conditions.
      b. Each compartment shall be provided with a separate hinged door or a removable panel for servicing without exposing circuits in adjacent compartments.
      c. Each metal-clad compartment shall be segregated by grounded metal barriers into separate compartments for draw-out circuit breakers, instrument transformers, main bus, instruments and relays, and outgoing bus.
   2. Doors and Panels:
      a. Each circuit breaker compartment shall be provided with a formed, hinged interior front door with handle and three-point lockable latching system. Doors shall be formed of minimum 11-gauge sheet steel and shall be properly reinforced against distortions by suitable flanges and stiffening members.
      b. Doors and panels shall be provided with automatic stop mechanisms to securely hold the doors in the fully-open position. A manual defeating feature

for the stop mechanism shall be provided for moving the door from one position to another.

c. Full height doors shall be securely fastened in the closed position with a minimum of three (3) latches easily opened without the use of tools. For doors less than the full height of the switchgear, a minimum of two (2) latches will be acceptable.

d. Circuit breaker compartment doors shall not hinder withdrawal of the removable element from the compartment when the door is open and door-stop set. Hinges shall be heavy duty and of a type approved by the Engineer.

e. Access to main bus, incoming line high-voltage power cables, current transformers, bushings, and other stationary devices shall be provided with hinged, bolted panels.

f. Relays, instruments, meters, and secondary control devices shall be mounted on formed front-hinged panels and provided with handle, lockable latch, and stop to hold panel in the open position. Equipment mounted on the panel shall be isolated by grounded metal barriers from all primary circuit elements.

g. Metering compartments shall be provided with formed, hinged exterior access doors with handle stops to hold doors in the open position. Padlocks shall be provided, and keys submitted to the Engineer.

3. Circuit Breaker Components:

a. Circuit breaker compartment shall be designed to house a draw-out circuit breaker. Welded guide rails for positioning the circuit breaker shall be provided as an integral part of the compartment. Front ends of guide rails shall be flared and the bottom plate of the enclosure within the guide rails beveled to facilitate the lining-up and insertion of the circuit breaker removable element.

b. Each circuit breaker compartment shall be provided with protective shutters, which automatically close and cover live high-voltage terminals as the breaker element is racked out of the cubicle.

c. A ground bus shall extend into the compartment to automatically ground the circuit breaker frame in the CONNECTED and TEST positions.

d. Means shall be provided for positively holding the circuit breaker in place when it is in either the CONNECTED or TEST positions within the compartment.

e. Mechanical interlocks shall be provided to prevent removal of a circuit breaker to or from CONNECTED or TEST position unless the breaker is open and in DISCONNECTED position. The mechanical interlock shall also be able to prevent closing of a circuit breaker unless it is in the CONNECTED or TEST positions.

4. Bus Potential Transformer Compartment:

a. Shall house a removable-type transformer assembly. Compartment door shall be furnished with interlock to prevent access to the transformer and primary fuses unless they are DISCONNECTED from the primary circuit. The CONNECTED/DISCONNECTED positions shall be clearly visible when the compartment front door is closed. Automatic shutters shall be provided to prevent accidental access to the stationary primary contacts when the transformer and fuses are not in the CONNECTED position. Provision shall be made for automatically disconnecting the potential transformer secondary circuits when the primary circuit contacts are disconnected.

5. Bus and Bus Connections:
   a. Main buses and bus taps shall be constructed out of high-conductivity beveled copper bars. Bus connections shall be brazed or bolted.
   b. Bus connections and joints shall have an ampacity equal to that of the bus ampacity, and be fabricated so that there will be no loss of conductivity during the life of the equipment.
   c. The entire contact area of all bolted current carrying connections in copper buses shall be factory silver plated. Silicon bronze bolts, nuts and lock washers, or approved equal, shall be used. Connections shall be made with a minimum of two (2) bolts at each end of a joint.
   d. All buses and bus connections shall be insulated with anti-hygroscopic, track resistant, non-flammable, molded insulation in accordance with IEEE C37.20.2.
   e. Bus Supports and Bushings: The buses shall be supported by porcelain or glastic or approved equal supports and bushings of sufficient strength to withstand, without damage or permanent distortion; all stresses produced by short-circuit currents equal to the momentary ratings of the main circuit breaker.
   f. The main bus and connections shall be braced to withstand the mechanical stresses associated with rated short-circuit momentary currents without deformation or damage to supports.
   g. Ground Bus: A continuous copper ground bus, minimum 2 x 1/4 inch, shall extend the full length of the switchgear assembly. A bolted-type terminal lug, with a NEMA two-bolt tongue shall be provided at each end of the ground bus for field connection to the station ground. Ground bus splices shall be made with a minimum of four (4) bolts, two (2) bolts on each side of the splice plate.
6. 125 Volt DC Control Power Bus:
   a. An ungrounded, two-conductor, 125 Vdc control bus, with 1,000 Volt insulation, shall be furnished for the full length of each switchgear assembly. The bus shall be terminated on a terminal block for connection to the power supply. The bus shall be tapped at each cubicle served and extended to each breaker control circuit.
   b. A double-pole pullout fuse block shall be provided at each circuit breaker. These fuses shall prevent the blowing of main control circuit fuses during closing circuit faults.
   c. A control power voltage-monitoring relay shall be furnished and connected to the incoming line terminals of the 125 Vdc control power bus. This relay should be set to drop out at 70 Vdc and shall initiate local and remote supervisory annunciation.

7. Space Heaters:
   a. Each section unit of switchgear shall be provided with 120 Volt, single-phase, 60 Hertz, 250 Watt heating elements to facilitate drying and prevent condensation. Two (2) strip heaters shall be installed in each unit. One (1) heater located in the front, the other heater located in the rear, both controlled by a thermostat, adjustable from 32° to 77° Fahrenheit.
   b. Heaters shall be enclosed in grille-guard, with no sharp edges, and located so that they are accessible for replacement without requiring de-energization of the switchgear bus. The thermostat shall be set in accordance with the manufacturer's recommendations.

2.02 OUTDOOR HIGH VOLTAGE METERING ENCLOSURES:

A. The enclosures shall comply with DLC construction guideline for 15001 to 27000 volt service.

B. The enclosures shall be NEMA 3R outdoor with ANSI 61 light gray finish equipped with space heaters to prevent moisture condensation.

C. The CT's and the PT's shall be rated at 150 kV BIL, ratio information shall be furnished by the utility company.The primary of the PT's shall be fused.

D. The no-load switch shall provide complete electrical isolation with visible break.

2.03 SERVICE ENTRY

A. Each switchgear assembly shall have provisions for service power and control cables entering from the bottom.

B. The switchgear incoming service feeder cabling compartments shall have adequate space to accommodate terminations for conductor sizes per phase, in accordance with contract documents. Provisions for supporting, connecting, and shield grounding the service feeder cables shall be included. Station class surge arresters shall be installed at this location.

2.04 MEDIUM-VOLTAGE AC CIRCUIT BREAKERS

A. Power circuit breakers shall be indoor, three-pole, draw-out type, with sealed vacuum interrupters and motor-operated, spring-charged mechanisms. Circuit breakers of the same type and rating shall be physically and electrically interchangeable.

B. Ratings:
   1. Circuit breakers shall be rated on a symmetrical current basis and have the following ratings in accordance with ANSI C37.06 as defined in IEEE C37.04.

All related required capabilities shall be in accordance with above referenced standards:

a. Nominal operating voltage – 23 kV
b. Rated maximum voltage – 27 kV
c. Rated voltage range factor, (K) – 1.0
d. Rated continuous current – 1,200 A
e. Rated frequency – 60 Hz
f. Rated withstand, low frequency rms – 60 kV
g. Rated impulse, crest – 125 kV
h. Rated short-circuit current at (max. voltage) – 22 kA
i. Nominal three phase MVA class – 1,000 MVA
j. Rated maximum interrupting time – 5 cycles
k. Rated permissible tripping delay – 2 seconds

C. Insulation - Materials used for circuit breaker insulation shall be of a type that will not support combustion or absorb moisture. The mechanical strength and physical characteristics of the insulation shall match the stresses imposed by the circuit breaker rated momentary current.

D. Circuit Breaker Removable Element:

1. Each circuit breaker shall be mounted on an integral mobile steel frame (removable element) equipped with main and secondary circuit disconnecting devices. The frame shall be permanently attached to the circuit breaker and shall be equipped with wheels for rolling the circuit breaker on the floor of the substation.
2. The removable element shall be equipped with pull-bar or handles suitable for manual removal and insertion out of and into the circuit breaker compartment without the need for lifts or ramps.
3. Each switchgear unit housing a circuit breaker shall be equipped with a threaded-shaft type cranking device for moving the removable breaker element to and from it operating position. The cranking device shall be permanently attached to either the stationary housing or to the removable element. Suitable guide rails which prevent misalignment shall be provided for centering the breaker in proper position when inserting or withdrawing the removable element. A positive stop shall be provided for the test position and fully disconnected position. Provisions shall be made for padlocking the removable element in the operating and fully disconnected positions. Provisions shall be made to the front of the cubicle's hinged door to provide a sliding shutter to cover the aperture utilized for the cranking device. The circuit breaker shall be able to be racked or cranked from the "test" position to the "operating" position with the breaker compartment door closed.
4. Mechanical interlocks shall be provided on each circuit breaker to prevent the withdrawal of the removable element when the breaker is in the closed position and to prevent the insertion of a closed breaker from the test to the operating position. The interlocks shall also discharge the spring of the stored energy

operating mechanism before the breaker removable element can be fully withdrawn from its housing.

5. The circuit breaker shall be provided with heavy-duty, self-aligning, spring-loaded, silver-plated, primary disconnecting contacts that engage with the line and load-side stationary disconnecting contacts.
6. In addition to auxiliary switches required for control, interlock, indication, and alarm circuits, provide each circuit breaker with a minimum of four (4) "a" and four (4) "b" spare auxiliary switch contacts wired to outgoing wiring terminal block for Authority's use. Auxiliary switches mounted on stationary structures are acceptable.
7. Auxiliary switches and breaker control circuit wiring connected through the secondary disconnecting devices shall be operable when breaker is racked to the test position so that the breaker can be closed and tripped, electrically or mechanically, with primary disconnecting devices open.
8. Normally closed auxiliary switches mounted on the removable element and used for interlocking shall be shunted with truck operated cell switches to permit operation of interlocked equipment when breaker is in the withdrawn position. A minimum of two (2) "a" and two (2) "b" spare cell switch contacts shall be provided, wired to outgoing wiring terminal block for Authority's use.
9. The circuit breaker vacuum interrupters shall be provided with means for determining contact wear.

E. Operating Mechanism:
   1. The circuit breaker operating mechanism shall be of the motor-charged, spring-operated type. The design of the mechanism shall prevent overcharging and ensure that the release of stored energy for closing the circuit breaker main contacts is prevented unless the mechanism has been fully charged. The mechanism shall be non-pumping, mechanically and electrically trip-free, and shall ensure positive opening of the breaker main contacts and circuit interruption when the tripping impulse is received. Energy storage shall be sufficient for an opening-closing-opening operation at rated short-circuit current.
   2. The spring-operated mechanism shall be automatically recharged after each circuit breaker closing operation, with provisions for manually charging the closing springs.
   3. The operating mechanism shall be provided with a mechanism charging motor cut-off switch mounted on the breaker removable element and an OPENED and CLOSED mechanical breaker contact position indicator visible from the front when the breaker is inserted in its housing.
   4. The stored-energy mechanism shall be provided with a mechanical indicator to show the CHARGED and DISCHARGED status of the closing springs. An interlock shall be provided to prevent the complete withdrawal of the circuit breaker element from the stationary compartment when the mechanism is in a fully charged state; or alternatively, automatically discharge the stored energy when the removable element is withdrawn from or inserted into the compartment.

5. A four-digit, non-resettable, register-type operations counter shall be provided on each circuit breaker to record tripping operations.
6. The mechanism shall be provided with OPEN and CLOSE mechanical control push buttons, mounted on the removable element escutcheon plate, for test purposes and for use in emergency.

F. Circuit Breaker Control:
1. The circuit breakers shall be designed for both local and remote supervisory electrical close/open operations at 125 Vdc nominal control power supply.
2. The closing mechanism shall be provided with a spring release coil, anti-pump relay, and spring charging motor suitable for operation over a voltage range of 100 to 140 Vdc. The tripping mechanism shall be provided with a shunt trip coil suitable for operation over a voltage range of 70 to 140 Vdc.
3. Each circuit breaker unit shall be provided with an oval handle LOCAL - REMOTE control selector switch, with a white indicating light showing switch position in the local mode. The switch shall be arranged for operation as follows:
   a. Local Position - Permits local open and close operation of the circuit breaker by its associated electrical control switch when the removable element is in the CONNECTED or TEST positions.
   b. Remote Position - Permits open and close operation of the circuit breaker from the remote supervisory control system when the removable element is in the CONNECTED position. Also permits local tripping of the breaker when the removable element is in the CONNECTED position.

2.05 SURGE ARRESTERS

A. The Contractor shall provide on the line side of the incoming supply feeder cubicle, rectifier transformer feeders, auxiliary feeders and passenger station feeders three (3) 24 kV, MCOV metal-oxide type station class surge arresters.

B. Arrangement:
1. Arrester pressure relief diaphragm shall be arranged in the enclosure so that the vent ports are directed away from all adjacent apparatus.
2. Arrester ground terminals shall be directly connected to the ac switchgear ground bus.

2.06 RELAYS, INSTRUMENTS AND METERS

A. The switchgear assemblies shall be furnished with protective relays as indicated on the Contract Drawings.

B. All protective relays shall comply with the requirements herein and shall be subject to the approval of Duquesne Light Company.

C. Protective relays shall be semi-flush mounted, solid state microprocessor-based adjustable drawout relays, overcurrent and under/over voltage type, each with test switches surface mounted on a fixed portion of the structure. Relays shall have self-checking functions. The relays shall hold all programmed target and alarm information in nonvolatile memory and provide that information locally through LED's, and remotely via communication ports.

D. The relays shall include three independent general-purpose communication ports including a front and rear RS-232 port and a rear RS-485 port. All communications port shall support Modbus or DNP3.0 options. The relays shall be capable of being set by Windows-based graphical user interface and ASCII terminal interfaces.

E. PC software compatible with Windows XP Professional shall be included at no charge. The software must include serial communications for settings upload and download and the ability to display event files.

F. The relay case shall be rectangular of rustproof metal finished in dull black:
   1. With targets, hand reset for targets and seal-in units.
   2. Designed, constructed and tested in accordance with applicable requirements of ANSI C37.90.

G. Overcurrent relay general requirements: Select overcurrent relay characteristics, ranges and settings to provide the protection and coordination specified.

H. Incoming Line Unit Overcurrent relays:
   1. The relays shall be single phase.
   2. Device 50/51 phase inverse time and instantaneous overcurrent relays, device 50N/51N residual ground inverse time and instantaneous overcurrent relay.
   3. Relays 50/51 and 50N/51N operate relay 86 to trip the incoming line breaker.
   4. Relays 50/51 and 50N/51N set as low as practicable to provide maximum fault protection and to coordinate with bus tie unit and other feeder overcurrent relays.
   5. Setting of overcurrent relays to be coordinated with and approved by Duquesne Light Company.
   6. Current test switch, 10-pole, ABB Style 129A517G01, provided between current transformer and relay.

I. Voltage relays:
   1. Relays 27/59 undervoltage/overvoltage single phase, time voltage relay. Adjustable range: 55 to 140 Volts or 30 to 120 Volts.
   2. Relay 27/59 trips incoming line breaker.
   3. Potential test switch, 4-pole, ABB Style No. 129A506G01, or approved equal, provided between potential transformer and relay.

J. Bus Tie Unit Overcurrent relays:
   1. Device 50/51 phase inverse time and instantaneous overcurrent relays, device 50N/51N residual ground inverse time and instantaneous overcurrent relay.
   2. Relays 50/51 and 50N/51N operate relay 86BT to trip the bus tie circuit breaker.

3. Relays 50/51 and 50N/51N set as low as practicable to provide maximum bus fault protection and to coordinate with transformer-rectifier unit overcurrent relays.

K. Transformer-Rectifier Feeder Unit Overcurrent relays:
   1. Device 50/51 phase inverse time and instantaneous overcurrent relays, one (1) 50N/51N residual ground inverse time and instantaneous overcurrent relay, three (3) 51-A phase inverse time overcurrent relay and three (3) relays 51B phase inverse time overcurrent relay.
   2. Relay 51A to protect against overloads beyond the 300 percent, one (1) minute capability of the units.
   3. Relay 51B to protect against overloads beyond the 450 percent, 15 second capability of the units and coordinated with relay 51A.
   4. Relays 50/51 and 50N/51N set as low as practicable to provide maximum fault protection and to coordinate with relays 51A and 51B.
   5. Relays 51A, 50/51 and 50N/51N operating associated lockout relay, to trip the transformer-rectifier feeder breaker.
   6. Relay 51B equipped with auxiliary relays 51BX to trip all dc track feeder breakers on the associated dc bus.

L. Passenger Station Feeder Unit Overcurrent relays:
   1. Device 50/51 phase inverse time and instantaneous overcurrent relays, device 50N/51N residual ground inverse time and instantaneous overcurrent relay.
   2. Relays 50/51 and 50N/51N operate relay 86 to trip the associated feeder breaker.
   3. Relays 50/51 and 50N/51N set as low as practicable to provide maximum fault protection.

M. Lockout relays: Rotary, hand-reset, 125 Volts, dc, lockout relay, equipped with green light for indicating reset position, General Electric Company, Type HEA, or approved equal.

N. Auxiliary relays: Provided where required, General Electric Company, Type HGA or HFA, or approved equal, mounted inside instrument compartment.

O. Relay test equipment: One test set for testing all relays furnished.

P. Switch and Indicating Lights:
   1. General: Rotary type, cam actuated switches with escutcheon and silver-to-silver contacts, rated at 20 amperes. Contacts enclosed in easily removable covers.
   2. Circuit Breaker Control Switch: Equipped with heavy duty pistol-grip handles and operation targets. Escutcheon engraved Trip-Close" with spring return to normal. Wired to operate the associated circuit breaker when the Local Remote selector switch is in the Local position, with indicating lights as follows:
      a. Red Light: Circuit Breaker closed, wired to supervise the trip coil.
      b. Green Light: Circuit Breaker is open.
      c. Amber Light: Circuit Breaker is automatically tripped.

3. Ammeters and voltmeters shall be switchboard type, with 270° scales. The cases shall be dustproof, with dull-black finish, and covered with a non-reflecting glass window.
4. Ammeter Selector Switch: Equipped with knurled handle. Escutcheon engraved "OFF-1-2-3".
5. The accuracy of all indicating instruments shall be within one percent of full-scale reading.
6. Voltmeters shall be suitably rated for use with the corresponding potential transformer as shown on the contract drawings. Ammeters shall be suitably rated for use with the corresponding current transformers.
7. Scales shall be of a suitable range, equal to the associated potential transformer and current transformer primary rating.

Q. Control Panel: For relays, meters and control equipment, hinged panel of formed steel, with rolled edges, door stop and conveniently located handle for opening.

R. Line Voltage Indicators: Neon glow-tube capacitance coupled high voltage indicators, Airco, Type RS, or approved equal. Glow tubes shall be installed on the rear door of incoming line breaker cubicles and shall be visible without opening the rear door.

S. Digital Power Meter:
1. Metering unit shall be provided at the substation in accordance with the design plans and the following requirements:
    a. Yokogawa Electrical Corporation, Model PR300 Power and Energy Meter, or approved equal.
    b. Universal, 3-phase, 3-wire system. Metering accuracy class.
    c. Panel mount, with simultaneous digital display of three-phase quantities.
    d. Rated Nominal Input – Voltage 120 Vac, 60 Hz.
    e. Rated Nominal Input – Current 5 Amps ac, 60 Hz.
2. As a minimum, the following shall be contained:
    a. Capable of display of Watts, Vars, Volts, and Amperes.
    b. Analog output, rated 4-20 mA, for Voltage, Watts, and Vars.
    c. Insulation withstand of 2,500 Volts, from terminal-to-terminal to ground.
    d. Ambient temperature of 32 to 122° Fahrenheit.
    e. Relative humidity of 20 to 90 percent, non-condensing.
    f. Display digits: minimum size of 10 millimeters.
    g. RS-485, or Ethernet capability.
    h. Power supply: 100-300 Vac and 130 Vdc.

2.07 INSTRUMENT TRANSFORMERS

A. Furnish instrument transformers in compliance with the Contract Drawings and IEEE Standards C37.20.2 and C57.13.

B. Current Transformers:

1. Secondary wiring shall be run to readily-identifiable terminal block points with suitable covers in the control compartment. Terminal block points shall have integral shorting bars for the current transformer leads.
2. Current transformers and secondary wiring shall be protected from induced voltages by metallic shielding.
3. Relaying accuracy C200 class, minimum, under the burdens imposed by the devices specified.
4. Instrument transformers shall be provided with 600 Volt insulation, minimum.

C. Voltage Transformers:
   1. Primary and secondary circuits of all potential transformers shall be fused by means of cartridge-type fuses. Secondary-circuit fuses shall be installed in the low-voltage circuits and shall be located to permit replacement when the switchgear is in operation.
   2. The primary fuses and potential transformers shall be mounted on a trunion-type arrangement. Upon opening the dead-front door, the primary fuses and potential transformers shall be automatically disconnected and shall be visibly grounded.
   3. Voltage transformer ratings shall be established by the Contractor to coordinate with the actual equipment procured.
   4. Voltage transformers shall have a minimum accuracy rating of 0.3 Class under the burden imposed by the devices specified.
   5. Voltage transformer voltage class shall be 25 kV, with corresponding impulse withstand of 125 kV BIL.

2.08 SUPERVISORY CONTROL REQUIREMENTS

A. Each switchgear assembly shall be provided with the following circuits to interface with the remote supervisory control system at the supervisory control interface terminal cabinet (IFTC):
   1. Control Circuits:
      a. Circuit Breaker – CLOSE
      b. Circuit Breaker – OPEN
   2. Status Indication Circuits:
      a. Circuit Breaker – CLOSE
      b. Circuit Breaker – OPEN
      c. (When the circuit breaker is in the test or disconnected position, a 'Circuit Breaker – OPEN' shall be reported.)
   3. Lock-out relay operation indication for each circuit.
   4. Analog Indication Circuits:
      a. AC Bus Voltage: 0 to 27 kV
      b. AC Load Current: 0 to 250 A
      c. DC Transducers: 0 to 50 mV

2.09 LOCAL ANNUNCIATOR PANEL CIRCUITS

A. Circuits shall be provided between the switchgear assembly and the local control/annunciator panel for the alarm points indicated on the Contract Drawings.

2.10 NAMEPLATES

A. Nameplates shall be three-ply, laminated, plastic plates, engraved through black-face to white-core, and attached by means of stainless steel rivets or screws. Vertical gothic lettering using a round or square cutter shall be provided. Using a V-shaped groove is prohibited.

B. Provide the switchgear assembly with a nameplate identifying the assembly, indicating the manufacturer's drawing number and the following ratings: voltage (kV nominal, maximum design, and BIL), short circuit rating – interrupting, momentary, and fault closing (MVA, three-phase symmetrical).

C. Provide additional functional nameplates for each component including relay, terminal block and other devices:

1. The switchgear compartment labeled, front and back, with nameplates 2-1/2 inches by 6-1/2 inches, inscribed in letters 1/2 inch high: INCOMING LINE PRIMARY BREAKER NO. 1, 2: RECTIFIER-TRANSFORMER FEEDER BREAKER NO. 1, 2; AUXILIARY COMPARTMENT NO. 1, 2 ETC.
2. In addition to other information normally displayed on equipment, provide nameplate one-inch by length as required, showing in letters ½ inch high switch positions, meaning of indicator lamp and other pertinent information.

2.11 SWITCHGEAR MAINTENANCE ACCESSORIES

A. There shall be a complete set of accessories for the substation.

B. One (1) circuit breaker test cabinet, wall-mounted, with provision for electrical operation of circuit breaker with control switch. Provide breaker secondary control disconnect coupler.

C. Crank for manually racking circuit breaker in switchgear cubicle.

D. One (1) circuit breaker maintenance lever with insulated handle.

E. Fifth wheel provided for moving the circuit breaker outside the cubicle.

F. One (1) spare set of each type of high-voltage fuse.

G. One (1) complete set of relay test plugs and relay test switch.

H. One (1) grounding device, complete in a dedicated auxiliary cubicle.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Install the specified ac switchgear equipment within the substation enclosure secure, plumb and level and in true alignment with related adjoining work.

B. Install supporting members, fastenings, framing hangers, bracing, brackets, straps, bolts, and angles, as required to set and rigidly connect the work.

C. Control erection tolerance requirements so as not to impair the strength, safety, serviceability, or appearance.

D. Exercise special care during installation to avoid rough handling of any part of the structure. Repair or replace any item damaged due to rough handling, at no additional cost to Authority.

E. Arrange with Duquesne Light Company for making connections with incoming lines; and for installation of CT, PT, PT fuses, and metering equipment.

3.02 FACTORY TESTING

A. The following standard factory tests shall be performed on the circuit breaker element provided under this Section. All tests shall be in accordance with the latest version of ANSI standards:
   1. Alignment test with master cell to verify all interfaces and interchangeability.
   2. Circuit breakers operated over the range of minimum to maximum control voltage.
   3. Factory setting of contact gap.
   4. One-minute dielectric test per ANSI standards.
   5. Final inspections and quality checks.

B. The following production test shall be performed on each breaker housing:
   1. Alignment test with master breaker to verify interfaces.
   2. One-minute dielectric test per ANSI standards on primary and secondary circuits.
   3. Operation of wiring, relays and other devices verified by an operational sequence test.
   4. Final inspection and quality check.

C. The manufacturer shall provide three (3) certified copies of factory test reports and test certificates.

D. Factory tests, as outlined in Article 3.02.B of this Section, shall be witnessed by the Engineer.
   1. The manufacturer shall notify the Engineer two (2) weeks prior to the date the tests are to be performed.

E. Perform all field tests in accordance with Section 16360, "Traction Power Substation Testing"; approved Test Plan, short-circuit and relay coordination study.

3.03 INSTALLATION SUPPORT AND TRAINING

A. Provide services of a factory qualified engineer to commission the equipment and supervise field tests.

B. Provide services of a qualified engineer to train Authority personnel in the operation and maintenance of the switchgear equipment. Training shall be in accordance with Section 01910, "Operations, Maintenance and Repair Data", and shall include protective relay calibration and setting procedure. Provide ten (10) copies of Authority approved Operation and Maintenance manuals as training text material. Classroom and hands-on training shall be conducted at Authority's facilities for four (4) consecutive days, from 7:00 a.m. to 5:00 p.m., no later than thirty (30) days before Final Acceptance of the installed and tested equipment. Coordinate training schedule with the Engineer.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16220.001 – Traction Power Substation 27 kV AC Switchgear shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16220.001 – Traction Power Substation 27 kV AC Switchgear will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16221

TRACTION POWER SUBSTATION
27 KV FUSIBLE LOAD INTERRUPTER SWITCHES

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes furnishing, installation, testing and commissioning of 27 kV load interrupter switchgear in a metal-enclosed assembly consisting of a switch, bus and fuses for the new prefabricated-type traction power substation.

B. The metal-enclosed switchgear assemblies shall consist of indoor, single-height, self-supporting units rated for operation on a nominal 23 kV, three-phase, 60 Hz service from Duquesne Light Company.

1.02 RELATED SECTIONS

A. Section 16200, "Traction Power Substation General Requirements."

B. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

C. Section 16220, "Traction Power Substation 27 kV AC Switchgear"

D. Section 16270, "Traction Power Substation 125 VDC Battery System."

E. Section 16360, "Traction Power Substation Testing."

1.03 REFERENCE STANDARDS

A. All equipment furnished under this Section shall be in accordance with the latest applicable standards of the IEEE, ANSI, NFPA, NEMA, ICEA, ASTM, UL, and National Electrical Code with regard to material, design, construction and testing. Contractor shall also comply with the applicable provisions of referenced Duquesne Light Company guide specifications; in case of a variance, the more stringent requirements shall apply. The standards applicable shall include, but not be limited to, the following:

1. American National Standards Institute (ANSI):
   a. C37.22
   b. C37.57
   c. C37.58
2. Institute of Electrical and Electronic Engineers (IEEE):
   a. C37.20.3 - IEEE Standard for Metal-Enclosed Interrupter Switchgear
   b. C37.20.4 – IEEE standard for Indoor AC switches (1kV – 38kV) for use in Metal-Enclosed Switchgear
   c. C37.30 – IEEE standard requirements for High Voltage Switches

d. C37.32 – High Voltage Air Switches, Bus supports and switch accessories – schedules of preffered ratings, manufacturing specifications and application guide
e. C37.34 – IEEE Standard Code for High-Voltage Air Switches
f. C37.41 – IEEE Standard Design Tests for High Voltage fuses, Enclosed Single Pole Air Switches, Fuse Disconnect Switches and accessories
g. C62.11 – IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits
h. C62.22 – IEEE Guide for the Application of Metal-Oxide Type Surge Arresters for Alternating Current Power Circuits
i. 693 – Recommended Practice for Seismic Design of Substations

3. National Electrical Manufacturers Association (NEMA):
   a. SG 5 – AC High-Voltage Switches
   b. SG 6 – Power Switching Equipment

1.04 SUBMITTALS

A. The following information shall be submitted for approval:
1. Manufacturer's descriptive literature, catalog data and other pertinent information sufficient to clearly demonstrate compliance with the Contract Documents.
2. Detail drawings for each fusible load interrupter switchgear assembly. These drawings shall include dimensional outline drawings of all major equipment and devices indicating their location relative to other equipment. Dimensioned floor plans and front, rear, top, and section views shall be included.
3. Bills of Material and nameplate schedules keyed to the submitted drawings.
4. Complete description of high voltage fuses, including coordination curves.
5. Conduit entry/exit locations
6. Assembly ratings including short circuit rating and Voltage.
7. Certified design test reports and test certificates.
8. Production test schedule, certified test reports, and test certificates.
9. Submit six (6) sets of the following to the Engineer:
   a. Drawings showing load side cable termination details
10. Submit short-circuit calculations and protective relay coordination study for system protection and selective over-current coordination to the Engineer for approval within sixty (60) days of NTP, as follows:
    a. In accordance with ANSI/IEEE 141 and ANSI/IEEE 242 for fault calculations and coordinated system protection.
    b. Include high voltage source, relays on high voltage switchgear, auxiliary transformer secondary switchgear.
    c. Available short-circuit currents, based on a power company contribution of 20 kA for 23 kV service.

1.05 QUALITY CONTROL

A. For Codes, Regulations, Reference Standards and specifications, refer to Article 1.03, above.

B. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

C. The short circuit and relay coordination study shall be performed by a licensed professional Engineer.

1.06 QUALIFICATIONS

A. The manufacturer must be regularly engaged in production of similar switchgear and has demonstrated a successful record of providing equipment of similar type and rating for extra heavy duty traction service for at least five (5) similar projects.

B. The proposed load interrupter switchgear shall have prior ANSI and NEMA certification.

ARTICLE 2 PRODUCTS

2.01 27 KV SWITCHGEAR ASSEMBLIES

A. Switchgear assemblies shall consist of integrated lineups of metal-enclosed switchgear

B. Arrange each assembly for supply to auxiliary transformer suitable for cable exit through the bottom.

C. The switchgear assemblies shall be rated as follows:
   1. Nominal voltage – 23 kV
   2. Maximum voltage – 27 kV
   3. Frequency – 60 Hz
   4. Insulation level, impulse withstand – 125 kV
   5. Rated continuous and load break current – 600 A
   6. Rated momentary withstand current – 40 kA
   7. Primary fuses shall be Cooper NX, or equal.
   8. Fuse continuous current shall be submitted for Engineer's approval.

D. Construction:
   1. The metal-enclosed load interrupter switchgear shall consist of dead front, completely metal-enclosed vertical sections containing load interrupter switches and fuses.
   2. The following features shall be supplied on every vertical section containing a three-pole, load interrupter switch:
      a. A large 8-inch x 16-inch high-impact viewing window that permits full view of the position of all three switch blades through the closed door. The window shall be suitably located to allow ease of inspection.
      b. Green OPEN, Red CLOSED switch position indicators.
   3. The switchgear assemblies shall consist of rigid, self-supporting and self-contained, electrically-welded steel structure units. Individual units shall be enclosed with not less than 11-gauge formed steel sheets. Each unit shall be bolted to each other to form a continuous, free standing switchgear assembly. The

enclosures shall be sufficiently rigid to support equipment under normal loads and short-circuit conditions.

4. Each compartment shall be provided with a separate hinged door for servicing without exposing circuits in adjacent compartments.
5. Insulation materials used for the disconnect switch shall be non-combustible, non-hygroscopic and tracking resistant. The mechanical strength of support insulators shall match the stresses imposed by the specified rated momentary current.
6. Disconnect Switch Compartment
   a. Disconnect switch compartment shall house a stationary type switch and main bus. Hinged and bolted grounded metal screens shall provide a secondary barrier against inadvertent access to components and primary connections, which may remain energized at high voltage when the switch is in the open position.
   b. Doors and panels shall be provided with automatic stop mechanisms to securely hold the doors in the fully-open position. A manual defeating feature for the stop mechanism shall be provided for moving the door from one position to another.
   c. Full height doors shall be securely fastened in the closed position with a minimum of two (2) latches easily opened without the use of tools.

E. High Voltage disconnect switches shall be manually operated load interrupter type, 3-pole, single throw, fused type. The three-pole switch will interrupt its rated load current with its quick-make, quick-break mechanism. Fuses shall provide short circuit protection at all times.

F. Each switch shall be provided with a grounded metal safety barrier to prevent inadvertent contact with any live part. Barriers shall be positioned to permit full view of the switch blade position.

G. The door shall be interlocked with the switch so that:
   1. The switch must be opened before the door can be opened.
   2. The door must be closed before the switch can be closed.

H. Each switch shall be furnished with two auxiliary switches. Each auxiliary switch shall have two normally open and two normally closed contacts. Control wiring shall be No. 14 AWG minimum provided between the auxiliary switch contacts and terminal blocks.

I. Operating Mechanism:
   1. The operating mechanism shall be of the stored energy quick-make, quick-break type, with opening and closing speed independent of the movement of the operating handle. The mechanism shall be Direct-drive. The operating handle for the load interrupter switch shall be mounted on the outside of the switch cubicle.
   2. An exclusively mechanical key interlocking system shall be provided with the following features:

a. To permit LOCKING of the disconnect switch, in either OPEN or CLOSED position, preventing its operation. LOCKING shall only be possible when the switch is completely and firmly OPEN or CLOSED.

J. Switch Contacts and Blades
   1. The blades shall be made from electrical grade copper with all contact points silver-plated. The contacts shall be high-pressure, self-cleaning and self-aligning type.

K. Space Heaters:
   1. Each section unit of switchgear shall be provided with 120 Volt, single-phase, 60 Hertz, 250 Watt heating elements to facilitate drying and prevent condensation. Two (2) strip heaters shall be installed in each unit. One (1) heater located in the front, the other heater located in the rear, both controlled by a thermostat, adjustable from 0° Celsius to 25° Celsius.
   2. Heaters shall be enclosed in grille-guard, with no sharp edges, and located so that they are accessible for replacement without requiring de-energization of the switchgear bus. The thermostat shall be set in accordance with the manufacturer's recommendations.

2.02 SERVICE FEEDERS

A. Each switchgear assembly shall have provisions for service power feeders and control cables entering from the bottom.

B. The switchgear outgoing service feeder cabling compartments shall have adequate space to accommodate terminations for conductor sizes per phase, in accordance with contract documents. Provisions for supporting, connecting, and shield grounding the service feeder cables shall be included.

2.03 SUPERVISORY CONTROL REQUIREMENTS

A. Each switchgear assembly shall be provided with the following circuits to interface with the remote supervisory control system at the supervisory control interface terminal cabinet (IFTC):
   1. Status Indication Circuits:
      a. Switch – CLOSE.
      b. Switch – OPEN

2.04 LOCAL ANNUNCIATOR PANEL CIRCUITS

A. Circuits shall be provided between the switchgear assembly and the local control/annunciator panel for the alarm points indicated on the contract drawings.

2.05 NAMEPLATES

A. Nameplates shall be three-ply, laminated, plastic plates, engraved through black-face to white-core, and attached by means of stainless steel rivets or screws. Vertical gothic lettering using a round or square cutter shall be provided. Using a V-shaped groove is prohibited.

B. Provide the switchgear assembly with a nameplate identifying the assembly, indicating the manufacturer's drawing number and the following ratings: voltage (kV nominal, maximum design, and BIL), short circuit and momentary rating.

C. Provide additional functional nameplates for each switchgear assembly:
   1. The switchgear compartment labeled, front and back, with nameplates 2-1/2 inches by 6-1/2 inches, inscribed in letters 1/2 inch high: AUXILIARY TRANSFORMER 1, 2.

2.06 SWITCHGEAR MAINTENANCE ACCESSORIES

A. One (1) spare set of high-voltage fuses.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Install the specified ac interrupter switchgear assembly within the substation enclosure secure, plumb and level and in true alignment with related adjoining work.

B. Install supporting members, fastenings, framing hangers, bracing, brackets, straps, bolts, and angles, as required to set and rigidly connect the work.

C. Control erection tolerance requirements so as not to impair the strength, safety, serviceability, or appearance.

D. Exercise special care during installation to avoid rough handling of any part of the structure. Repair or replace any item damaged due to rough handling, at no additional cost to the Authority.

3.02 FACTORY TESTING

A. All standard factory tests shall be performed on the switch assembly provided under this section. All tests shall be in accordance with the latest version of ANSI standards:

B. The manufacturer shall provide three (3) certified copies of factory test reports.

C. Factory tests as outlined above under 3.02.A shall be witnessed by the owner's representative.
   1. The manufacturer shall notify the owner two (2) weeks prior to the date the tests are to be performed.

D. Perform all field tests in accordance with Section 16360.

3.03 INSTALLATION SUPPORT AND TRAINING

A. Provide services of a factory qualified engineer to commission the equipment and supervise field tests.

B. Provide services of a qualified engineer to train Authority personnel in the operation and maintenance of the switchgear equipment. Training shall include operation and preventive maintenance procedure. Provide ten (10) copies of Authority approved Operation and Maintenance manuals as training text material. Classroom and hands-on training shall be conducted at the Authority's facilities for one (1) day, from 7:00 a.m. to 5:00 p.m., no later than thirty (30) days before final acceptance of the installed and tested equipment. Coordinate training schedule with the Engineer.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16221.001 – Traction Power Substation 27 kV Interruptor Switches shall be measured per each, complete in place.

4.02 PAYMENT

A. Item 16221.001 – Traction Power Substation 27 kV Interruptor Switches will be paid at the unit price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16230

TRACTION POWER SUBSTATION TRANSFORMER-RECTIFIER UNITS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for Traction Power Substation Transformer-Rectifier Units, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Furnishing and installing transformer-rectifier units and associated anode and cathode buses for extra-heavy traction service inside the new prefabricated-type traction power substation. The work includes the low-voltage ac busduct connecting the transformer secondary to the rectifier input.
   2. Transformer-rectifier units shall consist of separately-enclosed rectifier transformers and rectifiers, complete with auxiliaries, controls, raceways, interconnecting buses, and all necessary hardware, wiring and devices.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data."

B. Section 16200, "Traction Power Substation General Requirements."

C. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

D. Section 16240, "Traction Power Substation Metal-Enclosed DC Switchgear."

E. Section 16280, "Traction Power Substation Enclosure."

F. Section 16295, "Traction Power Substation Wire and Cable."

G. Section 16360, "Traction Power Substation Testing."

1.03 REFERENCE STANDARDS

A. ANSI:
   1. C34.2 – Semiconductor Power Rectifiers

B. ASTM:
   1. ASTM D3487, Insulating Oil PCB Free Compounds

C. EIA:
   1. EIA-282-A – Standard for Silicon Rectifier Diodes

D. ICEA

E. IEEE:
   1. C37.23 – IEEE Standard for Metal-Enclosed Bus
   2. C57.12.00 – General Requirements for Oil filled Power Transformers
   3. C57.12.90 – Test Code for Power Transformers
   4. C57.18.10 – IEEE Standard Practices and Requirements for Semiconductor Power Rectifier Transformers
   5. C62 – IEEE Surge Protection Standards Collection
   6. 519 – IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

F. NEMA

G. NFPA

H. UL

I. 1952 AIEE paper by Witzke, Kresser and Dillard, "Voltage Regulation of 12-Phase Rectifiers"

1.04 SUBMITTALS

A. The following information shall be submitted for approval:
   1. Manufacturer's product descriptions, catalog data and information.
   2. Transformer-rectifier unit design and performance calculations that provide the following information: (Voltage regulation calculations shall comply with the approach described in the 1952 AIEE paper by Witzke, Kresser and Dillard, "Voltage Regulation of 12-Phase Rectifiers". Impedances of busbars, bus ducts and interconnecting circuit elements shall be included in the calculations. If computer simulations are submitted in lieu of calculations, all program input data, technical assumptions, and results must be clearly documented to the Engineer's satisfaction.)
      a. No-load voltage output.
      b. Rectifier transformer nameplate kVA rating.
      c. Inherent % voltage regulation, light load to 100 percent rated load.
      d. Inherent voltage regulation curve, light load to 450 percent load.
      e. Displacement power factor vs. load curve, light load to 450 percent load.
      f. Efficiency vs. load curve and loss tabulations, light load to 450 percent load.
      g. Harmonic voltage amplitude vs. load curve for 11th, 13th, 23rd and 25th harmonics, light load to 450 percent load.
      h. Short circuit and commutating impedances.
      i. Momentary peak and symmetrical short circuit currents.
      j. Calculations to show compliance with this Section on number of parallel diodes furnished.
   3. Interphase transformer rating data, including percent unbalance limits.

4. Manufacturer's arrangement and detail Shop Drawings for each item of the transformer-rectifier unit.
5. Internal wiring and elementary diagrams.
6. Certified test reports of design tests performed on transformer, rectifier and Transformer-rectifier unit.
7. Certificates from manufacturers verifying that equipment conforms to specified requirements.
8. Six (6) copies of Operations and Maintenance Manual.
9. Spare parts lists.
10. Provide proof that similar units, presently being used on extra heavy rail transit systems, have developed a satisfactory operating history for a minimum of five (5) years.

1.05 QUALITY ASSURANCE

A. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

B. Factory Testing: All performance requirements and qualities of the transformer-rectifier units shall be proven by actual test on transformers, rectifiers and transformer-rectifier units to be provided. Tests shall be of three (3) types; (1) Design tests, made on a single transformer, rectifier of each type and rating to be provided under this Contract. (2) Routine tests, made on each transformer, rectifier and diode to be provided under this Contract. (3) Transformer-Rectifier Unit Tests, made on a transformer-rectifier unit of each type and rating. Tests shall be conducted according to guidelines given by applicable ANSI standards.
   1. Test plans and procedures shall be submitted for approval at least twenty (20) working days in advance of scheduled test dates. No test results will be accepted prior to receipt and approval of test plans test plans and procedures.

C. Transformer-Rectifier Design Tests, including temperature and two (2) hour loading cycle test, specified in Figure 16230-1, at the end of this Section, to verify the temperature limits specified.

1.06 QUALIFICATIONS

A. Design shall be that of a field proven product. No prototypes will be considered. A proven product is considered to be similar units presently being used on extra heavy rail transit systems and having developed a satisfactory operating history for a minimum of five (5) years.

ARTICLE 2 PRODUCTS

2.01 TRANSFORMER-RECTIFIER UNIT PERFORMANCE REQUIREMENTS

A. Circuit configuration: 12-pulse, double-way ANSI circuit 31 with interphase transformer.

B. Full (100%) load rating: 3,000 kW, at 650 Vdc.

C. Service Rating Class: Extra-Heavy Traction. Transformer-rectifier units shall be capable of carrying two peak period loading cycles per day within a six (6) hour interval of each other, as shown in Figure 1.

D. Overall efficiency: Greater than 97 percent, at 100 percent load rating.

E. Displacement power factor: Greater than 0.96 lagging, from 25 percent to 100 percent load rating, at rated ac primary voltage.

F. Transformer-rectifier units shall be capable of operating in parallel with one additional unit, without exceeding 10 percent maximum deviation from the proportionate share of its load, when carrying any load between 50 percent and 150 percent of rated load.

G. Transformer-rectifier units shall be capable of withstanding 100 percent of the theoretical short circuit current, with the short circuit applied at the load terminals of the dc cathode breaker, without damage to any component, including diodes and diodes fuses, until cleared by the cathode circuit breaker.

H. Inherent Voltage Regulation: In accordance with the following upper and lower limits, with rated voltage applied to the rectifier transformer primary terminals and the transformer at nominal tap position.

TABLE 16230-1 "Inherent Voltage Regulation"

% of Rated Load Current	**Lower Limit (Volts)**	**Upper Limit (Volts)**
1%	700	730
100%	650	690
150%	623	642
300%	545	560
450%	475	490

I. Maximum no load (0%) voltage: 740 Vdc.

J. Maximum harmonic distortion: In accordance with IEEE Standard 519.

K. Maximum permissible rectifier unit bridge, phase leg and diode group unbalance at 150 percent of rectifier rated load: ±10 percent.

2.02 MANUFACTURERS

A. Manufacturers Qualifications: Select manufacturers/installation contractors who are regularly engaged in production of similar transformers or rectifiers and have demonstrated successful record of providing equipment and installation of similar type and rating for extra heavy duty traction service, for at least five (5) similar projects.

2.03 EQUIPMENT NAMEPLATES

A. Nameplates shall be three-ply, laminated, plastic plates, engraved through black-face to white-core, and attached by means of stainless steel rivets or screws. Vertical gothic lettering using a round or square cutter shall be provided. Using a V-shaped groove is prohibited.

B. Provide a nameplate on each transformer and rectifier showing manufacturer's name and brand designation, the referenced standard, type, class and rating, as applicable.

C. Provide additional functional nameplates for each component.
   1. Each transformer and rectifier labeled, front and back, with nameplate 2-1/2 inches by 6-1/2 inches, inscribed in letters ½ inch high: RECTIFIER-TRANSFORMER NO. 1, 2, or RECTIFIER NO. 1, 2, as appropriate.
   2. In addition to other information normally displayed on equipment, provide one-inch nameplate showing in letters ½ inch high switch positions, meaning of indicator lamp and other pertinent information.

2.04 RECTIFIER TRANSFORMERS

A. Rectifier-transformers shall be three-phase, 60 Hz, oil filled-type, cooling class OA, for outdoor service in proximity to a prefabricated substation enclosure.

B. Provide electrostatic shield between primary and secondary windings to suppress electrical noise.

C. Primary and secondary winding conductors will be made of copper.

D. Primary and secondary kVA ratings: In accordance with IEEE C57.18.10 and suitable for the specified rectifier.

E. Dielectric ratings:
   1. Nominal primary voltage: 23,000 Volts
   2. Primary winding insulation class: 27,000 Volts
   3. Primary winding BIL: 200,000 Volts
   4. Secondary voltage for supplying rectifier to produce 650 Vdc, at rated output
   5. Secondary winding BIL: 30,000 Volts

F. Insulation System class: 248° F thermally upgraded, UL Listed.

G. The average winding temperature rise of 149° F at the end of a two (2) hour overload cycle (See Figure 16230-1). Average winding temperature rise by resistance is not to exceed 131° F after stabilized, continuous operation at 100 percent rated ac voltage and dc load.

H. Impedance: Selected to comply with specified voltage regulation requirements.

I. Maximum audible sound level: 62 decibels (A) at rated voltage and frequency at no load when measured in accordance with ANSI C57.12.91.

J. Design and Construction of Oil filled transformer:
   1. Transformer shall be designed that parts are easily accessible for maintenance.
   2. Transformer tank shall be sealed, welded cover type, liquid tight with all fittings in place. Tank shall be designed to withstand internal pressure under normal and fault conditions without leaks and suitable for full vacuum filling and drying in the field.
      a. Tanking guides shall be provided to center core and coil assembly.
      b. Handholes shall be sized for convenient access to required devices or connections with covers sealed by corrosion resistant gaskets; with lifting eyes on tank and tank cover.
      c. Tank base constructed of I-beams or formed channel, suitable for skidding in any direction on rails or rollers and with jacking facilities at each corner.
   3. Core and Coil Assembly: Core construction shall be step-lap type to maximize efficiency, and noise reduction laminations shall be non-aging alloy, grain oriented, cold-rolled, high-permeability silicon steel, per ASTM specifications.
      a. Joints in winding or at terminals to be either brazed or multi-indent clamped.
      b. Insulation material, varnish and compounds in contact with liquid shall neither affect nor be affected by it.
      c. Core bolt insulation shall be high temperature resistant.
      d. The entire assembly shall be braced or bolted adequately to prevent displacement and distortion under all normal conditions of handling and operation under short-circuit conditions.
      e. Locking provisions shall be made for all inside bolted members or connections.
      f. Serial number shall be stamped on the core in a conspicuous place.
      g. Provide ground core clamps with bolted copper strap near handhole.
   4. The insulating oil for cooling shall be of high flash-point type, free of PCB and PCB compounds conforming to ASTM D3487.

K. Joints and Gaskets: All gasketed joints shall have machined surfaces on both sides, and be provided with gasket retainers and metal-to-metal stops so as to assure even and effective pressure to avoid overstressing gasket. Gaskets shall maintain liquid and gas tightness of joints under all service and fault conditions.

L. Buses: Electrical grade copper braced to withstand maximum available short circuit forces.

M. Bus Connections:
   1. The entire contact area of all bolted current carrying connections in copper buses shall be factory silver-plated. Ring-plated method of silver-plate and tin-plated contact surfaces will not be accepted.
   2. Bolted connections shall use silicon bronze bolts and washers. Connections shall be made with a minimum of two (2) ½ inch bolts. Bolt holes must be positioned such that the entire surface area of all washers is in direct contact with the bus bars being fastened.

N. Primary Taps:
   1. The primary taps shall be manually operated, no-load full capacity, on the high voltage winding. Provide six (6) 2.5 percent, full-kVA no-load taps, three (3) above nominal and three (3) below nominal.
   2. The operating handle shall be conveniently located on the exterior of the tank, arranged for operation at no-load only through key interlocking, with the transformer feeder breaker. The operating handle shall be lockable in any position with the position indicator clearly visible from the ground.

O. Bushings: In accordance with ANSI and NEMA standards for outdoor interchangeable bushings with silver-plated terminal pads.
   1. High Voltage: Glazed porcelain jacket, mounted in a suitable air-filled junction box on a transformer sidewall, rated 23 kV, 200 kV BIL.
      a. High-voltage bushings shall be connected to terminators with stress cones for single conductor shielded cables.
      b. The junction box shall have a removable cover and be designed for termination of one (1) conduit with three (3) single-conductor and one (1) single conductor shielded cable from above, as shown on the contract drawings.
   2. Low Voltage: Rated 1.2 kV, 30 kV BIL.
      a. Terminate transformer output windings on low voltage bushings with provision for mounting bus duct as required for flush-type connection to the rectifier.
      b. The low-voltage connection shall be compatible with the flange and busbar connections.
      c. Provide a bonding strap for bonding bus enclosure to transformer case.
   3. Input and output terminal phases shall be clearly and permanently marked.

P. Ground Pads:
   1. Provide copper-faced, steel ground pads two-hole with NEMA standard CC1 Mounting holes for connection of 4/0 AWG copper ground cables.
   2. The ground pads shall be diagonally-opposite corners of each transformer, near the bottom.

Q. Monitoring and Protective Devices:

1. Winding Temperature Indicator (Device 49T1 & 49T2): The indicator shall have a maximum reading pointer to detect transformer winding over-temperature, and configured with a factory-set, two-stage contact device.
    a. The first stage provided with a contact which opens on temperature increase to initiate annunciation.
    b. The second higher temperature stage shall be provided with two contacts; one opening on temperature increase to initiate annunciation and one closing on temperature increase to actuate the rectifier-transformer ac feeder breaker lock-out relay.
2. Low Oil Level Indicator (63QL): Contact opens on decrease of oil level to initiate annunciation.
3. Dial-Type Top Oil Thermometer (Device 26T1 & 26T2): To detect transformer oil over-temperature, and configured with a factory-set, two-stage contact device.
    a. The first stage provided with a contact which opens on temperature increase to initiate annunciation.
    b. The second higher temperature stage shall be provided with two contacts; one opening on temperature increase to initiate annunciation and one closing on temperature increase to actuate the rectifier-transformer ac feeder breaker lock-out relay.
4. Mechanical Pressure Relief (Device 63MR): Self-resetting type, factory-set contact device and hand reset contact. The pressure relief device shall be provided with three (3) contacts, one (1) opening on gas pressure increase in the transformer to initiate an alarm and two (2) closing on the gas pressure increase to initiate the tripping of ac rectifier transformer feeder breaker and actuate its associated lock-out relay (Device No. 86).
5. Sudden Pressure Relay (63 SP): Designed for alarm and tripping on occurrence of a fault in the transformer, causing an abnormal rise of pressure. The relay shall have a pressure-sensative device which could detect a pressure differential and through an occurrence would energize the relay. The relay shall have three (3) contacts. On energization of relay, one (1) opened contact shall initiate the alarm and two (2) closed contacts shall initiate the tripping of the rectifier transformer ac feeder breaker and actuate the rectifier transformer ac feeder breaker lock-out relay.
6. Valves: Combination lower drain, filter and sampling valve, upper filter valve.
7. Pressure: Gauge.
8. Components, limit switches, relays, assemblies and subassemblies: All shall be UL listed or labeled and be rated utility or heavy duty industrial use. All components that are not listed shall be identified as NOT LISTED in the parts list, submitted for approval, prior to manufacture.
9. Wiring: All control, auxiliary power and alarm circuits shall be completely wired in the factory. All wiring shall be run in rigid metallic raceway, with the exception that watertight fittings may be used on runs of two (2) feet or less. Connections to external circuits must be brought to a junction box equipped with a bolted gasket cover and terminated on terminal blocks.

10. Finish: Metallic surfaces degreased, primed and finished with light gray enamel, Color No. 61, ANSI Z55.1.

2.05 SEMICONDUCTOR POWER RECTIFIERS

A. Natural convection cooled, metal-enclosed for indoor service in a prefabricated substation enclosure. The rectifiers shall be rated 3,000 kW continuous, dc output voltage shall be 650 Vdc, at 100 percent load, and 4,615 A.

B. Rectifier shall use building air for cooling under ambient conditions specified in Section 16280, "Traction Power Substation Enclosure."

C. Maximum audible sound level: 60 decibels, at rated voltage and frequency, at no load.

D. Rectifier Performance Requirements:
   1. Provide a sufficient quantity of parallel diodes to fulfill all the performance requirements of this Section with one (1) diode per diode group removed ("N + 1" design). There are twelve (12) diode groups in a Circuit 31 type rectifier.
   2. The rectifier shall be capable of withstanding a bolted short circuit on the rectifier output terminals following the two (2) hour overload period until the fault is cleared by the rectifier ac circuit breaker, without damage to any component, including protective fuses and rectifier elements.
   3. Loss of one (1) diode in each phase leg shall not adversely affect the ability of the rectifier to withstand a short circuit.
   4. The rectifier shall be capable of carrying the specified overload with one (1) diode removed from service, in each rectifier diode group, without exceeding the safe junction temperature of the remaining diodes.
   5. Rectifiers shall be designed so that the diodes and other rectifier elements are protected against overcurrents and overloads by the upstream 23 kV protective relays. The upstream protective relays shall be selective with the individual diode fuses so that the diode fuses will not blow on a through fault. Diode fuses shall blow on a diode shorting failure only.
   6. Each diode shall be individually protected with a current-limiting fuse. The fuses shall be designed to disconnect the diode in case of failure and protect the other components of the rectifier. Fuses shall be so sized that they will not blow on any external dc fault or loading condition but will blow to clear any fault permitting reverse conduction.
   7. Rectifier shall be adequately protected against transient surge voltages caused by lightning, faults or switching operations and the operation of rolling stock.
   8. The rectifier shall be designed to maintain current balance between parallel-connected bridges, phases, and diodes in each phase. This current balancing scheme shall maintain individual diode currents within their capabilities under the specified load conditions with one (1) fuse open per circuit element. Current balancing shall not be achieved by use of selectively matched diodes or by balancing reactors.

9. Interphase transformers shall be designed for maximum noise suppression, and shall be mounted on tuned vibration dampers to mitigate the transfer of noise and vibration to the rectifier and substation enclosures.

E. Enclosure
   1. Rectifier enclosure shall be a rigid, self-supporting NEMA 1 steel structure, not less than 12-gauge formed steel sheets. The enclosure shall be constructed of structural members of sufficient strength to provide trouble-free operation of access panels and doors, and to prevent damage and distortion during shipping, handling and installation.
   2. Provide hinged doors for front access and bolted panels for rear access to the rectifier. Doors shall be provided with safety glass windows, arranged to permit inspection of all indicating fuses and surge protection fuse failure indicating lights. The doors shall be formed of minimum 14-gauge sheet steel and shall be properly reinforced against distortions by suitable flanges and stiffening members. Doors and panels shall be provided with protected openings sized to provide adequate natural convection ventilation for the rectifier. Convenient access shall be provided for normal maintenance and inspection.
   3. Enclosure sections shall be electrically bonded together such that the entire enclosure is an equi-potential surface. Welding, bolting of bare metal-to-metal surfaces, or electrical bonding jumpers are all acceptable bonding methods.
   4. Rectifier enclosure shall be electrically isolated from all other substation structures, enclosures and devices in accordance with a high-resistance enclosure grounding scheme.
   5. Each door shall be equipped with at least two (2) vibration-resistant mechanical latches to hold the door securely closed without the use of tools. Provide stops to hold each door securely open at 90 degrees.
   6. The control/auxiliary section shall be completely isolated from the rectifier section by suitable sheet steel barriers. It shall contain the instruments and devices required for control and monitoring of the rectifier transformer, rectifier and the rectifier dc main breaker. The control/auxiliary section shall be provided with hinged front for access to devices and terminal blocks and for mounting of relays, instruments and control devices. The doors shall be formed of sheet steel of minimum 14-gauge and shall be properly reinforced against distortions by suitable flanges or stiffening members. The door shall be securely fastened in the closed position and easily opened without the use of tools.

F. Buses: Electrical grade copper braced to withstand maximum available short circuit forces.

G. Bus Connections:
   1. The entire contact area of all bolted current-carrying connections in copper buses shall be factory silver-plated. Ring-plated method of silver-plate and tin-plated contact surfaces will not be accepted.

2. Bolted connections shall use silicon-bronze bolts and washers. Connections shall be made with a minimum of two (2) ½ inch - 13 bolts.
3. Bolt holes shall be positioned such that the entire surface area of all washers is in direct contact with the bus bars being fastened.

H. Negative Bus Compartment: Provide separate metal-enclosed compartment in each rectifier containing the equipment described below:
   1. Negative Disconnect Switch Device 89N:
      a. Provide a no-load disconnect switch with an insulated operating handle, key-interlocked with the rectifier main dc (cathode) circuit breaker. Interlocking shall prevent opening of the 89N switch unless the cathode circuit breaker is open, and similarly, prevent the cathode breaker from closing unless the disconnect switch is closed.
      b. Switch type and ratings: Single-pole, single-throw, bolted contact, stationary type, 1,000 Vdc, 5,000 A continuous with momentary current rating to match the rectifier main dc circuit breaker ratings.
   2. Negative Bus Current Measuring Equipment:
      a. Dc shunt: 5,000 A, 50 mV
      b. Dc ammeter: 0-6,000 A, analog type
      c. Dc current transducer: 0-1 mA output
   3. Terminations for Negative Return Cables:
      a. Provide adequate space for the quantities and sizes of cables indicated on the Contract Drawings.
      b. See Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

I. Rectifier Relay, Control and Indication Devices:
   1. Two-stage rectifier surge protection failure (Device No. 99):
      a. Annunciates the failure of rectifier surge protection equipment using a combination of micro-switches and indicating fuses.
      b. Device 99A: Annunciates on loss of first device.
      c. Device 99T: Trips 86-1 lockout on loss of second device.
   2. Two-stage factory-set rectifier over-temperature detector (Device No. 26R):
      a. First stage 26R1 shall annunciate a sustainable operating over-temperature condition.
      b. Second stage 26R2 shall annunciate and operate the rectifier unit lockout relay device No. 86-1 upon detection of an unacceptable operating over-temperature condition.
   3. Two-stage diode failure (Device No. 98):
      a. First stage 98A shall annunciate the failure of any single diode.
      b. Second stage 98T shall annunciate and trip the rectifier unit lockout relay device No. 86-1 upon failure of a second diode.
      c. Diode failure indication shall be provided by micro-switches and indicting fuses located at each diode.
      d. Solid-state device with self-monitoring and blown fuse location features.

4. Dual-function high resistance ground structure relay (Device No. 64):
   a. Device No. 64G shall annunciate a dc switchgear or rectifier structure ground.
   b. Device No. 64 shall annunciate and trip lockout relay device Nos. 86-1 and 86-2 upon detection of an energized dc switchgear or rectifier structure ("hot structure").
   c. Provide self-monitoring feature and 125 Vdc control power.
   d. Provide a 3.5 to 18 Vdc device, No. 64G setting range, and a 50 to 80 Vdc device, No. 64 setting range.
   e. Relay ground shall be connected to the enclosure ground bus (not directly to the ground grid).
5. Rectifier door interlock contacts (Device No. 33R):
   a. Operates rectifier unit lockout relay (Device No. 86-1), on opening of a rectifier compartment door.
   b. Prevents closing of the rectifier unit ac circuit breaker and the rectifier main dc circuit breaker when any of the rectifier compartment doors are open.

J. Control Power Requirements:
   1. Provide 125 Vdc power for all rectifier controls from the station battery system.
   2. Rectifier control power voltage-monitoring relay, device No. 27DC-R, shall be furnished and connected to the incoming line terminals of the rectifier 125 Vdc control power bus. Relay shall be set to drop out at 70 V and shall annunciate.

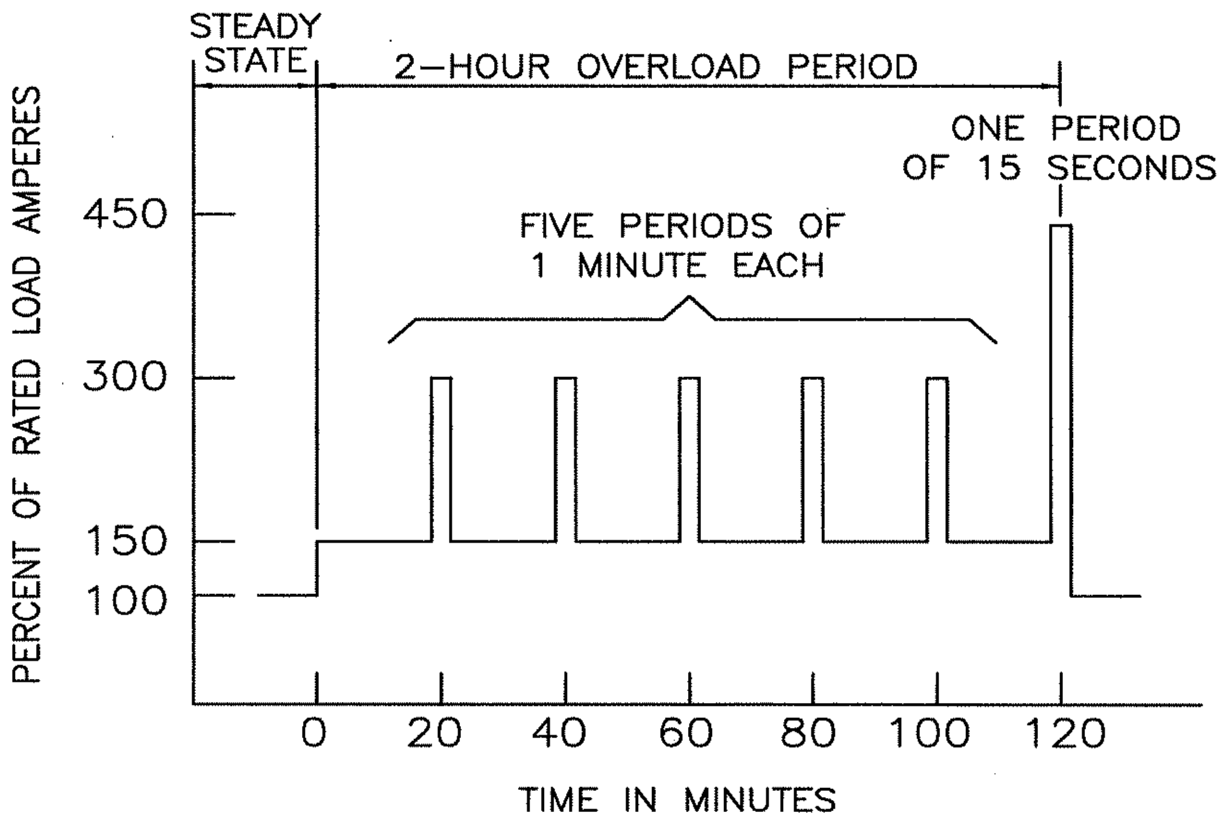
K. Surge Protection Requirements:
   1. Provide approved surge protection circuit between rectifier positive and negative terminals.
   2. Provide approved, fused snubber-type diode surge protection equipment between rectifier phase legs R1-R3-R5, and between phase legs R2-R4-R6.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Install the outdoor transformer and rectifier unit and bus assemblies for the substation as shown on the Contract Drawings and in accordance with approved Shop Drawings.

FIGURE 16230-1 "Transformer-Rectifier Peak Period Loading Cycle"



ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16230.001 – Traction Power Substation Transformer-Rectifier Units shall be measured per each, complete in place.

4.02 PAYMENT

A. Item 16230.001 – Traction Power Substation Transformer-Rectifier Units will be paid at the unit price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16235

TRACTION POWER SUBSTATION AUXILIARY POWER SYSTEM

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Traction Power Substation Auxiliary Power System, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Two pad-mounted outdoor three-phase auxiliary transformers dead-front construction including 480 Volt panels, 208/120 V distribution panels, UPS and automatic transfer switches as indicated schematically on the Contact Drawings.
   2. The Contractor shall be responsible for the final sizing, detailed design, integration and coordination of the auxiliary power system to satisfactorily operate the substation equipment installed under this Contract.

C. The Contract Documents provide the performance parameters and design criteria to complete the Traction Power Substation Basic Electrical Materials and Methods portion of the Work. The Contractor shall be responsible to provide a complete design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16200, "Traction Power Substation General Requirements."

B. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

C. Section 16220, "Traction Power Substation 27 kV AC Switchgear."

D. Section 16360, "Traction Power Substation Testing."

1.03 REFERENCE STANDARDS

A. ANSI:
   1. C57.12.90 – Requirements for Oil-filled Transformers
   2. C57.12.70 – Terminal Markings and Connections for Distribution and Power Transformers

B. ASTM

C. ICEA

D. IEEE:

1. C37.21 – IEEE Standard for Control Switchboards
2. C37.90 – Relays and Relay Systems Associated with Electric Power Apparatus
3. C62 – IEEE Surge Protection Standards Collection

E. NEC

F. NEMA:
1. AB-1 – Molded-Case Circuit Breakers, Molded-case Switches, and Circuit Breaker Enclosures
2. AB-3 – Molded Case Circuit Breakers and Their Application
3. ICS-6 – Industrial Control and Systems: Enclosures
4. LS-1 – Low Voltage Surge Protection Devices
5. PB-1 – Panelboards
6. ST-20 – Dry-Type Transformers for General Applications

G. NFPA

H. UL

1.04 SUBMITTALS

A. The following information shall be submitted for approval:
1. Manufacturer's descriptive literature, catalog data and other pertinent information sufficient to clearly demonstrate compliance with the Contract Documents.
2. Auxiliary power transformer load calculations:
   a. In units of kVA with load power factors indicated.
   b. For both Winter and Summer operation.
3. Detail Shop Drawings for the auxiliary power control cabinet. Shop Drawings shall include dimensioned outline drawings of all major equipment and devices indicating their location relative to other equipment. Include dimensioned floor plans and front, top, and section views.
4. Ac panelboard schedule.
5. Bills of Material and nameplate schedules keyed to the submitted Shop Drawings.
6. Complete descriptions of all protective devices including device coordination (TCC) curves, setting procedures and instruction manuals.
7. Protective device time-current coordination (TCC) curves illustrating satisfactory coordination among protective devices. TCC curves shall include device names, transformer and HVAC inrush currents, maximum available fault currents, auxiliary power transformer damage curve, and any multipliers used to change indicated Ampere values.
8. Automatic transfer switch.
9. After approval of schematic diagrams, submit interconnection and wiring diagrams.
10. Certified design test reports and test certificates.
11. Production test schedule, certified test reports, and test certificates.

12. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

1.05 QUALITY ASSURANCE

A. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

ARTICLE 2 PRODUCTS

2.01 AUXILIARY POWER TRANSFORMER

A. Three-phase, liquid-filled outdoor pad-mounted dead-front construction, 60 Hz, self-cooled class OA. Contractor to submit calculations with recommended kVA rating.

B. Construction: The transformers shall be high fire point liquid-filled and shall be in accordance with the latest edition of the NEC. Primary and secondary winding conductors shall be Copper. Primary windings shall be delta-connected. Secondary windings shall be wye-connected.

1. Transformers shall be supplied with a welded main tank cover and be of a sealed tank construction designed to withstand pressures 25 percent greater the required operating design value without permanent deformation.
2. The transformers shall be compartmental type, self-cooled and tamper-resistant for mounting on a pad. The units shall restrict the entry of water into the compartments so as not to impair its operation.
3. Finish: Transformer units shall include suitable outdoor paint finish. Each transformer shall be painted utilizing an initial phosphatizing cleaning treatment, followed by manufacturer's standard paint process baked on a total of three to five mils average thickness. Units shall be painted pad mount green, Mumnsell No. 7GY3.29/1.5.

C. The transformers shall receive power supply at 23 kV and supply power to the associated low-voltage ac power distribution system.

D. Dielectric ratings:

1. Normal primary voltage: 23,000 Volts
2. Primary winding insulation class: 25,000 Volts
3. Primary winding BIL: 125,000 Volts
4. Normal Secondary voltage: 480/277 Volts
5. Secondary winding BIL: 10,000 Volts

E. Impedance: Standard.

F. Polarity: Standard.

G. Maximum temperature rise by resistance at full load: 149° Fahrenheit.

H. The transformer shall be designed to meet the audible sound levels standards of oil-filled transformers in accordance with ANSI C57.12.90 standards.

I. Primary Taps:
   1. Provide four (4) 2.5 percent, full-kVA no-load taps, two (2) above nominal and two (2) below nominal.

J. Accessories: Transformer features and accessories shall include:
   1. Dial-type thermometer with electrical contacts to annunciate when unsafe temperature is reached.
   2. Liquid level gauge
   3. Pressure-vacuum gauge
   4. One (1) inch drain valve with sample valve
   5. Pressure relief valve
   6. Non-PCB label
   7. M.O.V.E. dead front surge arrestors

K. Primary Overcurrent Protection:
   1. Current limiting fuses air immersed in dry well canister draw-out for fuses replacement.

2.02 480 VOLT AUXILIARY PANEL

A. Provide general purpose, free standing, dead-front, NEMA Type 1 switchboard-type enclosed cabinet.

B. Cabinet shall be 12-gauge steel with full-height hinged door.

C. Controls and instruments shall be individually mounted and fully front accessible.

D. Provide ¼ inch by 2 inch interior copper ground bus of electrical grade copper mounted on stand-off insulators.

E. Incoming Main circuit breakers:
   1. Molded case type, 3-pole, 600 Vac, certified for use within enclosures at 100 percent rated current.
   2. 250 A frame with 250 A trip, 65 kA interrupting at 480 Vac (Contractor to confirm ratings).
   3. Front-adjustable solid-state trip unit with long time, short time, instantaneous and ground fault adjustable trips.
   4. Provide Form C auxiliary contact for future breaker status indication.
   5. Two incoming breakers shall be key interlocked such that only one breaker can be closed at one time.

F. 480 Volt Feeder Breakers

1. Provide four (4) three-pole feeder breakers to feed various loads in the substation such as step-down transformers, battery charger, UPS etc.

G. Meters and Instruments:
1. Ac analog voltmeters: 0-600 V, door-mounted.
2. Ac analog ammeters: Rating shall be determined by the Contractor.
3. Current transformers: Window-type, 300:5 ratio, C10 accuracy class, one (1) per phase.

H. Relays:
1. Ac undervoltage monitor relays (Device Nos. 27A-1 and 27A-2): 120 V phase undervoltage indication and annunciation, adjustable drop-out range of at least 80 to 100 V, 10 A DPDT contacts, LED output status indicator, one (1) relay per phase.
2. Battery charger failure, instantaneous relay circuit (Device No. 27BI).
3. Battery charger failure, 8-hour time delay relay circuit (Device No. 27B).
4. APCC 125 Vdc control power undervoltage relay (Device No. 27DC-A).
5. Intrusion detection alarm relay circuit (Device No. IDX).
6. Smoke alarm detection relay circuit (Device No. SDX).

2.03 SUBSTATION LOW-VOLTAGE AC PANELBOARD

A. Provide a wall-mounted, dead front, UL-Listed 208/120 Vac low-voltage ac panelboard that accommodates all required 120 V and 208 V circuits and necessary accessories for substation power and control. Minimum requirements for this panelboard are as follows:
1. Main breaker, 225 A (Contractor to confirm rating).
2. 24 branch circuits, with unrestricted mounting locations.
3. Circuit directory holder located on inside of panelboard door.
4. ANSI 61 gray polyester powder coat paint.
5. Integral transient voltage surge suppressor (TVSS):
    a. 125 percent maximum continuous operating voltage (MCOV).
    b. Three-mode protection: line-neutral, line-ground, and neutral-ground.
    c. 65 kA symmetrical withstand and UL-1449, 400 V suppressed voltage rating per mode.
    d. Status indicating lights.

2.04 RELIABLE POWER INVERTER

A. Provide one 125 Vdc to 120 Vac inverters with the following minimum requirements.
1. Output power rating: Contractor shall size and submit for Engineer's approval.
2. True sine wave output with less than 3 percent THD.
3. Automatic bypass to 120 Vac supply upon unit failure.
4. Alarm contacts for no ac input, no dc input, no ac output, and inverter failure.

5. 19-inch rack mount or surface mount, at Contractor's option. Contractor shall integrate the design of these components with their associated enclosures and interconnections.
6. Surge withstand capability, per IEEE C37.90.1.
7. RFI withstand capability, per IEEE C37.90.2.
8. Behlman model ACDC1200-125, Exceltech MX Series, or approved equal.

2.05 AUTOMATIC TRANSFER SWITCH

A. The Automatic transfer switch shall be furnished with microprocessor logic in compliance with following standards:
   1. Complies with UL-1008 and UL-489 standards.
   2. Seismic qualified for UBC and BOCA zone 4.

B. The transfer switch shall be rated for 480 Vac, three-phase, four-wire, true four-pole switched neutral type. All four poles for each source being fully rated and connected to a common shaft.

C. Microprocessor Logic shall:
   1. Monitor normal and alternate source voltage. Submit sequence of operation for Engineer's approval.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Install the specified auxiliary equipment within substation enclosure secure, plumb and level and in true alignment with related adjoining work.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16235.001 – Traction Power Substation Auxiliary Power System shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16235.001 – Traction Power Substation Auxiliary Power System will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16240

TRACTION POWER SUBSTATION METAL-ENCLOSED DC SWITCHGEAR

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Traction Power Substation Metal-Enclosed DC Switchgear, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Furnish and install metal-enclosed 800 Vdc power switchgear assemblies and associated accessories for the new prefabricated-type traction power substation and the Tie-Breaker station. (The transformer-rectifier units supply 650 Vdc nominal to the DC Power Switchgear.)
   2. Furnish one (1) spare dc feeder breaker and one (1) spare cathode breaker.

C. The Contract Documents provide the performance parameters and design criteria to complete the Traction Power Substation Basic Electrical Materials and Methods portion of the Work. The Contractor shall be responsible to provide a complete design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16200, "Traction Power Substation General Requirements."

B. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

C. Section 16310, "Traction Power Substation Local Annunciator Panel."

D. Section 16360, "Traction Power Substation Testing."

1.03 REFERENCE STANDARDS

A. ANSI:
   1. C37.16a – Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors - Preferred Ratings, Related Requirements and Application Recommendations
   2. C37.17 – Trip Devices for General Purpose DC Low Voltage Power Circuit Breakers
   3. C37.20.1 – Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
   4. C37.90 – IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus

B. ASTM

C. ICEA

D. IEEE:
   1. C37.14 – IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures
   2. C37.90.1 – Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
   3. C37.90.2 – Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers
   4. C62 – IEEE Surge Protection Standards Collection

E. NEC

F. NEMA

G. NFPA

H. UL

1.04 SUBMITTALS

A. The following information shall be submitted for approval:
   1. Manufacturer's descriptive literature, catalog data and other pertinent information sufficient to clearly demonstrate compliance with the Contract Documents.
   2. Detail Shop Drawings for the switchgear assembly. Shop Drawings shall include dimensioned outline drawings of all major equipment and devices indicating their location relative to other equipment. Include dimensioned floor plans and front, rear, top, and section views.
   3. Relay and metering diagrams and schematic wiring and internal connection diagrams showing all power and auxiliary circuits, protective devices, transducers, shunts, meters and contact development.
   4. Bills of Material and nameplate schedules keyed to the submitted Shop Drawings.
   5. Tabulated equipment trip and lockout schedules.
   6. Short circuit calculations and system coordination study, including relay settings for all protective devices, performed by a Professional Engineer.
   7. Complete descriptions of all protective devices, including coordination curves, setting procedures and instruction manuals.
   8. After approval of schematic diagrams, submit interconnection and wiring diagrams for approval.
   9. Certified design test reports and test certificates.
   10. Production test schedule, certified test reports and test certificates.
   11. Provide proof that similar units, presently being used on extra heavy rail transit systems, have developed a satisfactory operating history for a minimum of five (5) years

1.05 ENVIRONMENTAL REQUIREMENTS

A. The switchgear shall be suitable for indoor application in a prefabricated substation.

1.06 QUALITY ASSURANCE

A. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

1.07 QUALIFICATIONS

A. Design shall be that of a field proven product. No prototypes will be considered. A proven product is considered to be similar units presently being used on extra heavy rail transit systems and having developed a satisfactory operating history for a minimum of five (5) years.

ARTICLE 2 PRODUCTS

2.01 DC SWITCHGEAR ASSEMBLIES

A. Switchgear assemblies shall consist of integrated lineups of metal-enclosed, dead-front enclosures equipped with high-speed draw-out type dc cathode and feeder circuit breakers, as indicated on the Contract Drawings. Additionally, all associated power, control, indication and auxiliary equipment shall be provided. The switchgear assemblies shall be suitable for indoor service.

B. The switchgear assemblies shall be rated as follows:
   1. Voltage class: 800 Vdc
   2. Insulation level, 60 Hz withstand: 3.7 kV
   3. Maximum vehicle regeneration voltage: 950 Vdc
   4. Continuous current: 8,000 A for cathode / 4,000 A for feeder
   5. Short circuit current [peak]: (to match rectifier main dc breaker)
   6. Short circuit current [sustained]: (to match rectifier main dc breaker)

C. Switchgear Enclosure:
   1. Switchgear assemblies shall consist of rigid, self-supporting and self-contained, electrically-welded steel structure units. Individual units shall be enclosed with not less than 12-gauge formed steel sheets. Each unit shall be bolted to each other to form a continuous, free-standing switchgear assembly. The enclosures shall be sufficiently rigid to support equipment under normal loads and short-circuit conditions.
   2. Enclosures shall be suitable for accommodation of draw-out circuit breakers and shall include stationary disconnecting device contacts and supporting rails for the circuit breakers. The design shall allow the circuit breakers to be easily drawn in or out of their compartment and connected or disconnected from the buses and auxiliary circuits by means of self-aligning, self-coupling primary and secondary

disconnecting devices. The devices shall be suitably shrouded or provided with automatic safety shutters to prevent accidental contact with live parts. Guide rails or cradles for positioning the removable element shall be provided as an integral part of the compartment.

3. Provide means for positively holding the circuit breaker in place when the removable element is in either the CONNECTED, TEST, or DISCONNECTED position. Interlocks shall be furnished to prevent removal of a closed circuit breaker to, or from, the CONNECTED position and to prevent electrical closing of the circuit breaker within the compartment except in the CONNECTED or TEST position.
4. Circuit breaker compartments shall permit the interchange of circuit breaker removable elements, but only of the same type and rating.

D. Doors and Panels:
1. Each circuit breaker compartment shall be provided with either a formed, hinged interior front door or a full-width draw-out panel.
2. Doors and panels shall be formed of minimum 12-gauge sheet steel and shall be properly reinforced against distortions by suitable flanges and stiffening members.
3. Doors shall be securely fastened in the closed position with a minimum of two (2) latches easily opened without the use of tools. Door handles, latches, stops and hinges shall be heavy-duty type, subject to the Engineer's approval.
4. Provide automatic stop mechanisms to securely hold the doors in the fully-open position, with manual defeating feature for moving the door from one position to another. Doorstops shall facilitate unhindered withdrawal of the circuit breaker removable element from the compartment. With the front door of any compartment open at 90 degree position, the adjacent compartment door shall be capable of being opened and its breaker completely removed from the enclosure.

E. Dimensions and Arrangement:
1. Dimensions and arrangement of the switchgear shall provide adequate isolation from other equipment as well as clearance to ground. Where necessary, install GPO-3 type glastic insulation panels to obtain required dielectric insulation.
2. Main and feeder breaker switchgear compartments shall have a nominal width of twenty-four (24) inches. If this dimension is not achievable due to enclosure size constraints, nominal width may be reduced to twenty (20) inches, but only with the permission of the Engineer (Contractor's bid shall be based on a 24 inch compartment width).
3. The cable compartment of each circuit breaker unit shall be isolated from the cable compartment of adjacent units.
4. The circuit breaker compartments shall be completely enclosed except for the insulated vent opening at the top, designed for rapid exhaust and deionization of ionized gases. The design shall prevent striking an arc to conductive members of the switchgear during and after fault interruption. Screws made of non-conducting material and insulating barriers shall be provided for all surfaces exposed to ionized gases; metal screws covered with insulating caps are not

acceptable. Insulation of circuit breaker compartment and its vent openings are not required if the Contractor can prove to the satisfaction of the Engineer that the gases exhausted from the circuit breaker removable element during fault interruption are completely de-ionized.

5. Vent openings shall be designed to prevent damage to or malfunctioning of the circuit breaker, control circuits and other components from foreign objects and shall be so located that hot gasses or other materials cannot be discharged through them in a manner which might be injurious to operating personnel. Each circuit breaker housing shall be provided with protective shutters which close and block access to the positive bus and breaker load terminals as the removable element of circuit breaker is racked from the cubicle.

F. Main Bus and Connections:

1. A dc switchgear positive main bus of high-conductivity electrical grade copper shall be furnished for the full length of the switchgear assembly. The bus and bus connections shall be of adequate strength to withstand the thermal and mechanical stresses associated with short circuit currents equal to the peak current rating of the circuit breakers.
2. The main bus overload rating shall be coordinated with that of the upstream rectifier unit such that the permissible bus hot-spot temperature rise will never be exceeded.
3. The entire contact area of all bolted current-carrying connections shall be factory silver-plated. Ring-plated method of silver-plate and tin-plated contact surfaces is not acceptable.
4. Bolted connections shall use silicon-bronze bolts and washers. Connections shall be made with a minimum of two (2) ½ inch bolts and suitable washers. Bolt holes must be positioned such that the entire surface area of all washers is in direct contact with the bus bars being fastened.

G. Space Heater:

1. Each unit of switchgear shall be provided with 120 Vac heating element to facilitate drying and prevent condensation.
2. Heaters shall be enclosed in grille guards, with no sharp edges, and located so that they are easily accessible for replacement without de-energization of the switchgear bus. Also, heaters shall not be located close to any equipment which may be adversely affected by their heat.
3. Heaters shall be controlled by humidistat, adjustable from 60 percent to 100 percent relative humidity. Heater current in each unit shall be measured by an individual ammeter located in front panel. Panel ammeters shall be approximately 2.5 inches square, marked to indicate heater load.

H. 125 VDC Control Power Bus:

1. A two-conductor, 125 Vdc control power bus insulated for 1,500 V shall be installed for the full-length of each switchgear assembly. The bus shall be terminated on a terminal block for connection to the 125 Vdc supply.

2. The 125 Vdc control power bus shall be tapped at each dc circuit breaker compartment served for provision of compartment 125 Vdc control power. Provide double-pole, pull-out fuse blocks in each control power bus tap; fuses shall be selectively coordinated with upstream protective devices so that a control bus fault in one compartment will not cause loss of control power to the other compartments.
3. A control power voltage-monitoring relay (Device No. 27DC-2) shall be furnished, and connected to the incoming line terminals of the 125 Vdc control power bus. Relay shall be set to drop out at 70 Vdc and shall annunciate.

I. Switchgear Negative Bus: 1,000 Vdc, insulated cable:
   1. Substation: Extend the full length of the switchgear assembly and terminated on a terminal block for connection to the negative drainage switchboard and for measuring the negative track potential for operating dc circuit breaker reclosure circuitry.
   2. Tie Breaker Station: Extend the full length of the switchgear assembly and terminate on terminal blocks for connection to the negative reference cabinet. Tap the negative bus at each circuit breaker unit and extend to the load measuring circuit.

2.02 DC POWER CIRCUIT BREAKERS

A. Dc power circuit breakers shall be single-pole, air-break, high-speed, draw-out type, capable of withstanding a continuous no-load or light-load voltage of 740 Vdc.

B. Dc power circuit breakers shall be Whipp & Bourne high-speed air circuit breakers, or approved equal.

C. The circuit breakers shall be manufactured in accordance with ANSI C37.14 and rated to the preferred ratings listed in ANSI C37.16. The circuit breakers shall be suitable for operating on a substation positive dc bus, supplied by the 3,000 kW, 650 Vdc full-load rectifier units, provided under this Contract.

D. Current interrupting, removable arc chutes shall be of the metal-plate, cold-cathode, steel-splitter, plate-type, designed for positive interruption of all uni-directional currents within the circuit breaker ratings. Low current arc interruptions shall not be dependent on mechanical puffer devices or external iron circuits.

E. Cathode and feeder dc circuit breakers shall be of the same manufacturer.

F. Application of reactors between the rectifiers and dc switchgear, or between the rectifiers and negative bus, to limit circuit breaker short circuit current will not be acceptable.

G. The dc main and feeder circuit breakers shall have the following ratings:
   1. Rated maximum voltage: 800 Vdc
   2. Insulation level, 60 Hz withstand: 3.7 kV

3. Maximum vehicle regeneration voltage: 850 Vdc
4. Continuous current for cathode breaker: 8,000 Amps, dc
5. Continuous current for feeder breaker 4,000 Amps, dc
6. Short circuit current [peak]: 200 kA
7. Short circuit current [sustained]: 120 kA
8. Short-time current (250 msec.): 80 kA
9. Trip coil voltage range (min.): 70-140 Vdc
10. Closing coil voltage range (min.): 100-140 Vdc

H. Removable Element:
1. Truck or cradle-mounted on wheels with handles and/or other means of lifting suitable for easy manual removal and insertion without the need for hoists or ramps.
2. Provided with a fully interlocked, manually-operated racking mechanism to move the circuit breaker between the DISCONNECTED, TEST, and CONNECTED positions. A clearly visible position indicator shall be provided.
3. Provide suitable guide rails for centering the removable element in proper position during insertion or withdrawal. Front ends of guide rails shall be flared and the bottom plate of the enclosure within the guide rails beveled to facilitate the lining-up and insertion of the circuit breaker removable element. A positive stop shall be provided to prevent over-travel of the removable element when moving it into operating position. A similar positive stop shall be provided for the test position.
4. Primary disconnecting contacts shall be composed of heavy-duty, self-aligning, spring-loaded, silver-plated, copper disconnect fingers that engage with the line and load-side stationary disconnecting contacts.
5. Contact surfaces of the main and arcing contacts shall be silver, non-welding silver alloy or equivalent which combines high conductivity and arc-resistant properties.
6. Circuit breaker control wiring connections between the removable element and stationary compartment shall have provisions for maintaining, or automatically reinstating, circuit continuity when the removable element is moved between the CONNECTED and TEST positions within the compartment. Means shall be provided for simultaneous disconnection of control wiring connections when the removable element is moved to the DISCONNECTED position. The control disconnecting devices shall provide rugged, heavy-duty connections for the control circuits and interlocks between the removable element and the housing. The devices shall be precisely located and securely mounted to maintain alignment.
7. Normally-closed auxiliary switches mounted on the removable element and used for interlocking shall be shunted with truck-operated cell switches to permit operation of interlocked equipment when breaker is in the DISCONNECTED position. A minimum of two (2) "a" and two (2) "b" spare cell switch contacts shall be provided, wired to outgoing wiring terminal block.
8. All auxiliary switches, whether cell-mounted or mounted on removable element, and breaker control circuit wiring connected through control disconnecting

devices, shall be made up and operable when breaker is racked to the test position so the breaker may be closed and tripped electrically or mechanically.

9. The removable elements of the same type and rating shall be completely physically and electrically interchangeable. Removable elements not of the same type or rating shall not be interchangeable.

I. Operating Mechanisms:
   1. Solenoid-operated type closing mechanism, designed for intermittent operation that actuates the main contacts through a linkage. Solenoid-operated mechanism shall be connected such that control voltage is removed from the closing coil after a preset time.
   2. Provided with an electromagnetic trip device, acting via a holding coil type trip latch.
   3. Provide with a bucking bar/inductive shunt combination to trip the circuit breaker upon high rates of rise of current flowing in the desired trip direction.
   4. Mechanically and electrically trip-free, non-pumping.
   5. Provides positive opening of the moving contacts and circuit interruption when the tripping impulse is received at the fully closed or any partially closed position.
   6. Furnished with mechanical indicators to show the OPEN and CLOSED positions of the main moving contact.
   7. Provided with a four-digit, non-resettable register-type operation counter to record each circuit breaker trip operation.

J. Circuit Breaker Interlocks:
   1. The main dc circuit breaker closing mechanism shall be furnished with a unique key interlock coordinated with the associated rectifier negative disconnect switch (Device No, 89N). The interlock system shall prevent closing of the main circuit breaker unless the 89N disconnect switch is closed, and shall prevent the opening of the 89N disconnect switch unless the main dc circuit breaker is open.

K. Remote/Local Control and Indication:
   1. Provide a front panel-mounted LOCAL/REMOTE control selector switch (Device No. 43D) for each dc circuit breaker as follows:
      a. LOCAL Position: Permits local open and close operation of a circuit breaker by its own electrical control switch when its removable element is in either the CONNECTED or the TEST position. For feeder circuit breakers, CLOSE operations in the CONNECTED position shall normally be performed through the automatic reclosing and load measurement devices specified.
      b. REMOTE Position: Permits open and close operation of a circuit breaker by the remote supervisory control system when its removable element is in the CONNECTED position only. For feeder circuit breakers, CLOSE operations shall be performed only through the automatic reclosing and load measurement devices. A circuit breaker shall have the ability to be locally opened (tripped) when its 43D device is in REMOTE position.

2. Stored-energy mechanism indication: Provide front panel-mounted white light for indication of charged state.
3. OPEN/CLOSED indication: Provide front panel-mounted red light for CLOSED position indication, and green light for OPEN position indication.
4. Manual Operation: Provide mechanical means for manually tripping each circuit breaker when in the TEST and CONNECTED positions. This function shall be available with the compartment door closed. An indicator, visible when the door is closed, shall be provided to show when the circuit breaker is in the OPEN and CLOSED position.

L. Spare Auxiliary Contacts: Not less than four (4) spare, electrically-separate sets of reversible auxiliary switch contacts shall be provided, in addition to those required for the circuit breaker control and indication circuits, for use as "a" or "b" contacts. All auxiliary switch contacts shall be operated by the breaker mechanism in both the CONNECTED and the TEST positions. All auxiliary switch contacts, both used and spare, shall be wired to terminal blocks on the stationary structure through secondary disconnecting device contacts.

M. Locking Provision: Circuit breakers shall be furnished with provision for locking of the breaker in the OPEN position without having to withdraw the breaker.

2.03 PROTECTIVE DEVICES AND METERING

A. Dc switchgear assemblies shall be furnished with protective systems, meters and related functions, as indicated on the Contract Drawings, and as specified herein. Additional components such as auxiliary relays, isolating diodes and similar devices not shown on the Contract Drawings, but required for complete installation, shall be provided by the Contractor.

B. Devices shall be arranged to be conveniently accessible and visible. The grouping shall be neat, modular and logical, with related functions in close proximity. Devices and nameplates shall be plumb and square with the lines of the panel, and mounted as recommended by the manufacturer. Care shall be taken to avoid wiring congestion. All auxiliary devices shall match the general appearance as much as possible with a matching dull-black finish. All devices on the panel face shall be semi-flush mounted with transparent protective barriers. Devices of the same general type shall be manufactured by the same company and shall be similarly arranged and mounted.

C. Rectifier Main (Cathode) Circuit Breaker Protection:
1. Furnish with a uni-directional, reverse current, direct-acting instantaneous trip (Device No. 32).
2. Annunciates and operates the rectifier unit lockout relay device No. 86-1 upon detection of reverse current.
3. Adjustable between 5 and 100 percent of the breaker rated current, factory set at 1,000 Amps.

D. Dc Feeder Circuit Breaker Protection – Integral Device 176:
   1. Provide high-speed, direct-acting, bidirectional instantaneous trip device No. 176, adjustable for 100 to 400 percent of rated current.
   2. Device 176 shall annunciate upon operation.

E. Dc Feeder Circuit Breaker Protection – Multifunction Device 150M:
   1. Provide a microprocessor-based, multifunction digital feeder protection package for each dc feeder breaker (Device No. 150M). Proposed device shall be of proven design in current use and manufacture, and will be subject to the Engineer's approval. This device shall include the following features, as a minimum:
      a. Instantaneous overcurrent detection channel:
         1) Uni-directional high current detection, with target indication.
         2) Adjustable pickup, with maximum pickup setting equal to at least 400 percent of the feeder breaker frame rating.
      b. Short time overcurrent channel (STOC):
         1) Uni-directional overcurrent detection with target indication.
         2) Adjustable pickup and time delay based on a family of inverse-time characteristic curves.
      c. Long time overcurrent channel (LTOC):
         1) Uni-directional overcurrent detection with target indication.
         2) Adjustable pickup and time delay suitable for thermal protection of an overhead contact system comprised of a 500 kcmil copper messenger and 350 kcmil copper contact wire.
         3) LTOC channel operation shall trip the feeder breaker, but not lock it out.
      d. Current rate-of-rise detection channel:
         1) Uni-directional overcurrent detection with target indication.
         2) Adjustable initial slope (di/dt), current step, and time duration.
      e. Adequate shielding for radiated and conducted EMI to prevent false operations from other equipment and devices, including portable radios.
      f. LCD operator interface, with keypad.
      g. Isolated inputs, rated 5 kVdc for one (1) minute, minimum.
      h. Alarm log and trip event recording capability with data storage in nonvolatile memory, downloadable to a laptop computer.
      i. Annunciation of any overcurrent trip.

F. Dc Feeder Automatic Reclosing and Load-Measuring System:
   1. Provide an integrated, solid state automatic reclosing and load measuring system for each dc feeder breaker, consisting of Device No. 182, Device No. 183, load measuring shunt resistors and contactors, and associated auxiliary equipment. The system shall be a proven design in current use and manufacture, and shall function as follows:
      a. The load measuring and automatic reclosing cycle shall be initiated when (1) a feeder circuit breaker receives a CLOSE signal from the SCADA System,

or (2) the local control switch, or (3) when the circuit breaker is tripped automatically by the feeder protective Device Nos. 176 or 150M.

b. Initiation of the load measuring cycle shall be preceded by an adjustable time delay to permit the faulted overhead contact system section to become fully de-energized.

c. At the commencement of the load measurement cycle, a shunt power resistor shall be switched into the load measuring circuit by an appropriately-sized dc contactor(s). Contactor and resistors shall be rated for at least 1,000 Vdc, and the resistor shall be sized to sustain the full number of worst-case sequential load measuring cycles permitted by the load measuring system without overheating. Load measuring resistors shall be mounted external to the circuit breaker compartments.

d. After a time delay for breaker deionization time, the voltage sensor (Device No. 183) shall determine whether there is voltage still present in the affected section. If the voltage measuring circuit detects voltage higher than the preset value, it shall reclose the affected circuit breaker immediately. Pickup adjustment range shall include the minimum voltage for train operation of 450 Vdc.

e. If the voltage measuring circuit detects no voltage on the section, the load measuring relay (Device No. 182) shall make repeated load measurements at suitable adjustable time intervals. If any load measurement determines that no fault is present, automatic reclosing of the circuit breaker shall be initiated. A successful reclosure with no subsequent automatic trip within five (5) seconds shall complete the load measurement cycle and reset the devices to their initial state.

f. Provision shall be made for selection of up to three (3) circuit breaker reclosure cycles, at fifteen (15) second intervals, within a three (3) minute period. If no successful reclosure takes place in the three (3) minute period, the automatic reclosing and load measuring system shall lock-out until another circuit breaker CLOSE signal is received from the SCADA System or by operation of a manual RESET push button at the device. System lock-out shall be annunciated.

2. Automatic reclosing and load measuring systems shall be furnished with test features that check the functioning of the system. The test cycle shall be initiated by a local TEST push-button, but shall not close the circuit breaker when the removable element is in the CONNECTED position. System status during the load measuring sequence steps shall also be indicated on the front of the device.

G. Dual-Function High Resistance Ground Structure Relay – Device 64/64G:

1. Structure relay shall continually monitor the dc switchgear and rectifier structures for grounds or unsafe impressed voltages ("hot structure").
2. Device No. 64G shall annunciate a dc switchgear or rectifier structure ground and operate a strobe warning light provided with an acknowledge pushbutton.
3. Device No. 64 shall annunciate and trip lockout relay device Nos. 86-1 and 86-2 upon inverse time-delayed detection of an energized dc switchgear or rectifier

structure, and operate an annunciator strobe warning light provided with an acknowledge pushbutton.

4. Provide with self-monitoring fail-safe annunciation feature, 64 and 64G self-test pushbuttons, and 125 Vdc control power operation.
5. Provide with 3.5 to 18 Vdc (Device No. 64G) setting range, and 50 to 80 Vdc (Device No. 64) setting range.

H. Lock-out Relay – Device 186:

1. Rotary, hand reset, 125 VDC, equipped with green light for indicating reset position and amber light for indicating tripped position. Lights shall be LED wired to trip and lockout all cathode breakers, dc feeder breakers and transformer-rectifier ac feeder breakers.

I. Surge Arrestors:

1. Provide dc surge arrestor for each feeder breaker. The arrestor shall be metal-oxide type, suitable for dc transit system, 870 Vdc, maximum continuous operating voltage. The base shall be insulated from the switchgear enclosure.

J. Substation Emergency Trip System (ETS) – Device No. 99E:

1. All substation ac and dc power circuit breakers shall be immediately tripped upon operation of the ETS trip pushbuttons, located near each doorway.
2. ETS pushbuttons shall energize interposing relays in the IFTC that will trip lockout relay devices 86-1 and 86-2.

K. Metering:

1. Cathode Circuit Breaker Metering: Dc ammeter, complete with ammeter shunt and zero to 15,000 Ampere scale.
2. Feeder circuit Breaker metering: Dc ammeter complete with ammeter shunt, with 10,000–0–10,000 Ampere scale.
3. Bus Voltage Metering: One (1) dc voltmeter with 0 – 1,000 Volt scale, complete with current limiting fuses for each 650 Vdc positive bus.
4. Shunt Isolation Amplifier (Voltage Transducer): Provide voltage transducer as shown in the one-line diagram. The shunt amplifier shall be a linear amplifier designed to amplify dc shunt millivolt signals. The input shall be from 0 – 1,000 Volts, and output shall be one (1) milliamp. Provide complete isolation of the input signal. A magnetic amplifier shall be used in the input circuit to isolate the inputs from all other circuits and grounds. The input shall be tested at 4,000 Vdc for one (1) minute to ensure that no breakdown will occur when connected to shunts operating at high voltage above ground. The transducer shall be compatible with the rating of the dc switchgear.
5. Shunt Isolation Amplifier (Current Transducer): Provide a current transducer for each of the cathode circuit breakers, as shown. The shunt amplifier shall be a linear amplifier designed to amplify dc shunt milliamp signals. The input shall be a 50 mV, rated at 15,000 A, for 8,000 A cathode breaker, with one (1) milliamp output. Provide complete isolation of the input signal. A magnetic amplifier shall

be used in the input circuit to isolate the inputs from all other circuits and grounds. The input shall be tested at 4,000 Vdc for one (1) minute to ensure that no breakdown will occur when connected to shunts operating at high voltage above ground. The transducer shall be compatible with the rating of the dc switchgear.

6. DC Watt Transducer: Provide a dc watt transducer for each of the cathode circuit breakers as shown. The dc watt transducer shall be able to measure direct current watts.

2.04 FEEDER SCABLE TERMINATIONS

A. Each positive dc feeder circuit is comprised of four (4) 1,000 kcmil feeder cables. Provide sufficient space, cable supports and terminations for six (6) 1,000 kcmil cables, with two (2) spare terminal connectors in each substation dc feeder breaker cable compartment. Cable entry shall be from below, via fiberglass conduits.

B. Provide bolted cable floor entry cover plates to permit field drilling of holes for conduit and cable entry. Cover plates shall be at least twenty (20) inches distance from the termination lugs, to provide adequate space for cable spreading.

2.05 DC SWITCHGEAR MAINTENANCE ACCESSORIES

A. Provide the following with each dc switchgear assembly:
   1. Dc circuit breaker test cabinet:
      a. Wall-mounted unit suitable for the circuit breakers provided under this Contract, installed complete with all power, control, and testing cables and connectors.
      b. Set of test jumpers for connecting breaker units to the test cabinet.
   2. One (1) set of tools required for normal switchgear maintenance and repair.
   3. One (1) set of circuit breaker removal accessories, including handling devices.

2.06 DC SWITCHGEAR SCADA INTERFACE

A. Each switchgear assembly shall be provided with the following circuits to interface with the SCADA System at the Supervisory Control Interface Terminal Cabinet (IFTC):
   1. Control Circuits:
      a. Cathode circuit breaker – CLOSE
      b. Cathode circuit breaker – OPEN
      c. Feeder circuit breaker – CLOSE
      d. Feeder circuit breaker – OPEN
   2. Status Indication Circuits:
      a. Cathode circuit breaker – CLOSE
      b. Cathode circuit breaker – OPEN (When the circuit breaker is in the test or disconnected position, a circuit breaker – OPEN shall be reported.)
      c. Feeder circuit breaker – CLOSE

d. Feeder circuit breaker – OPEN (When the circuit breaker is in the test or disconnected position, a circuit breaker – OPEN shall be reported.)

3. Analog Indication Circuits:
   a. Dc bus voltage: 0 to 1,200 Volts
   b. Rectifier load current: 0 to 8,000 Amps
   c. Feeder load current: 5,000 Amps – 0 – 5,000 Amps
   d. Dc transducers shall be in accordance with Section 16210, "Traction Power Substation Basic Materials & Methods"

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Install the dc power switchgear in a secure, plumb, level and true alignment with related adjoining work, within the substation enclosure.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16240.001 – Traction Power Substation Metal-Enclosed DC Switchgear shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16240.001 – Traction Power Substation Metal-Enclosed DC Switchgear will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16250

TRACTION POWER SUBSTATION DRAINAGE AND NEGATIVE RETURN SWITCHBOARD

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Traction Power Substation Drainage and Negative Return Switchboard, in accordance with the Contract Documents.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data."

B. Section 16200, "Traction Power Substation General Requirements."

C. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

D. Section 16230, "Traction Power Substation Transformer-Rectifier Units."

E. Section 16240, "Traction Power Substation Metal-Enclosed DC Switchgear."

F. Section 16295, "Traction Power Substation Wire and Cable."

G. Section 16300, "Traction Power Substation Busways."

H. Section 16360, "Traction Power Substation Testing."

1.03 REFERENCE STANDARDS

A. ANSI:
   1. Z55.1 – Paint Colors

B. ASTM:
   1. B187 – Copper Bus Bars and Rods

C. ICEA

D. IEEE:
   1. 316 – Direct Current Instruments (Shunts)

E. NEMA:
   1. CC1 – Electrical Power Connectors for Substations
   2. 250 – Enclosures for Electrical Equipment (1,000 V max.)

F. NFPA:
    1. 70 – National Electrical Code (NEC)

G. UL

1.04 SUBMITTALS

A. Submit the following Shop Drawings, technical data and certificates, and test procedures for approval in accordance with Section 16200, "Traction Power Substation General Requirements":
    1. Shop Drawings.
    2. Certified test reports for specified factory testing.
    3. Certificates from manufacturer verifying that equipment conforms to specified requirements.

B. Submit product data on the following:
    1. Negative switch.
    2. Dc negative bus and cable connections.
    3. Negative return cable terminal connections.
    4. Stray current corrosion control equipment: Comprising fuse holder and current limiting fuse, shunt, variable resistor, reverse current switch, disconnect switch and connection to drainage bus.

C. Operations and Maintenance Manuals

D. Spare Parts List

E. Provide proof that similar equipment, presently being used on extra heavy rail transit systems, have developed a satisfactory operating history for a minimum of five (5) years

1.05 QUALITY ASSURANCE

A. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

B. Factory Testing: Submit test plans, procedures and scheduled test date for approval at least twenty (20) working days in advance of scheduled test date. No test results will be accepted prior to approval of test plans and procedures. Factory test requirements are as follows:
    1. Switchboard Dielectric Withstand Test: Test all live parts of the switchboard completely assembled, except without reverse current switches at a voltage level of 4,100 Vdc for 60 seconds.

1.06 QUALIFICATIONS

A. Selection of a manufacturer will depend upon their being regularly engaged in production/installation of similar equipment. The selection will also depend upon demonstration of a successful record providing equipment and installation of similar type and rating on extra heavy rail transit systems for at least five (5) similar projects.

ARTICLE 2 PRODUCTS

2.01 MATERIALS AND EQUIPMENT

A. Drainage and Negative Switchboard:
   1. Free-standing, metal-enclosed, suitable for indoor service and including the following equipment:
      a. Negative switches.
      b. DC negative bus and bus connections.
      c. Stray current corrosion control equipment.
      d. Drainage bus and bus connections to stray current corrosion control equipment.
      e. Negative return cable terminal connections.
   2. Enclosure:
      a. Metal-enclosed, rigid, self-supporting, self-contained, ventilated steel structure, assembled as one unit, switchboard construction.
      b. Designed and arranged to provide convenient access to all components for normal operation and maintenance.
      c. Terminal connectors provided for connecting the switchboard metal enclosure to the substation ground bus.
      d. Finish: Metallic surfaces degreased, primed and finshed with light gray enamel, Color No. 61, ANSI Z55.1, in accordance with referenced standard; two (2) mils minimum, dry film thickness.
   3. Negative Switches:
      a. Description:
         1) No-load break, single pole unfused, enclosed knife switches, connected to the negative bus mounted in compartments in the switchboard with danger signs provided at each switch. Signs made of 20-gauge steel, seven (7) inches by ten (10) inches with corner mounting holes and worded to say NO LOAD BREAK SWITCHES – OPEN ALL RECTIFIER DC CATHODE CIRCUIT BREAKERS BEFORE OPENING THESE SWITCHES.
         2) Back-connected with provisions for connecting 1,000 kcmil negative return cables from the running rails, as shown.
         3) All current-carrying components electrically isolated from the switchboard enclosure.
         4) Designed to allow the compartment doors to close with the negative switch in the open position.
      b. Rating: 750 Vdc, 6,000 A, dc continuous and capable of withstanding short circuit currents imposed by parallel silicon rectifier units of 6,000 kW total capacity.

c. Connectors: Terminal connectors of the long barrel, double indentation compression type with two-hole contact pad and of one piece tubular construction formed of pure electrolytic copper and tin-plated to resist corrosion. Terminal connectors in accordance with NEMA CC1. Eight (8) connectors per switch shall be furnished.
d. Cable Terminations: Adequate space shall be provided for spreading and terminating all stranded copper insulated conductors entering the switchboard. The cable entry cover plates shall be bolted to permit field drilling of holes for conduit and ducts. The cover plates shall be 18 inches minimum distance from the cable termination bus.

4. DC Negative Bus and Bus Connections:
   a. Material and Rating: High quality copper, electrical conductivity, 750 Vdc, rated dc continuous current as shown. Size based on a maximum current density of 800 A per square inch.
   b. Insulation: Bare, except where close clearances may make insulation necessary. Bus bars mounted on barrier-type insulation or post type insulators of sufficient strength to withstand, without damage or permanent distortion, all stresses produced by specified short circuit currents.
   c. Bus Connections:
      1) Connection surfaces silver or tin-plated.
      2) Joints treated to prevent corrosion. Each joint having a conductivity at least equal to that of the bus bar.
      3) Bolted with cadmium plated, galvanized or similarly coated high strength steel bolts of sufficient number and size to provide solidly bolted connection.
      4) Terminate negative bus on a terminal block for connection to the negative bus of the DC switchgear; size will be as shown on Contract Drawings.
5. Stray Current Corrosion Control Equipment:
   a. Each stray current corrosion drainage circuit, number as indicated, consists of the following:
      1) Cable connector
      2) Fuse holder and current limiting fuse
      3) Shunt
      4) Variable resistor
      5) Reverse current switch
      6) Disconnect switch
      7) Connection to drainage bus
   b. Cable Connector: Long barrel, double indentation compression type of one piece tubular construction, formed of pure electrolytic copper and tin-plated to resist corrosion, for 250 kcmil cable, in accordance with NEMA CC1, except contact pads may be one hole.
   c. Fuse holders and fuses: Rated 1,000 Vdc:
      1) Fuses: Current limiting, non-venting, rated and coordinated with the withstand capability of the drainage disconnect switches. Bolt-on, 60 A, Chase-Shawmut Form 101, Catalog No. A100P60, or equal.

d. Disconnect Switches:
   1) Installed between the incoming stray current control cable and the substation negative bus, as shown.
   2) Fused disconnect switches: single pole, load break, knife-blade fused switches rated at 60 A continuous, at 600 Vdc. Coordinate switch rating with current-limiting fuse to provide adequate withstand capability under fault conditions.
   3) Mounted on an insulated base with adequate clearances to increase strike and creepage voltage levels to 720 Vdc, minimum.

e. Variable resistors: 1.1 ohms, 11 to 104 A, 620 to 820 Watts heat dissipation, cylindrical core type, furnished with an adjustable clamp-type terminal.

f. Drainage cable test shunts: Copper, 100 A, 100 mV (one mV per Ampere).

g. Drainage cable ammeters: Utility grade, accurate to within ± 2 percent of full-scale 60-0-60 Ampere center-zero type.

h. Reverse current switch (diode): Low threshold, solid-state reverse current switch (diode) rated 60A, 1,000V peak inverse voltage, 400 to 700 mV threshold voltage, complete with connectors. Switch (diode) shall be specifically designed and tested for use as a stray current control device. Associated protective devices, wiring and terminals shall be adequately ventilated.

i. Space for future equipment: provide space a minimum of four (4) sets of drainage equipment and cables.

6. Drainage Bus and Bus Connections:
   a. Description and rating: High quality copper, electrical conductivity grade, rated 400 A continuous, and 750 Vdc.
   b. Insulation: Bus bars mounted on barrier-type insulation or post-type insulators. Bare, except where close clearances may make insulation necessary.
   c. Bus Connections:
      1) Connection surfaces silver or tin-plated.
      2) Joints treated to prevent corrosion. Each joint having a conductivity at least equal to that of the bus bar.
      3) Bolted with cadmium-plated, galvanized or similarly coated high-strength steel bolts of sufficient number and size to provide solidly bolted connection.
      4) Drainage bus solidly connected to the dc negative bus.
   d. Bus Compartment: Isolated from the stray current corrosion control equipment compartments. Compartment includes drainage bus work, connection bars, bus supports, cable connections and cable supports.

B. Negative Rail Grounding Relay and Switch:
   1. The grounding relay shall be a solid state relay connected to sense the voltage of the substation negative bus with respect to the ground. The relay shall continuously monitor the negative to ground potential rise, and upon exceeding a preset threshold voltage and time delay, will activate the negative grounding

switch to short the negative bus to the substation ground system. The controls shall preclude operating on any transients, and the switch shall provide visual display when the unit is tripped, the polarity of the voltage when trip occurs and the magnitude of current conducted to ground. Alarms shall be provided for local and remote annunciation.

C. Nameplates:
   1. Nameplates shall be three-ply, laminated, plastic plates, engraved through black-face to white-core, and attached by means of stainless steel rivets or screws. Vertical gothic lettering using a round or square cutter shall be provided. Using a V-shaped groove is prohibited.
   2. Provide nameplate on the switchboard showing manufacturer's name and brand designation, the referenced standard, type, class and rating as applicable in accordance with referenced standard.
   3. Provide additional functional nameplates for each component:
      a. Each enclosure labeled, front and back, with nameplate 2-1/2 inches by 6-1/2 inches, inscribed in letters ½ inch high: "DRAINAGE AND NEGATIVE SWITCHBOARD".
      b. In addition to other information normally displayed on equipment, provide one-inch nameplate showing in letters ½ inch high switch positions, meaning of indicator lamp and other pertinent information.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Install Drainage and Negative Switchboard in accordance with approved Shop Drawings.

B. Install conduit and raceway in accordance with approved Shop Drawings and Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

C. Install negative bus duct as shown and in accordance with approved Shop Drawings and Section 16300, "Traction Power Substation Busways."

D. Make cable connections in accordance with approved Shop Drawings and Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

E. Drainage equipment shall be installed completely isolated from ground.

F. Use services of manufacturer's engineering representative for assistance during field testing and energization.

3.02 TESTING

A. Use services of manufacturer's engineering representative for assistance during field testing and energization. Such information is provided within Section 16360, "Traction Power Substation Testing."

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16250.001 – Traction Power Substation Drainage and Negative Return Switchboard shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16250.001 – Traction Power Substation Drainage and Negative Return Switchboard will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16270

TRACTION POWER SUBSTATION 125 VDC BATTERY SYSTEM

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Traction Power Substation 125 Vdc Battery System, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Furnish and install a complete substation 125 Vdc battery system for indoor use in a prefabricated-type traction power substation.
   2. The 125 Vdc battery system includes storage batteries, battery-eliminator type battery chargers, battery racks, dc distribution panelboards, and accessories to provide reliable dc control power for substation equipment.

1.02 RELATED SECTIONS

A. Section 16200, "Traction Power Substation General Requirements."

B. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

C. Section 16360, "Traction Power Substation Testing."

1.03 REFERENCE STANDARDS

A. IEEE:
   1. 450 – IEEE Recommended Practice for Maintenance, Testing and Replacement of Vented Lead-Acid Batteries for Stationary Applications
   2. 484 – Recommended Practice for Design and Installation of Vented Lead-Acid Batteries for Stationary Applications
   3. 485 – IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
   4. C37.90.1 – Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
   5. C62 – IEEE Surge Protection Standards Collection

B. NEMA:
   1. AB-1 – Molded-Case Circuit Breakers, Molded-case Switches, and Circuit Breaker Enclosures
   2. AB-3 – Molded Case Circuit Breakers and Their Application
   3. FU-1 – Low Voltage Cartridge Fuses
   4. ICS-6 – Industrial Control Systems: Enclosures
   5. 250 – Enclosures for Electrical Equipment (1,000 Volts Maximum)

6. PB-1 – Panelboards
7. PE-5 – Utility Type Battery Chargers

C. NFPA:
   1. 70 – National Electrical Code (NEC)

D. UBC

E. UL:
   1. 67 – Panelboards

1.04 SUBMITTALS

A. The following information shall be submitted for approval:
   1. Manufacturer's descriptive literature, catalog data and other pertinent information sufficient to clearly demonstrate compliance with the Contract Documents.
   2. Manufacturer's arrangement, wiring, and detail Shop Drawings.
   3. Detailed design calculations and associated assumptions for batteries, battery charger/eliminators, interconnecting equipment and protective devices.

1.05 QUALITY ASSURANCE

A. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

ARTICLE 2 PRODUCTS

2.01 OPERATION

A. The battery and charger/battery eliminator shall operate in parallel. The charger, in addition to charging the battery, shall provide the continuous connected dc load via the dc panelboard. When the ac supply to the charger is interrupted, the battery shall supply all the required power for the specified load cycle.

B. The battery eliminator shall be capable of operating without any batteries in the circuit.

2.02 BATTERIES

A. Stationary Batteries shall be sealed, non-spillable, valve-regulated, lead-acid, absorbed glass mat separator, reduced maintenance type. Cells shall have a design life of 20 years when operated in float service under normal usage for the intended duty. The battery shall be capable of operating in temperatures ranging from -40° F to +140° F.

B. Batteries shall consist of a sufficient number of cells to provide a nominal output floating voltage of 135 Volts. Float voltage shall be 2.25 volts per cell, at 77° F. Each cell shall have a self-resealing safety valve that operates under a nominal pressure of 6 p.s.i. A flame arrestor shall be incorporated in the valve design.

C. The battery capacity shall be sized in accordance with IEEE 485. Contractor shall establish the required capacity in rated ampere-hours for an eight (8) hour discharge rate to 1.75 Volts per cell, at 77° F. The battery shall be capable of a 90 percent recharge within eight (8) hours.

D. Battery capacities shall be based on the following load cycle over a period of eight (8) hours from a fully charged state with the battery charger out of service:
   1. Normal continuous demand of traction power substation auxiliary loads including emergency lighting, relays and coils, monitors, transducers, indicating lamps, local annunciator panel, and supervisory control.
   2. Sequential closing of two (2) dc feeder circuit breakers followed by simultaneous tripping of two (2) dc feeder circuit breakers.
   3. After a continuous eight (8) hours of battery charger outage, a timer shall trip and lockout the main 23 kV ac circuit breakers and all four (4) 650 Vdc circuit breakers via the 86-1 and 86-2 lock-out relays.

E. Each positive and negative cell assembly shall be designed for the required battery duty and a long life cycle. Cell elements shall be Lead Antimony positive plate and negative plates shall be constructed of lead calcium grid alloy.

F. The positive and negative plates shall be separated by a low resistance absorbent microporous glass fiber mat to immobilize and retain battery electrolyte. The positive plate shall be individually wrapped, allowing maximum active material utilization. The separator shall be compressed sufficiently to maintain separator to plate contact throughout the life of the cell.

G. Cell containers shall be impact and heat resistant polypropylene or equivalent conforming to UL-94 V-O class requirements. Polarity of cell terminal posts shall be clearly and permanently identified.

H. The electrolyte shall be introduced to the cell through a computer controlled fill-by-weight process. Cells electrolyte shall have a specific gravity of 1.310, at 77° F, when fully charged.

I. Cells shall be housed in a protective modular 12-gauge steel tray that provides thermal management attributes. Each cell shall be compartmentalized to maintain consistent compression throughout the life of the battery, and to simplify single cell removal and replacement. The trays shall facilitate the direct dissipation of heat and provide structural integrity for the operating battery. The trays shall maintain cell compression without requiring adjustments by the user. Tray/cell assembly must be capable of being stacked up to (10) units high. No separate racks shall be required.

J. No special ventilation shall be required during the battery operation. Batteries shall have front accessible terminals with clear removable covers to facilitate visual inspections and allow ease of service.

K. Cell posts shall have a threaded integral solid copper insert to directly accept the intercell connector bolt. Posts seals shall be formed by either fusing the lead bushing to the lead post or by utilizing the same heat seal method incorporated into the jar/cover seal. The cell post shall carry a one (1) minute current rating without damage.

L. All battery lug connectors shall be of the circumference compression type. Lugs using a bolt or screw connector to the cable will not be permitted. Lugs shall be sized appropriately for the cable used.

2.03 BATTERY FLOOR SUPPORTS:

A. The battery support structure shall be constructed of modular steel trays supported by a non-conductive, floor mounted pedestal system. The floor supports shall be designed to electrically insulate the battery stack from the floor.

B. The battery support structure shall be treated with acid-resistant finish paint coat.

C. The steel modules shall be UBC, seismic Zone 4 qualified.

2.04 BATTERY ACCESSORIES

A. Each battery shall be furnished with the following accessories:
   1. Intercell and intermodule connectors and terminal plates. The connectors shall be lead-tin plated copper and shall include stainless steel hardware.
   2. Module lifting straps.
   3. No-Ox-ID grease.
   4. One set of numerals (one numeral per cell) suitable for permanent attachment to cells.
   5. Assembly Shop Drawings.
   6. Material Safety Data Sheets
   7. Each module shall include an easily removable transparent "snap on" safety shield to cover all electrical connections.
   8. Shims for battery leveling.

B. Spill containment kit:
   1. Shall be at least two (2) inches longer and one (1) inch wider than rack footprint.
   2. Containment rails, splices and corner pieces: Minimum four (4) inch high sides, with 28+ oxygen index and V-0 flammability rating.
   3. Membrane liner: 6 mil thick plastic with 28+ oxygen index and VTM-0 flammability rating.
   4. Provide absorbent neutralizing pillows, as required.
   5. Electrolyte resistant plastic mat with ¼ inch raised lip to contain drips shall be provided under each battery rack, extending not less than 12 inches outside the rack.

C. Nameplates: Each battery bank shall be provided with a stainless steel nameplate attached to the battery housing by stainless steel rivets and marked with the following information, as a minimum. The nameplate must be readily visible from the front of the battery:
   1. Manufacturer's name
   2. Month and year of manufacture
   3. Battery and cell type
   4. One-minute, 1-hour, and 8-hour ampere ratings
   5. Ampere-hour capacity at 8-hour rate

2.05 BATTERY DISCONNECT SWITCH

A. Provide a two pole, external-handle operated, 250 Vdc rated fused disconnect switch to permit electrical isolation of the station batteries.

B. Contractor shall coordinate the fuse and switch ratings with the battery charger dc output circuit breaker.

C. The fused disconnect switch shall be mounted in a NEMA Type l enclosure located near the battery rack. The fuses shall comply with NEMA FU-1 and shall provide short circuit protection for the battery and main cables to the dc distribution panelboard.

D. The fused disconnect switch shall be provided with auxiliary contacts and shall annunciate when opened.

2.06 BATTERY CHARGER/ELIMINATOR

A. Battery chargers shall be completely automatic, microprocessor-controlled, fully regulated, convection cooled, designed for use as a battery eliminator, and complying with NEMA PE-5.

B. Battery charger enclosure shall be NEMA 250, Type 1 or 4, sheet steel of 18-gauge for skin and 16-gauge for chassis and door, minimum. Enclosure shall be provided with a hinged front panel complete with lockable handle and two-point latches, minimum. Contractor shall be responsible for ensuring that the proposed enclosure fits satisfactorily in the available substation floorspace.

C. Battery chargers shall be rated as follows:
   1. Capacity: In accordance with battery size and substation dc loads.
   2. Recharging: Shall be able to recharge the battery from 1.75 Volts per cell to 90 percent of the battery capacity in 8 hours, maximum.
   3. Input Voltage: 480 Vac, 60 Hz three-phase.
   4. Output Voltage: In accordance with specified battery voltage.
   5. Output Current: In accordance with battery size and continuous dc load.

6. Regulation: ±1 percent of output dc voltage over the complete load range with ±10 percent variation of input ac voltage.
7. Output Current Limiting: Adjustable from 90 to 110 of rated output, factory set at 110 percent.

D. The charger output voltage and current shall be controlled by a microprocessor which also monitors the internal components of the charger for faults in performance.

E. The charger shall monitor battery ambient temperature via a remote probe and provide compensation accordingly. Automatic probe failure detection and fail-safe control override features shall be provided.

F. The charger shall provide error messages, self-diagnostics and operating conditions via a digital display.

G. Provide the following front-panel LED lamp alarm indicators, and alarms with output contacts:
1. High dc voltage (annunciates)
2. Low dc voltage (annunciates)
3. Dc output failure (annunciates initiates Device 27B timer)
4. Positive ground fault indicator (annunciates)
5. Negative ground fault indicator (annunciates)
6. Ac input failure (annunciates and initiates Device 27B timer)
7. Common alarm

H. Each battery charger shall be furnished with the following accessories. Meters may be combined into digital meters, provided the specified functionality is provided:
1. One dc voltmeter, 0 to 200 Volts
2. One dc ammeter, range as applicable
3. One ac input pilot light marked AC POWER ON
4. One selector switch or pushbutton for FLOAT and EQUALIZE modes
5. "EQUALIZATION METHOD" selector
6. "EQUALIZE HOURS REMAINING" indication
7. One ac input three-pole molded-case circuit breaker
8. One dc output two-pole molded-case circuit breaker
9. Ac input and dc output MOV-type transient overvoltage protection
10. High temperature shutdown with user-selectable shutdown temperature
11. Surge withstand protection in accordance with IEEE C37.90.1

I. Battery charger shall be provided with a communications module that provides remote control and indication features. The Contractor shall integrate this module and resulting serial data stream so it successfully communicates with the Traction Power Substation SCADA system. The communications module shall include the following features:
1. Modbus protocol via RS-232 or RS-485 serial connection.

2. Transmittal of all alarms listed in Article 2.06 (G) of this Section, plus common alarm relay.

2.07 DC DISTRIBUTION PANELBOARDS

A. Dc panelboards shall comply with the requirements of NEMA PB-1 and certified to UL-67, and shall be suitable for 2-wire, 125 Vdc ungrounded power distribution service. Panel-board shall be equipped with main and branch circuit breaker type disconnects complying with NEMA AB-1.

B. Panelboards shall be surface mounted, dead-front type, housed in a NEMA Type 1 steel enclosure with hinged front cover, lockable handle, and two-point latch, minimum.

C. A moisture resistant circuit directory shall be furnished and attached to the inside face of the cover.

D. Establish the required current rating of the dc control power distribution panel-boards. Branch circuit breakers shall be 100 A frame size (AF), with 10,000 A interrupting rating (AT), minimum.

E. Panelboards shall be furnished with the required number of branch circuit breakers as indicated on the Contract Drawings, plus four (4) spares.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Install battery and specified equipment within each substation enclosure: secure, plumb and level and in true alignment with related adjoining work.

B. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, angles, as required to set and rigidly connect the work.

C. Battery cells shall be assembled on the battery racks, filled with electrolyte, and given an equalizing charge, following the installation of the prefabricated unit substation at the site, but not before the start of field testing.

D. Battery intercell connectors shall be assembled, torqued and tested per the battery manufacturer's specifications. The completed battery shall have the intercell connectors tested with a micro ohmmeter. Any intercell connector that fails the manufacturer's specified requirement by twenty (20) percent shall be disassembled, cleaned, prepared, reassembled and re-tested until it tests within the specified limits.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16270.001 – Traction Power Substation 125 Vdc Battery System shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16270.001 – Traction Power Substation 125 Vdc Battery System will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16280

TRACTION POWER SUBSTATION ENCLOSURE

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Traction Power Substation Enclosure, in accordance with the Contract Documents

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design, construction and installation of the enclosure for a new prefabricated-type traction power substation. The 6 MW rating shall be obtained by the use of two (2) 3 MW transformer/rectifier units.
   2. Enclosure work includes lighting, HVAC, and other interior and exterior furnishings.
   3. The contractor shall provide architectural cladding on the exterior of the substation walls that will be coordinated with Authority.

C. This is a performance specification. The Contractor shall be responsible for the selection and complete design of the Traction Power Substation Enclosure system. The Contract Documents provide parameters and design criteria for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16200, "Traction Power Substation General Requirements."

B. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

C. Section 16360, "Traction Power Substation Testing."

D. Section 16742, "Supervisory Control and Data Acquisition (SCADA) System"

E. Section 16135, "Intrusion Detector"

1.03 REFERENCE STANDARDS

A. AISC

B. ANSI:
   1. Z55.1 – Gray Finishes for Industrial Apparatus and Equipment
   2. Z358.1 – Emergency Shower and Eyewash Equipment

C. ASHRAE:

1. 52.1 – Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
2. 52.2 – Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size

D. ASTM:
1. A36/A36M – Standard Specification for Carbon Structural Steel
2. A446/A446M – Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot Dip Process, Structural (Physical) Quality
3. B117 – Standard Practice for Operating Salt Spray (Fog) Apparatus
4. D229 – Standard Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation
5. E136 – Standard Test Method for Behavior of Materials in a Vertical Tube Furnace
6. E84 – Standard Test Method for Surface Burning Characteristics of Building Materials

E. ARI:
1. 210/240 – Unitary Air-Conditioning and Air-Source Heat Pump Equipment

F. IEEE:
1. 693 – Seismic Design of Substations

G. NEMA:
1. WD1 – General Requirements for Wiring Devices

H. NFPA:
1. 70 – National Electrical Code (NEC)
2. 72E – Automatic Fire Detectors
3. 90A – Standard for the Installation of Air Conditioning and Ventilation Systems

I. UBC

1.04 SUBMITTALS

A. Submit Shop Drawings, technical data and certificates for all items of equipment under this Section:
1. Manufacturer's descriptive literature, catalog data, and other information required to demonstrate compliance with the Contract Documents.
2. Layout arrangement and detailed Shop Drawings of the enclosure with all installed accessories and substation equipment.
3. Certificates of compliance for specified enclosure materials and performance.
4. Samples of architectural cladding on substation enclosure exterior, for approval by Authority.
5. Structural analysis calculations for building and seismic loadings as detailed below:
   a. Structural calculations shall be certified by a structural Professional Engineer.

   b. Compare stress capacities/allowable stresses to applied stresses.
   c. Include manufacturers gauge metals cut sheets showing material properties.
   d. Clearly define assumptions, loads, constants and abbreviations used.
6. Heating capacity calculations, as detailed below:
   a. Provide heating calculations for the winter season at the minimum exterior ambient temperatures and thermostat set points, specified in Section 16200, "Traction Power Substation General Requirements." Clearly define assumptions, loads, constants and abbreviations used.
   b. Neglect electrical equipment heat contribution.
7. Air conditioning capacity calculations, as detailed below:
   a. Provide air conditioning calculations for the summer season at the maximum exterior ambient temperatures and thermostat set points, specified in Section 16200, Traction Power Substation General Requirements." Clearly define assumptions, loads, constants and abbreviations used.
   b. Include the heat contributions of all enclosure electrical equipment with the equipment operating at 100% rated continuous load.
8. Lighting layout plans showing illumination levels, at the specified heights, indoors and within the fenced limits of the substation yard.
9. Certified test results of thermal, electrical and acoustical insulation.
10. Site installation working drawings, including the following:
    a. Foundation piers and door entry pads
    b. Enclosure base anchorage locations
    c. Conduit stub-up locations
11. Enclosure and equipment grounding details.
12. HVAC equipment wiring and schematic diagrams.
13. Substation equipment interconnection wiring diagrams and raceway schedules.
14. Provide proof that similar equipment, presently being used on extra heavy rail transit systems, have developed a satisfactory operating history for a minimum of five (5) years.
15. Electrical system calculations as detailed below:
    a. Raceway % fill analysis, each raceway
    b. Arc-flash hazard analysis
16. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

1.05 QUALITY ASSURANCE

A. The equipment manufacturer shall maintain ISO 9001, or ISO 9002, certification.

1.06 QUALIFICATIONS

A. Design shall be that of a field proven product. No prototypes will be considered. A proven product is considered to be similar units presently being used on extra heavy rail transit systems and having developed a satisfactory operating history for a minimum of five (5) years.

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. The enclosure shall be designed in accordance with AISC specifications to withstand live roof loading, wind loading and seismic loading with all equipment and architectural treatments installed based on the service conditions described in Section 16200, "Traction Power Substation General Requirements," and the stresses caused during loading, transportation and installation. Doors, walls, and roof panels shall be reinforced by braces, stiffeners, and/or structural members as required to provide a rigid, modular structure.

B. Overall substation dimensions shall not exceed those indicated on the Contract Drawings. The height of the substation shall be as low-profile as possible with a minimum interior height of 8.5 feet. Interior working spaces and clearances shall comply with NFPA 70, Article 110, both in size and arrangement.

C. The enclosure shall be a totally integrated, weatherproof unit, housing the indicated traction power substation equipment. The enclosure shall provide a dry, vermin-proof, and condensation-free, stable internal ambient temperature environment. The enclosure shall be provided with gutters and down spouts at each end. The enclosure shall have a Group B, Division 4 occupancy classification, Type I fire resistive construction and meet the requirements for prefabricated buildings as defined in the UBC.

2.02 HEATING, VENTILATION AND AIR CONDITIONING

A. Provide redundant, heavy duty, one-piece wall-mounted, factory-assembled modular HVAC units as detailed below:
   1. Cooling and heating capacities to meet the specified requirements with one (1) unit out of service.
   2. 480 Vac operation, 120 Vac maximum for controls.
   3. Economizer option with built-in exhaust damper to allow user-adjustable volumes of exterior cooling air input under appropriate conditions.
   4. Disposable filters adequate for preventing the entry of dust. Filters shall be replaceable pleated micro glass high efficiency filters, complying with ASHRAE Standards 52.1 and 52.2.
   5. Digital controller with the following features:
      a. Compressor current and dirty filter sensors.
      b. HVAC failure alarm relay outputs that annunciate.
      c. Alternating master-slave unit operation to provide approximately equal use of both HVAC units, and to preclude simultaneous startup of both units.
      d. Alarm contact that annunciates when substation interior temperature exceeds 100° Fahrenheit.
   6. Low ambient control option to permit cooling down to a 0° Fahrenheit external ambient temperature.

7. Cabinet of minimum 20-gauge galvanized steel with exterior finish capable of resisting a minimum 1,000 hour salt spray exposure, per ASTM B117.
8. Quiet operation as measured from the enclosure interior and exterior.
9. Proven method of leak-proofing at the unit interface with the enclosure.

B. Provide a vent fan to periodically exhaust the fumes generated by the station batteries. This fan shall be suitably mounted on the enclosure wall directly above the batteries. Failure of this fan shall annunciate.

2.03 WALLS AND FLOOR

A. Exterior wall panels shall be 12-gauge galvanized steel, minimum, with architectural cladding to match color and finish, as approved by Authority. Interior walls shall be 14-gauge galvanized steel, minimum.

B. The floor shall be designed to accommodate all conditions of load, installation, service and insulation. Electrical insulation shall be provided in floors and walls to provide a dielectric strength of 300 Volts/mil.

C. The floor under equipment and immediately in front of equipment shall provide for equipment glide bars or skids so that repeated equipment removal will not damage the floor.

D. Floor load designs shall provide for full, safe support of the heaviest equipment item which may be skidded across the floor during removal/replacement, and in no case shall the floor capacity be less than 100 psf, providing deflection no greater than 1/360 of span.

E. Floor surfaces shall have a non-skid waterproof long-wearing floor covering.

F. Where conduit stub-ups penetrate the floor for access to equipment for cabling, the floor shall be panelized to permit the fabrication and installation of a neat hand access panel near or at the stub-up to facilitate complete sealing of the cable entrance fitting.

2.04 DOORS

A. The substation shall have two (2) entry doors, located as indicated on the Contract Drawings. One (1) door shall be the main entry double door.

B. Doors shall be equipped with panic hardware consisting of three-point crash-bar safety latches to permit opening from within under all conditions. The latches shall have tamper-proof locks integrated with entry handles; equipped with visual indication that door is locked or unlocked.

C. All entry doors shall be keyed alike, with provision for re-keying by Authority after energization.

D. Locking arrangement will be coordinated with Authority access control requirements.

E. Door closers shall be provided and doorstops furnished to hold the door in the open position. Hinged exterior access doors, with three-point latches and padlocking lugs, shall be provided behind equipment requiring access for cable makeup or maintenance.

F. Main entry door shall be not smaller than as shown on the Contract Drawings and sized to permit removal of substation equipment including the rectifier units.

G. The inside face and all panic hardware components for the door nearest the dc switchgear shall be covered with an insulation material of a suitable rating to prevent electric shock of personnel when the dc switchgear enclosure is fully energized.

H. All hinged interior and exterior doors providing access to circuit breaker cubicles, rectifier compartments and other equipment, shall have three-point latches and handle stops to hold doors in the open position.

2.05 FINISHES

A. Interior and exterior metal surface finishes: in accordance with Section 16200, "Traction Power Substation General Requirements."

B. Epoxy electrical floor insulation:
   1. Provide a permanent layer of approved epoxy electrical floor insulation in the rectifier and dc switchgear area of the substation enclosure as indicated on the Contract Drawings.

C. Exterior metal floor bottom and base framing (base assembly):
   1. All welds shall be ground smooth prior to cleaning.
   2. Cleaning shall include grit or high-pressure water blasting followed by phosphatizing to remove all oils, grease and other contaminants.
   3. High-build industrial grade epoxy paint coats shall be applied to the entire assembly to providing minimum dry film thicknesses of 4 mils for the floor and 6 mils for the sides.
   4. Additional black polyurethane paint layer of minimum dry film thickness shall be applied to the bottom of the base.

2.06 THERMAL INSULATION

A. Provide minimum R-11 insulation level for substation walls and ceiling.

B. All insulating materials shall have a certified classification of non-combustible, as defined by ASTM E136 and ASTM 84.

2.07 INTERIOR ELECTRICAL WORK

A. Power Receptacles:

1. Duplex, heavy-duty, 20 ampere, 120 Vac, 3-wire grounded type receptacle, conforming to UL-498 and NEMA WD-1, shall be provided at each entry door near the ac and dc switchgear.
2. A weatherproof, heavy-duty 20 ampere duplex outlet shall also be provided at each entry door on the exterior wall. The receptacle shall be located behind a vandal proof bolted panel.

B. Conduit, Cable Trays and Wireways:

1. Provide conduit, cable trays, wireways, supports, junction boxes, and related hardware as needed to meet applicable codes and equipment power, control and indication requirements.
2. Non-metallic cable trays and wireways will be required for all dc cables.

C. Portable Generator:

1. Provision for connection of a 480 Volt generator from the outside of the substation enclosure.

2.08 LIGHTING

A. Fluorescent lighting shall be furnished for the interior of the substation. Contractor's lighting design shall provide for the following minimum maintained lighting levels:

1. Normal lighting: 30 foot candles, average, at 30 inches above the aisle floor.
2. Emergency lighting: 5 foot candles, at 30 inches above the aisle floor.

B. Outdoor lighting shall be provided by mercury or sodium fixtures with unit photo-cell control for visibility and security, located as shown on the Contract Drawings. Design shall provide a minimum level of two foot-candles at ground level within an approximate 15 foot radius. The fixtures shall be weather and thermal resistant.

C. Location of lighting fixtures shall be coordinated to avoid interference with overhead raceways or other major wiring and shall not be directly above switchgear, rectifiers or transformers. Indoor lighting shall be controlled by a flush mounted single-throw, two-way switch located at each entry door.

D. A minimum of two (2) low power, high efficiency emergency lighting fixtures shall be powered from the substation auxiliary power system inverter. Provide controls to energize the lamps automatically upon failure of the ac power when a substation light switch is in the "ON" position only.

2.09 FIRE DETECTION

A. Provide smoke/fire detectors within the enclosure suitably mounted to provide as early warning as possible of the existence of fire. Detector alarm contact shall provide annunciation at Authority's Operations Control Center (OCC).

B. Smoke/fire detector shall be a UL listed, dual chamber, ionization type complying with NFPA 72E. Detector shall not be battery powered nor shall it contain radium. Sensitivity shall be adjustable. Detection system shall annunciate locally and remotely upon operation; local audible indication is not required.

2.10 INTRUSION DETECTION SYSTEM

A. Provide an intrusion detection device on each door.

B. Device shall be actuated upon opening the door by any means and shall be deactivated and activated manually by programmable coding with adjustable time delays after entry into and departure from the substation enclosure respectively.

C. Intrusion detection devices shall provide remote alarm to OCC upon operation.

2.11 EMERGENCY EYE WASH

A. Provide a portable eye-wash unit. The eyewash shall be a wall-mounted unit with two disposable bottles. Unit shall be manufactured by North Safety Products, catalog number 16-60-42, or approved equal.

B. Eyewash location shall be identified with a highly visible sign. The area around or behind the eyewash, or both, shall be painted a bright color and shall be well lit.

2.12 NOISE LEVELS

A. Interior noise levels: in accordance with OSHA requirements.

B. Exterior noise levels: in accordance with Section 16200, "Traction Power Substation General Requirements."

2.13 TEST CABINETS

A. Provide complete and separate wall-mounted breaker test set units for the testing of racked-out ac and dc power circuit breakers.

B. Test units shall be compatible with the type and rating of ac and dc circuit breakers installed in the substation.

C. The test cabinets shall include a control switch similar to that furnished with the switchgear to close and trip the breaker; red and green LED breaker position indicating lights; ten (10) feet of control cable with a connector at the end for connection to the breaker; a set of properly sized fuses to protect the control circuit; and, screw type terminals for a 125 Vdc control supply. An additional indicating LED with white lens shall be provided for monitoring the control supply. The 125 Vdc control power shall be provided from a dedicated circuit breaker in the substation dc distribution panel.

2.14 PORTABLE FIRE EXTINGUISHERS

A. A dry chemical type portable fire extinguisher, UL rating 3-A: 20-B: C, shall be provided and suitably mounted near each entry door, as indicated on the Contract Drawings.

2.15 WARNING SIGNS

A. A warning sign shall be installed on each of the four (4) exterior walls of the substation building. Warning signs shall conform to specifications as identified in Section 16200, "Traction Power Substation General Requirements."

B. Within the substation enclosure, warning signs shall be provided for indication of high resistance grounding.

2.16 SUBSTATION EMERGENCY STATION LIGHTS (BLUE LIGHTS)

A. Emergency station lights shall be provided as shown on the Contract Drawing for the substation. The Blue Light Station (BLS) shall consist of an emergency pushbutton, Blue Light fixture and emergency telephone, as indicated on the Contract Drawings.

2.17 TOOL CABINET

A. Provide heavy duty steel cabinet suitable for the expected small spare parts, tools, operating and maintenance manuals, and schematics to be provided by the Contractor, as indicated on the Contract Drawings.

ARTICLE 3 EXECUTION

3.01 COORDINATION WITH FOUNDATION AND ENTRANCE SLABS

A. The Contractor shall coordinate enclosure design and installation with foundation pier and entrance slab installation. The Contractor shall be responsible for the matching of enclosure anchor locations with piers, and the level mating of door slabs with as-installed enclosure doorways.

3.02 TRANSPORT

A. Prepare complete substation enclosures for transport by securing or removal of all loose items.

B. Remove and separately package all interior and exterior components which are likely to be damaged in transport due to vibration, lifting, or bumping, etc.

C. Disconnect and remove all battery cells and pack and secure in a pan for transport.

D. Use spreader bar for lifting so as not to damage form, fit, or finish of equipment.

E. The Contractor shall utilize the services of an experienced and fully bonded rigging contractor to perform all lifting and transport of the new substation.

3.03 FIELD INSTALLATION

A. Mount, re-assemble and anchor enclosure in accordance with the approved Shop Drawings and the manufacturer's requirements.

B. Re-connect substation components and systems as required and test as specified in Section 16360, "Traction Power Substation Testing."

C. Grounding connections shall be installed in accordance with the approved Shop Drawings.

D. All ac switchgear/equipment shall be confirmed connected to the substation ground bus.

3.04 FIELD TESTING

A. Reassembled substation enclosure shall be subjected to simulated, ASTM 45° degree Rain Test for a period of fifteen (15) minutes. Inspect enclosure interior for any water seepage.

3.05 FIELD TOUCH-UP

A. Damaged interior and exterior surface coatings shall be cleaned and repainted with the same coating system used in the factory painting.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16280.001 – Traction Power Substation Enclosure shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16280.001 – Traction Power Substation Enclosure will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16295

TRACTION POWER SUBSTATION WIRE AND CABLE

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Traction Power Substation Wire and Cable, in accordance with the Contract Documents.

B. The Work of this Section includes, but is not limited to, the following activities:
   1. Cable installation.
   2. Cable Testing.
   3. Product Replacement.

1.02 RELATED SECTIONS

A. Section 16200, "Traction Power Substation General Requirements."

B. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

1.03 REFERENCE STANDARDS

A. AEIC:
   1. CS8 – Specifications for Extruded Dielectric Shielded Power Cables Rated 5 through 46 kV

B. ANSI:
   1. C37.20.2 – Metal Clad and Station-Type Cubicle Switchgear

C. ASTM:
   1. B3 – Soft or Annealed Copper Wire
   2. B8 – Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
   3. B33 – Tinned Soft or Annealed Copper Wire for Electrical Purposes
   4. B98 – Copper-Silicon Alloy Rod, Bar, and Shapes
   5. B173 – Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members for Electrical Conductors

D. ICEA:
   1. S-73-532 – Standard for Control Cables
   2. S-93-639 – Shielded Power Cable 5-46 kV
   3. S-95-658 – Non-Shielded 0-2 kV Cables
   4. T-33-655 – Low-Smoke, Halogen-Free (LSHF) Polymeric Cable Jackets

E. IEEE:

1. 693 – Recommended Practice for Seismic Design of Substations
2. 1202 – Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies R (1997)

F. NFPA:
   1. 70 – National Electrical Code (NEC)

G. UL:
   1. Electrical Construction Equipment Directory (ECMD)
   2. 44 – Thermostat-Insulated Wires and Cables
   3. 83 – Thermoplastic-Insulated Wires and Cables
   4. 94 – Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
   5. 854 – Service Entrance Cables

1.04 SUBMITTALS

A. Submit Shop Drawings, product data, printed installation instructions, manufacturer's literature, manufacturers' printed testing and installation instructions. Submittals shall include, but not be limited to, the following:
   1. Product data for wire and cable and associated material.
   2. Shop Drawings and cable section details for cable assembly.
   3. Factory test program plan, test procedures, and test data.
   4. Field testing instructions.

B. Submit advance notice of factory testing.

C. Submit reports of tests. State that cable was tested to requirements of this Section, and include results of tests.

D. Submit As-Built Drawings of the cable installations, including 23 kV splices.

E. Submit evidence that the material furnished conforms to the specified standards and recommendations provided in this Section.

F. Provide proof that similar units, presently being used on extra heavy rail transit systems, have developed a satisfactory operating history for a minimum of five (5) years.

1.05 QUALITY ASSURANCE

A. Material shall conform to the latest IEEE, ASTM, ICEA, UL, NEMA, and ANSI standards. The Contractor shall submit evidence to the Engineer that the material furnished in accordance with this Section conforms to the specified standards and recommendations. The labeling of, or listing by UL will be acceptable evidence that material conforms to the requirements of UL. A certification or published specification data statement by a manufacturer, listed as a member of NEMA, to the effect that material conforms to the specified NEMA standards and to the Contract Documents will be acceptable evidence.

B. Electrical work shall conform to NFPA 70 (NEC). Codes referred to are minimum standards.

C. The cable/wire manufacturer shall maintain ISO 9001 or ISO 9002 certification.

1.06 QUALIFICATIONS

A. Design shall be that of a field proven product. No prototypes will be considered. A proven product is considered to be similar cable presently being used on extra heavy rail transit systems and having developed a satisfactory operating history for a minimum of five (5) years.

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Cable shall be round, copper conductors, concentric lay stranded, class B, conforming to ASTM B8, unless otherwise indicated.

B. Conductor coating, where specified, shall be tin-coated conforming to ASTM B33. Uncoated wire shall be electrolytic-grade, soft-drawn copper, in accordance with ASTM B3.

C. Cable marking shall include the name of the manufacturer, voltage rating, type and size, at a maximum spacing of 18 inches. The marking shall remain legible for the life of the cable under normal conditions of installation and service. Wire that is stamped with the name of a color or colored labels in lieu of colored insulation will not be accepted.

D. Wire and cable installed in cable trays shall be approved for use in cable trays.

E. For circuits operating below 600 Volts, wire and cable shall be insulated for 600 Volts and for circuits operating at 601 Volts through 1,000 Volts, wire and cable shall be insulated for 2,000 Volts. For circuits operating at 23 kV, cable shall be insulated for 25 kV.

2.02 AUXILIARY POWER CONNECTORS

A. Shall be copper and conform to UL-44, Type XHHW-2, UL-44, Type RHH (in dry locations only), or UL-854, Type RHW-2.

B. Number 10 AWG, and larger, shall be stranded; other sizes shall be solid.

C. Power feeders and branch circuit conductors shall have green insulated grounding conductors. Conductors including neutral conductors shall be the same size as branch circuit conductors. Reduced ground conductor sizes are acceptable, as per the NFPA 70 (NEC).

D. Conductors for light and power circuits shall be color coded as follows:

TABLE 16295-1 "AC Conductor Color Coding"

Phase	480/277 Volts	208/120 Volts
A	Brown	Black
B	Orange	Red
C	Yellow	Blue
Neutral	Grey	White
Ground	Green	Green

TABLE 16295-2 "DC Conductor Color Coding"

125 Volts DC	
Positive	Red
Negative	Black

2.03 CONTROL WIRE AND CABLE

A. Multi-conductor control cable shall be insulated with Type II Cross-linked Polyethylene or Type II Ethylene Propylene Rubber compound, and jacketed with a low-smoke, halogen-free (LSHF) Cross-linked Polyolefin compound, or approved equal. Temperature rating shall be 194° F, continuous. Color-coding shall conform to ICEA S-73-532, Method 1, Table E-2. Insulation shall conform to Part 3 of ICEA S-73-532. Jacket material and thickness shall meet the requirements for Thermoset Type II material in accordance with ICEA T-33-655. Multi-conductor control cables shall be cabled together into a circular cross-section by using non-hygroscopic filler and tape. Control cable shall be in conformance with UL-44. Single conductor shall comply with UL's VW-1 flame test and finished cable shall meet flame test requirements of IEEE-1202. Where multi-conductor control cable is indicated as 36-conductors, it shall be interpreted as 37-conductor cable with the green conductor cut back to be consistent with existing color-coding and cable installations.

B. Factory Test Requirements:

1. Single conductor control cable shall have each insulated length of conductor emmersed in a water tank for a minimum period of six (6) hours. Ac voltage withstand test shall be applied at the end of six (6) hours for a duration of five (5) minutes on each length of insulated conductor. Applied ac test voltage shall be 3.5 kV, for size 16 AWG to 9 AWG, and 5.5 kV, for sizes 8 AWG to 2 AWG.
2. Multi-conductor control cable shall have an ac voltage withstand test applied to each completed cable length for a duration of one (1) minute. Test shall be applied to the cable on the master reel. Applied ac test voltage shall be 3.5 kV, for size 16 AWG to 9 AWG, and 5.5 kV, for sizes 8 AWG to 2 AWG.
3. Insulation and jacket wall thickness shall be measured and recorded.
4. Dc resistance of each conductor shall be measured and recorded.

2.04 25 KV CABLE

A. Single-conductor 25 kV cable shall be No. 250 kcmil, copper, 19-strand insulated, shielded, and jacketed meeting requirements of ICEA S-93-639 and AEIC CS8. Conductor rating shall be 194° F, under continuous operation. Class B stranding shall be concentric lay and in accordance with ASTM B8. Cable insulation shall be concentric within the tolerances specified in Article 1.03 of this Section, and shall be Type III Ethylene Propylene Rubber, or accepted equivalent, minimum 260 mils thick. Conductor shielding shall consist of an extruded semi-conducting thermosetting material in accordance with AEIC CS8. Insulation shielding shall consist of an extruded semi-conducting thermosetting material and a non-embedded helically applied 5 mils minimum thickness copper tape in accordance with ICEA S-93-639. Extruded material shall be in accordance with AEIC CS8. A low-smoke, halogen-free Cross-linked Polyolefin jacket, minimum 80 mils thick, shall be extruded overall. The jacket material shall meet requirements for Thermosetting Type II material in accordance with ICEA T-33-655. Finished cable shall meet the flame test requirements of IEEE-1202.

B. Three-conductor 25 kV power cable Type MV or Type MC shall be 250 kcmil, copper, insulated, shielded and jacketed meeting the requirements of ICEA S-93-639 and AEIC CS8. Conductors rating shall be 194° F, under continuous operation. Class B stranding shall be concentric lay and in accordance with ASTM B8. Cable insulation shall be concentric within the tolerance specified in Article 1.03 of this Section, and shall be Ethylene Propylene Rubber, or accepted equivalent, minimum 260 mils thick. Conductor shielding shall consist of an extruded semi-conducting thermosetting material in accordance with AEIC CS8. Grounding conductor shall be annealed bare copper class B stranding per ASTM B8. Cable sheathing shall be impervious, continuous corrugated aluminum.

C. Factory Test Requirements:
   1. The 25 kV power cable shall have an ac voltage withstand test applied to each completed cable length for a duration of one (1) minute. Test shall be applied to the cable on the master reel. Applied ac test voltage shall be 38 kV.

2. The three-conductor 25 kV power cable shall have the insulated length of cable be emmersed in a water tank for a minimum period of six (6) hours. Ac voltage withstand test shall be applied at the end of six (6) hours for a duration of five (5) minutes on each length of insulated conductor. Test shall be applied to the cable on the master reel. Applied ac test voltage shall be 38 kV.
3. Insulation and jacket wall thickness shall be measured and recorded.
4. Dc resistance of each conductor shall be measured and recorded.

2.05 650 VOLT DC POWER CABLE

A. Cable for 650 Vdc power positive and negative feeders shall be single conductor, insulated, non-shielded cable, 1,000 kcmil (61 strands), Class B rated 2,000 V. Other cables for 650 Vdc service, installed in cable trays and conduit, shall be as indicated, but no smaller than No. 6 AWG, 19 strands (Class C), rated 2,000 V. Class B and Class C stranding shall be concentric lay, in accordance with ASTM B8. The insulation shall be heat, moisture, ozone, and flame-resistant. Cable shall comply with ICEA S-95-658 and UL-44 test requirements for 2,000 V, used at a conductor temperature of 194° F, and shall be UL-listed as Type RHW-2. Cable insulation shall be Type I Ethylene Propylene Rubber, in accordance with ICEA S-95-658, except that the minimum tensile shall be 1,000 psi. Insulation thickness shall be 90 mils for 650 kcmil cable, 65 mils for #1/0 AWG cable, and 55 mils for #6 AWG cable. Cable shall have an overall jacket consisting of a low-smoke, halogen-free (LSHF) Cross-linked Polyolefin material. Jacket thickness shall be in accordance with ICEA S-95-658, Table 4-2, for single-conductor, non-shielded cable. Plus, the material shall meet the requirements for Thermoset Type II, in accordance with ICEA T-33-655. Finished cable shall meet the flame test requirements of IEEE-1202.

B. Flexible cable for connections to power rail shall consist of a single-conductor insulated, non-shielded cable rated 2,000 V. Cable shall be identical to cable specified for positive and negative feeders except that the cable shall be 500 kcmil, as indicated on Contract Drawings, Class G rope lay stranding in accordance with ASTM B173 and the conductors shall be tin-coated conforming to ASTM B3.

C. Factory Test Requirements:
   1. The 2 kV power cable shall have each insulated length of conductor emmersed in a water tank for a minimum period of six (6) hours. Ac voltage withstand test shall be applied at the end of six (6) hours for a duration of five (5) minutes on each length of insulated conductor. Applied ac test voltage shall be 9.5 kV for 1,000 kcmil, and 7 kV for No. 1/0 AWG and under.
   2. Insulation and jacket wall thickness shall be measured and recorded.
   3. Dc resistance of each conductor shall be measured and recorded.

2.06 CABLE FITTINGS AND CONNECTORS

A. Control wire and cable terminals shall be nylon-insulated crimp-type, ring or lug terminals, or as indicated. Crimp type terminals shall be attached to conductors by means of a full stroke, ratchet release type compression tool of a make and model recommended by the terminal manufacturer for use with the terminal being utilized. Terminals shall be tin-plated electrolytic copper.

B. Lugs for 2,000 V power cable shall be heavy-duty, long barrel, double indent for Class G stranded, flex cable and circumferential crimp for Class C stranded cable, tin-plated, compression-type of heavy-wall, seamless, high-conductivity copper tubing. Lugs shall be of the two-hole type, spaced and sized to NEMA standards, for 96 percent IACS. Lugs shall have markings indicating manufacturer's die code number and shall be compatible with installation tool. Splicing of 2,000 V power cable shall only be performed where indicated on the Contract Drawings and shall be performed using a 5,000 V fire retardant splice kit or an equivalent kit of not less than the 2,000 V rating of the cable insulation.

C. Flexible 1,000 kcmil cable to power rail connection plates shall be compression lug type.

D. The 25 kV cables from the ac breaker to the transformer shall be terminated with double indent-type compression lugs and stress relief cones. Stress relief cones shall be a product of Raychem, or approved equal, and installed in accordance with manufacturer's printed instructions.

E. Conduit sealing bushing shall be Type CSBE conduit sealing bushing as manufactured by O. Z. Gedney Company, Inc., or approved equal. Conduit sealing bushings for the Negative Bus Box shall be CSBI-type. Conduit sealing bushings shall be UL listed as a conduit sealing device.

2.07 ELECTRICAL TAPES

A. Electrical tapes shall be:
1. Cross-linked, self amalgamating, ethylene propylene rubber (EPR): Plymouth Bishop No. W963, or approved equal.
2. Cross-linked, self amalgamating polyethylene: Plymouth Bishop No. 3 Bi-Seal, or approved equal.
3. Mastic: Plymouth Bishop No. 10 Plyseal, or approved equal.
4. Insulating, self-adhesive plastic: Plymouth Bishop Premium 85 CW Electrical Plastic Tape, or approved equal.

ARTICLE 3 EXECUTION

3.01 TESTING

A. Scope: The Contractor shall demonstrate that all equipment and material is manufactured, assembled, installed and tested in accordance with the Contract Documents, Contractor's design, the manufacturer's recommendations, and is in operable condition. The Contractor shall be responsible for the testing program.

Instruments, labor, tools and test procedures required for testing shall be provided by the Contractor. The Contractor shall furnish additional testing by an independent testing laboratory if the Contractor's test procedures are determined by the Engineer to be inadequate to verify Contract compliance. Such tests shall be accomplished without additional cost to Authority. The Engineer will observe tests and attest to the recording of data.

B. Test Program Plan: The Contractor shall prepare and submit for Engineer's approval a Test Program Plan including, test schedule, test procedures, test data, and test reports. All test scheduling, test procedures, test conduct, test data recording, and test data submittal shall be in accordance with the Contract Documents, and in the approved Test Program Plan.

C. Design Test Requirements: Design tests shall be required of the manufacturers unless certified designed test reports for duplicate or essentially duplicate product are submitted to the Engineer for review and approval.

D. Factory Tests: Factory testing shall be performed in accordance with Article 1.03 of this Section, and as required by modifications and additions herein. Tests shall include, but not be limited to, the tests listed in Article 2 of this Section. Certified copies of design and production test results which include actual test data sheets shall be furnished to the Engineer. Procedures for factory testing shall be submitted to and approved by the Engineer. The Contractor shall provide the Engineer two (2) weeks advance notice of a factory test.

3.02 CABLE INSTALLATION

A. Before installation of cable in any conduit system the Contractor shall pull a suitable wire brush, swab and mandrel through the conduit to remove extraneous matter and to verify that the raceway system is free of obstructions.

B. The mandrel for conduit systems shall be 1/2 inch smaller in diameter than the inside diameter of the conduit, and shall be composed of concentric steel rings for checking the internal clearance of the conduit. Mandrels composed of soft flexible material (leather, rubber) shall not be used.

C. Wireways and cable trays shall be inspected and cleaned of all debris before installation of cable. No kinks in cable will be permitted.

D. Cable shall be pulled directly into the conduit from the coil or reel on which it is received; cable shall not be pulled off and laid on the ground or ballast prior to installation. Pulls shall be made in one direction. Only lubricants recommended by the manufacturer of the cable shall be used. Cable shall be under tension after pulling, or tight against bushing or fittings. When pulling grips are used, damaged cable ends shall be removed upon completion of the pulling operation. No cable shall be pulled with its end open; a rubber tape seal shall be maintained on the cable end at all times.

E. If connections are not made immediately after and cable installation, ends of all cable shall be sealed to prevent entrance of moisture. Ends of cable shall be marked for identification in junction boxes and at terminals. Terminal ends at equipment and terminals between equipment shall be identified by permanent self-laminating vinyl labels of an Engineer-approved type. Groups of cable with the same circuit number shall be identified by a separate sleeve, tape, or tag, with the circuit number machine-printed on such sleeve, tape, or tag.

F. Cable shall be installed single-layer and fastened to the cable tray (or in groups in troughs) on 12-inch centers on vertical runs and on 4-foot centers on horizontal runs. Fastening shall consist of manually-applied, tool-tensioned, self-clamping nylon straps containing no metal parts. Fastening shall be tight enough to hold the cables in place without causing any deformation to the cable insulation and jacket.

G. Cables crossing over other cables in cable trays or troughs shall not be permitted.

H. Barriers to separate 650 Vdc cables from 600 V or less cables shall be provided, where required.

I. Cable shall be installed without splices, unless otherwise approved by the Engineer.

J. The Contractor shall install the 23 kV cable as shown on the Contract Drawings. Cable splices and pull boxes shall not be installed and located along the bend and alignment curve.

K. The Contractor shall install 650 Vdc positive and negative cables, as shown on Contract Drawings.

L. Concealed conduits or conduits embedded in concrete, where provided by others shall be extended by the Contractor, unless indicated otherwise on Contract Drawings.

M. The Contractor shall install risers from the equipment to interface with the cable troughs or trays as indicated on Contract Drawings or where a tray drop is more than two (2) feet.

N. Cables in manholes shall be installed on cable trays or nonmetallic racks furnished and installed under this Contract.

O. All dc cables emerging from underground conduits, through stub-ups, shall be supported with sealing bushings. Sealing bushings shall also be installed at ends of surface mounted guideway conduits, installed under this contract. Unless indicated otherwise on Contract Drawings, termination for positive and negative cables shall be as follows:
   1. The conduit stub-ups for the positive and negative cables, including jumper cables, shall be sealed after cable is installed with a sealing bushing at each end to hold the cable from movement in both directions and to make a water-tight seal.

2. Lengths of flexible cables shall allow for drip loop, distance to rail connection point. Cables between conduit risers shall be supported on 2 kV insulators to avoid coming into contact with any surface, supports or rails.

3.03 PRODUCT REPLACEMENT

A. If products fail tests, remove failed products and install new products, at no additional cost to Authority.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16295.001 – Traction Power Substation Wire and Cable shall be measured per linear foot, complete in place.

4.02 PAYMENT

A. Item 16295.001 – Traction Power Substation Wire and Cable will be paid at the unit price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16300

TRACTION POWER SUBSTATION BUSWAYS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Traction Power Substation Busways, in accordance with the Contract Documents.

B. The Work of this Section includes, but is not limited to, the following activities:
   1. Busway installation.
   2. Busway testing.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data."

B. Section 16200, "Traction Power Substation General Requirements."

C. Section 16210, "Traction Power Substation Basic Materials and Methods."

D. Section 16230, "Traction Power Substation Transformer-Rectifier Units."

E. Section 16240, "Traction Power Substation Metal-Enclosed DC Switchgear."

F. Section 16250, "Traction Power Substation Drainage and Negative Return Switchboard."

1.03 REFERENCE STANDARDS

A. ANSI:
   1. Z55.1 – Gray Finishes for Industrial Apparatus & Equipment

B. IEEE:
   1. C37.23 – Standard for Metal-Enclosed Bus

C. NEMA:
   1. BU-1 – Busways

D. NFPA:
   1. 70 – National Electrical Code (NEC)

E. UL:
   1. 857 – Busways

1.04 SUBMITTALS

A. Submit the following Shop Drawings, technical data and certificates, and test procedures for approval, in accordance with Section 16200, "Traction Power Substation General Requirements:"
   1. Shop Drawings.
   2. Certified test reports for specified factory testing.
   3. Certificates from manufacturer verifying that equipment conforms to specified requirements.

B. Operations and Maintenance Manuals.

C. Spare parts list.

D. Provide proof that similar equipment, presently being used on extra heavy rail transit systems, have developed a satisfactory operating history for a minimum of five (5) years.

1.05 QUALITY ASSURANCE

A. Factory Testing: Submit test plans, procedures and scheduled test date for approval at least 20 working days in advance of scheduled test date. No test results will be accepted prior to approval of test plans and procedures. Factory test requirements are as follows:
   1. Dielectric Withstand Test: Perform a 60 second dielectric withstand test on the busways as follows:
      a. Anode (ac) bus duct: Test between phases and phases to enclosure by applying 2,200 Volts, rms, 60 Hz, or 3,100 Vdc.
      b. Cathode bus duct: Test between live parts and enclosure by applying 3,700 Volts, rms, 60 Hz, or 5,200 Vdc.
      c. Negative bus duct: Test between live parts and enclosure by applying 3,700 Volts, rms, 60 Hz, or 5,200 Vdc.
   2. Continuous current test: Perform tests to demonstrate that bus assembly meets the temperature rise limitations, per IEEE C37.23.
   3. Short-circuit withstand test: To determine the electrical, thermal and mechanical adequacy of buses and connections under short circuit conditions.

B. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

1.06 QUALIFICATIONS

A. Design shall be that of a field proven product. No prototypes will be considered. A proven product is considered to be similar units presently being used on extra heavy rail transit systems and having developed a satisfactory operating history for a minimum of five (5) years.

ARTICLE 2 PRODUCTS

2.01 MATERIALS AND EQUIPMENT

A. General Requirements:
   1. In accordance with IEEE C37.23, NEMA BU-1, and UL 857.
   2. Bus Bars:
      a. Electrical conductor, high quality copper of 98% electrical conductivity, having all joint connection surfaces silver tin-plated and supported on insulators or self-extinguishing material. All bus connections bolted with cadmium-plated, galvanized or similarly coated, high strength steel bolts of sufficient number and size to provide solidly bolted connections.
      b. Sizes shall be based on current density (800 Amperes per square inch maximum), maximum allowable temperature rise per ANSI/IEEE standards, and as stated under Transformer-Rectifier unit design test.
   3. Enclosure: Totally enclosed, non-ventilated type. All bus bolted connections accessible through removable, gasketed covers.
   4. Finish: Metallic surfaces degreased, primed and finished with light gray enamel, Color No. 61, ANSI Z55.1, in accordance with the referenced standard. Two (2) mils dry film thickness, minimum.

B. AC Bus Duct:
   1. Bus Duct enclosure suitable for outdoor application.
   2. Six-phase: Designed for connecting transformer secondary terminals to rectifier.
   3. Rating: 1,000 Volts, 6,000 Amperes, as indicated on the one-line diagram. The ac bus duct shall be capable of carrying the rectifier loadings specified and withstanding stresses due to a bolted short circuit at the ac bus connection in the rectifier with a fault level of 1,000 MVA, for the 23 kV switchgear bus.
   4. Connection: Flexible connectors of the braided or laminated type provided for connecting bus conductors to the transformer terminals.
   5. Surge Suppression Capacitors: Voltage surge suppression capacitors, connected between each of the bus bars and the ground bus within the bus duct enclosure. Capacitor sizes and ratings determined by the Contractor. Capacitors shall be fused with blown fuse indicators visible from the outside of the rectifier enclosure.
   6. Strip Heaters: Provide 120 V, 60 Hz strip heaters, extending the entire length, mounted on the bottom, without thermostat and monitored by an ammeter located on the rectifier enclosure and with wiring terminated on a suitable molded case circuit breaker located in the rectifier enclosure.
   7. Enclosure:
      a. Designed for flange bolting over the transformer secondary terminals and to the rectifier.
      b. Electrically insulated from the rectifier enclosure.
      c. Equipped with a removable gasketed cover at the transformer connections for ease of maintenance and testing.

d. Provide internal fire barrier between bus and enclosure where bus crosses the substation building wall.

8. Ground Bus:
   a. Copper: Rated at 25% of the main bus capacity provided for connecting the sections to form one (1) continuous length without bridging the insulated section at the rectifier.

C. Cathode Bus Duct:
   1. Positive bus: Designed for connecting the positive bus of the rectifier to the cathode circuit breaker.
   2. Rating: 1,000 Vdc, 8,000 Amperes as indicated on the one-line diagram capable of carrying the rectifier loadings specified and capable of withstanding stresses due to short circuit currents.
   3. Enclosure:
      a. Electrically insulated from the rectifier enclosure and dc switchgear enclosure.
      b. Equipped with a removable gasketed cover at the rectifier connection for ease of maintenance and testing.
      c. Insulated from all supports to 1,000 Volts.

D. Negative Bus Duct:
   1. Designed for connecting negative bus of the rectifier to the negative switchboard bus.
   2. Rating: 1,000 Vdc, 8,000 continuous amperes as shown on the one-line diagram capable of carrying the rectifier loadings specified and capable of withstanding stresses due to short circuit currents.
   3. Enclosure:
      a. Electrically insulated from the rectifier enclosure by an insulating gasket of suitable material and thickness.
      b. Solidly tied to the drainage and negative switchboard enclosure.
      c. Equipped with a removable gasketed cover at the rectifier connection for ease of maintenance and testing.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Install bus duct in accordance with approved Shop Drawings. Provide bracing to prevent movement due to short circuit forces. Submit calculations for forces exerted on bus ducts based on layout shown on approved Shop Drawings.

B. The Contractor shall make bolted bus connections at each shipping split.

C. Use services of manufacturer's engineering representative for assistance in field assembly and installation.

3.02 TESTING

A. After completing installation, perform dielectric tests, as described in Article 1.05 of this Section.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16300.001 – Traction Power Substation Busways shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16300.001 – Traction Power Substation Busways will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16310

TRACTION POWER SUBSTATION LOCAL ANNUNCIATOR PANEL

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Traction Power Substation Local Annunciator Panel, in accordance with the Contract Documents.

B. The Work of this Section includes, but is not limited to, the following activities:
   1. Local Annunciator Panel installation.

1.02 RELATED SECTIONS

A. Section 16200, "Traction Power Substation General Requirements."

B. Section 16210, "Traction Power Substation Basic Electrical Materials and Methods."

C. Section 16305, "Traction Power Substation SCADA System."

D. Section 16360, "Traction Power Substation Testing."

1.03 REFERENCE STANDARDS

A. ANSI:
   1. ISA 18.1 – Annunciator Sequences and Specifications

B. ASTM

C. ICEA

D. IEEE:
   1. C37.90 – Relays and Relay Systems Associated with Electric Power Apparatus
   2. C62 – IEEE Surge Protection Standards Collection

E. ISA

F. NEC

G. NEMA:
   1. ICS-6 – Industrial Control Systems: Enclosures

H. NFPA

I. UL

1.04 SUBMITTALS

A. The following information shall be submitted for approval:
   1. Manufacturer's product description, catalog data and information.
   2. Manufacturer's logic diagram, schematics, arrangement, wiring, and detail Shop Drawings for the new substation.
   3. Provide proof that similar equipment, presently being used on extra heavy rail transit systems, have developed a satisfactory operating history for a minimum of five (5) years.

1.05 QUALITY ASSURANCE

A. The Contractor shall submit evidence to the Engineer that the material furnished in accordance with the Contract Documents conforms to the specified standards and recommendations. The labeling of, or listing by UL will be acceptable evidence that material conforms to the requirements of UL. A certification or published specification data statement by a manufacturer, listed as a member of NEMA, to the effect that material conforms to the specified NEMA standards and to the Contract Documents will be acceptable evidence.

B. Electrical work shall conform to NFPA 70 (NEC).

C. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

1.06 QUALIFICATIONS

A. Design shall be that of a field proven product. No prototypes will be considered. A proven product is considered to be similar units presently being used on extra heavy rail transit systems and having developed a satisfactory operating history for a minimum of five (5) years.

ARTICLE 2 PRODUCTS

2.01 CONSTRUCTION

A. Annunciator visual display assembly shall be suitable for flush or semi-flush mounting on the NEMA, Type 1, interface terminal cabinet (IFTC) metal enclosure and shall be front accessible. Each alarm shall occupy one (1) window on the annunciator.

B. Contractor may propose an alternate device for the Engineer's approval that incorporates touch screen technology, provided the system is rugged and proven for application in a substation environment.

C. Annunciator and accessories shall be housed in a metal enclosure complying with NEMA ICS 6. Enclosure shall be provided with a hinged front panel with lockable handle and two-point latches minimum.

D. The annunciator point requirements and arrangement shall be in accordance with the Contract Drawings.

E. Annunciators shall be of the integral logic type to include visual displays and electro-mechanical or optical isolation interface with field contacts. Logic shall be microprocessor based with communication ports to interface with the substation SCADA system via RS-232 or RS-485 serial Modbus protocol. The input circuits shall be of the plug-in type. Annunciator shall be designed for an ISA sequence designation "A".

F. Provide time-stamped alarm option based on the annunciator internal clock. Data for up to 500 events shall be stored including point number, alarm status, time and date.

G. Provide surge withstand capability, per IEEE C37.90.1.

H. The final point arrangement shall be adjusted to conform as nearly as possible to annunciator panel visual display assembly listings of this specification.

I. Windows shall be illuminated with white LEDs, minimum two (2) per window.

J. Where a point listed is not required at the substation the points shall be furnished as spare.

2.02 OPERATION

A. Each annunciator point shall be designed for operation from either a normally open or normally closed field (trouble) contact.

B. All points shall flash the Traction Power Substation (TPSS) external clear signal light.

C. When a field contact operates, the associated annunciator point logic sequence shall assume lock-in "ALARM" state and initiate a flashing visual display. When the trouble signal is "ACKNOWLEDGED" at the local annunciator panel, the visual display shall assume an "ON" state. When the field contact self-resets or is manually returned to its normal condition, the visual display shall automatically return to an "OFF" status, and the logic sequence reset to a "NORMAL" state.

D. The annunciator logic sequence shall be capable of accepting and displaying multiple trouble signals simultaneously or in sequence.

E. Operation of the "LAMP TEST" feature shall initiate an operational test of the logic sequence and visual display of all annunciator points.

2.03 RELAYS

A. Annunciator interface relays shall be hermetically sealed plug-in type. Coordinate the annunciator field contact voltage and logic relay minimum operating current with the type of field contact that is furnished.

B. Each annunciator point logic output device shall be provided with an electrically isolated normally open and normally closed contact, rated at not less than 100 mA resistive current and 50 mA inductive with L/R = 40 ms, at 125 Vdc. Contacts shall be used for initiating equipment trouble signals to the SCADA equipment through the Supervisory Control Interface Terminal Cabinet, as required.

2.04 DISPLAY WINDOWS

A. Separate inscribed display windows shall be furnished for each annunciator point. Windows shall be sized to accommodate four lines of inscription with a 1/4-inch character height. Windows shall be snap-on type, fabricated from translucent plastic and back illuminated by two (2) lamps.

2.05 POWER SUPPLY

A. Annunciator shall be designed to operate on a 125 Vdc control power supply from the substation battery and charger. Power supply shall be supervised by a voltage detector, which shall initiate remote supervisory annunciation on loss of supply.

2.06 ACCESSORIES

A. Pushbuttons – the annunciator assembly shall be furnished with pushbuttons for "ACKNOWLEDGE" and "TEST" initiation of the logic sequences. Pushbuttons shall be flush mounted, color black, heavy-duty, complete with identifying nameplates of black-face, white-core, engraved laminated plastic.

B. Selector Switch – the panel shall be furnished with a control power "ON-OFF" selector switch complete with a "POWER ON" indicating light. Indicator shall be flush mounted with white translucent lens.

C. Terminal Blocks – annunciator panel shall be furnished with sufficient terminal blocks for wiring to every annunciator field contact and trouble signal point connection, plus 20 percent spare terminals:
   1. Terminal blocks shall be installed in the control cabinet and wired to the annunciator panel.

2.07 INTERFACE

A. The annunciator panel shall interface with the following:

1. The Contractor shall be responsible for successfully integrating the annunciator serial Modbus communications with the substation SCADA PLC and the battery charger Modbus communications module.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. The local annunciator panel will be mounted in the TPSS interface terminal cabinet. Install the specified interface terminal cabinet secure, plumb, level and in true alignment with the related adjoining work.
   1. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts and angles, as required, to set and rigidly connect the work.
   2. Control erection tolerance requirements so as not to impair the strength, safety, serviceability, or appearance, as approved by the Engineer.
   3. Exercise special care during installation to avoid overloading any part of the structure. Repair or replace any item damaged due to overloading to the satisfaction of the Engineer, at no additional cost to Authority.

B. The annunciator manufacturer shall provide a field support engineer to provide technical support during installation and field testing of the substations.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16310.001 – Traction Power Substation Local Annunciator Panel shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16310.001 – Traction Power Substation Local Annunciator Panel will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16340

MEDIUM VOLTAGE METAL-ENCLOSED LOAD

INTERRUPTER SWITCHGEAR

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for medium voltage metal-enclosed load interrupter switchgear.

B. The work of this Section includes, but is not limited to, the following activities:
  1. Furnish and install two (2) Medium Voltage Load Interrupter Switchgear units at the Gateway Station substation.
  2. Furnish and install two (2) Medium Voltage Load Interrupter Switchgear units at the North Side Station substation.

1.02 RELATED SECTIONS

A. Section 03305, "Cast-in-Place Concrete."

B. Section 16050, "Basic Electrical Materials and Methods."

C. Section 16060, "Grounding and Bonding."

D. Section 16081, "Electrical Testing."

E. Section 16123, "Liquid-Insulated Transformer."

1.03 REFERENCE STANDARDS

A. ANSI/IEEE C37.20.3 Standard for Metal-Enclosed Interrupter Switchgear.

B. ANSI/IEEE C37.20.4 Standard for Indoor AC Medium-Voltage Switches used in Metal-Enclosed Switchgear.

C. ANSI/IEEE 24 Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings

D. ANSI/IEEE 48 Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Termination.

E. ANSI Z55.1 Gray Finishes for Industrial Apparatus and Equipment

F. NEMA

1.04 SUBMITTALS

A. The metal-enclosed switchgear assembly shall be in accordance with the contract documents, applicable codes and whichever is the most stringent.

B. The manufacturer shall furnish a detailed Bill of Material and complete set of drawings including:
1. Detailed front elevation
2. Single line
3. Floor Plan
4. Schematics
5. Wiring Diagrams

C. The manufacturer shall furnish comprehensive instruction manuals covering the installation of the switchgear and the operation of its various components.

D. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

1.05 QUALITY ASSURANCE

A. Manufacturer: Company specializing in medium voltage metal-enclosed switchgear with at least five years documented experience. The manufacturer of the switchgear must be the same as the manufacturer of the load interrupter switch.

B. Equipment shall be UL listed and labeled for metal-enclosed front accessible type switchgear assemblies.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver products to site under provisions of section 01650.

B. Store and protect products under provisions of Section 01660.

C. Accept equipment on site and inspect for shipping damage.

D. Protect equipment from weather and moisture by covering with heavy plastic or canvas and by maintaining heat within enclosure in accordance with manufacturer's instructions.

ARTICLE 2 PRODUCTS

2.01 MANUFACTURERS

A. Switchgear: The metal-enclosed load interrupter switchgear shall be manufactured by:

1. Square D
2. G & W
3. S & C
4. ABB
5. Or Approved Equal

B. Current limiting fuses shall be DIN style type or equal for 25kV voltage class. Fuses shall have a 65,000 amperes symmetrical interrupting capability at 25kV. Fuse side should be shown on the drawings.

2.02 LOAD INTERRUPTER SWITCHGEAR ASSEMBLY

A. The metal-enclosed switchgear assembly shall be compartmentalized into the following distinct compartments:
   1. Main bus compartment
   2. 600A amp rated Switch Compartment
   3. Cable connection/fuse compartment
   4. Mechanism compartment

B. The metal-enclosed switchgear with load interrupter switches shall be provided in an indoor enclosure. The sections shall be factory-assembled and operationally checked. The assembly shall be a self-supporting, floor mounted bay.

C. The equipment shall be designed for front accessibility only.

D. Cable entry top. Load side to transformer exit top.

E. The complete assembly shall be constructed in accordance with applicable provisions of ANSI/IEEE C.37.20.3-1987 and the minimum construction standards of the manufacturers of the major components such as power fuses or potential transformers. Provide adequate space for fuse handling when applicable.

F. In establishing the requirements for the enclosure design, consideration shall be given to such relevant factors as controlled access, tamper resistance, protection from ingress of rodents and insects.

G. The integrated fused switchgear assembly shall withstand the effects of closing, carrying and interrupting currents up to the assigned maximum short circuit rating.

H. The switchgear shall be low maintenance designed to reduce the requirement for the annual/periodic maintenance of the equipment. Equipment with scheduled maintenance of 5 or more years is preferred.

I. Two viewing ports shall be installed in the switch enclosure to enable visible verification of the switch blade position.

J. An animated mimic bus attached to the end of the operating shaft shall be provided to give visual indication of the position of the switch on each bay.

K. System Voltage: 23kV, three phase, solidly grounded, three phase 3 wire.

L. Operating frequency: 60 Hz.

M. Maximum Short Circuit Current:25kA RMS Symmetrical.

N. Maximum Design Voltage: 25.8 kV.

O. Basic Impluse LEVEL (BIL): 125 kV.

P. Power Frequency Withstand: 50kV.

Q. Short-Time Current (two second): Load interrupter switch 25kA.

R. Main Bus Ampacity: 600 amperes, continuous.

S. Integrated Short Circuit Rating: 65kA, RMS symmetrical.

T. Current limiting fuses shall be provided. Fuses shall be sized to protect the transformer. One set of spare fuses shall be provided.

2.03 COMPONENTS

A. Over Center Mechanism: The load interrupter switch, rated 600 amperes continuous and interrupting, shall be fixed mounted, electrically and manually operated, and shall be quick-make, quick break with the speed of operation independent of the operator. The grounding switch, on closing, shall be quick-make with the speed of operation independent of the operator. To provide for dependable operation, the device shall not rely on chains or cables to drive the blade assemblies open and closed. The operating mechanism shall be isolated from high voltage by a steel barrier and coupled through a direct drive shaft. Access to mechanism parts shall not require de-energizing of the equipment.

B. The switch shall have a four-time fault close capability.

C. The switch shall be capable of 100 operations at 600A Amperes.

D. The switch shall be capable of 1000 mechanical no load operations.

E. The switch blades shall be contained in a single SF6 filled bottle that is sealed for life enclosure. The SF6 pressure with the enclosure shall not exceed 6 PSI (0.4 Bars).

Periodic refilling of the switch shall not be required. Maintenance of the interrupter module shall not be required over its life

F. The switch operating handle shall be removable. The handle must be suitable to operate the load interrupter mechanism as well as the ground switch mechanism.

G. Voltage and Short Circuit Ratings: Match ratings specified for integrated assembly.

H. Momentary Rating: 40kA RMS Asymmetrical.

I. Fault Closing: 40 kA, RMS Asymmetrical.

J. Load side live line indicators shall be provided as standard on the mechanism compartment. The live line indicator assembly shall be mounted in the mechanism compartment and shall be an easily removable module containing three neon indicators powered from voltage dividers within the 3 standoff insulators.

K. Metering:
   1. The switchgear assembly shall include customer metering consisting of ammeter and selector switch, voltmeter and selector switch, kilowatt/kilowatt hour meter.
   2. The metering system shall include all three phase currents, all three line-line voltages and all three line-neutral voltages.
   3. Indicating meters shall be analog. Ammeter and voltmeter shall have a 300-degree scale.
   4. Switchgear assembly shall include all required potential and current transformers and associated fuses. Disconnecting – drawout type primary fuse holders shall be utilized for potential transformer primary fuses.

L. Control Wiring: All auxiliary power, control and alarm circuits requiring connection to external circuits shall be brought to suitable terminal blocks marked with circuit identification. These terminal blocks shall be located within the respective switchgear control section of the lineup. All terminal blocks shall be of the heavy, duty type and adequate for the service intended. The switchgear shall be wired with type SIS No. 14 AWG copper wire. Except, where larger size wire is specified and/or as required. All wires shall be tagged and identified using Brady type wire markers.

M. Heaters:
   1. Provide 250 watt, 240 volt heaters in each air interrupter switch and auxiliary compartment, connected 120 volts for extended life, which shall be supplied from the local panelboard. Number of space heaters required shall be determined by the manufacturer to comply with the following stipulations. The heaters shall be equipped with guards to prevent accidental contact by personnel.
   2. Heaters shall be of sufficient capacity to control moisture condensation in the compartments and be controlled by a thermostat and humidistat located inside switchgear auxiliary section. Thermostats shall be industrial type, high limit, to maintain compartment temperature of 35 degrees F (2 degrees C) when the

outside temperature is -5 degrees F (15 degrees C). Humidistats shall have a range of 30 percent to 60 percent relative humidity. Electric heaters in switchgear assemblies shall be energized while the equipment is stored or in place prior to being placed in service and shall permanently be connected after installation of the switchgear.

2.04 ACCESSORIES

A. Incoming Cable Termination: An anti-rotational mounting pad shall have provision for 1 single hole cable lugs.

B. Provide compression lugs for terminating cables onto the switchgear terminal pads.

C. Pad lock provisions for mechanism covers on the load interrupter switch and grounding switch mechanisms shall be supplied as standard to prevent unauthorized access to the operating mechanism.

D. Manufacturer provided and sized cable for transition to a close coupled transformer.

2.05 FABRICATION

A. Construction: Indoor. Each equipment bay shall be a separately constructed cubicle assembled to form a rigid free standing unit. Minimum sheet metal thickness shall be 11 gauge steel on all exterior surfaces. Adjacent bays shall be securely bolted together to form an integrated rigid structure. Each individual unit shall be braced to prevent distortion.

B. All bus joints shall use Belleville washers. Torque bolts that are used for bus joints or for insulators and direct support of any current carrying parts shall be marked with a bead of highly visible bright orange "torque seal", that will readily show when a bolt has loosened.

C. The high voltage non-disconnect type fuses, shall be accessible only through a separate panel mechanically interlocked with the switch. Screened or penetrable barriers which may allow intentional or inadvertent contact with energized parts shall not be permitted.

D. Main bus shall be tin-plated copper, rated 600 amps, and shall be supported directly by the switch.

E. Include a ground pad with lug.

2.06 FACTORY FINISHING

A. All non-painted steel parts shall be zinc plated.

B. All painted steel parts shall be cleaned and a zinc-phosphate pre-treatment applied prior to paint application.

C. Paint Color shall be ANSI-49 (gray) TGIC polyester powder, applied electrostatically through air. Following paint application, parts shall be baked to produce a hard durable finish. The average thickness of the paint film shall be 2.0 mils. Paint films shall be uniform in color and free from blisters, sags, flaking and peeling.

D. Adequacy of paint finish to inhibit the buildup of rust on ferrous metal materials shall be tested and evaluated per paragraphs 5.2.8.1-7 of ANSI C37.20.3-1987. Salt spray withstand tests in accordance with paragraph 5.2.8.4 shall be performed on a periodic basis to provide conformance to this corrosion resistance standard of at least 3500 hours minimum.

ARTICLE 3 EXECUTION

3.01 EXAMINATION

A. Visually inspect switchgear for evidence of damage and verify that surfaces are ready to receive work.

B. Visually inspect to confirm that all items and accessories are in accordance with specifications and drawings.

C. Verify field measurements are as shown on Drawings.

D. Verify that required utilities (e.g., control voltage for heater circuits on outdoor switchgear) are available, in proper location, and ready for use.

E. Beginning of installation means installer accepts existing surface conditions.

3.02 INSTALLATION

A. Install in accordance with manufacturer's instructions, applicable requirements of the NEC and in accordance with recognized industry practices.

B. Connect the primary surge arresters if not connected. If requires, use jumper cables, as provided by the switchgear manufacturer.

C. Bending of high-voltage cables should be avoided or minimized. All necessary bends should meet at least the minimum radii specified by the cable manufacturer.

3.03 FIELD QUALITY CONTROL

A. Field inspection and testing will be performed by the installing contractor.

B. Visually inspect switchgear for physical damage upon receipt.

C. Perform mechanical operator test in accordance with manufacturer's instructions.

D. Check torque of all bolted connections, including cable terminations, either by observing the bead of indicating compound to confirm that it is still intact, or with a torque wrench to confirm the joint is tightened to the manufacturer's specification.

E. Touch-up all chips and scratches with manufacturer-supplied paint and leave remaining paint with Owner.

F. Verify key interlock operation is applicable.

G. Perform insulation resistance test on each phase to ground and phase to phase. Record results for future reference.

H. Perform low-frequency withstand tests according to ANSI/IEEE C37.20.3, paragraph 5.5.

I. Perform contact resistance test across each switch blade; report any contact resistance in excess of 50 micro-ohms.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16340.001 – Medium Voltage Metal-Enclosed Load Interrupter Switchgear shall be measured per each, complete in place.

4.02 PAYMENT

A. Item 16340.001 – Medium Voltage Metal-Enclosed Load Interrupter Switchgear will be paid at unit price and shall include the cost of all work specified in this section.

END OF SECTION

SECTION 16360

TRACTION POWER SUBSTATION TESTING

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for Traction Power Substation Testing, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Developing Test Plan for the factory, field, acceptance, integrated and startup testing to be performed by the Contractor on the new traction power substation equipment furnished under this Contract.
   2. The Contractor shall be responsible for furnishing all test instruments and the equipment and materials necessary for performing all factory, field and acceptance tests required.
   3. The Contractor shall coordinate all factory and field tests on high-voltage ac switchgear with the Duquesne Light Company, in accordance with Duquesne Light Company requirements and this Section.
   4. Testing of the fiber optic communication system between the Substation and the Operation Control Center (OCC). This includes associated OCC modifications, as specified in Section 16305, "Traction Power Substation SCADA System."

1.02 RELATED SECTIONS

A. Section 16060, "Grounding and Bonding."

B. Section 16200, "Traction Power Substation General Requirements."

C. Section 16210, "Traction Power Substation Basic Materials and Methods."

D. Section 16230, "Traction Power Substation Transformer-Rectifier Units."

E. Section 16305, "Traction Power Substation SCADA System."

1.03 REFERENCE STANDARDS

A. ANSI:
   1. C34.2 – Semiconductor Power Rectifiers
   2. C37.20.1 – Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
   3. C37.50 – Low-Voltage Ac Power Circuit Breakers Used In Enclosures - Test Procedures
   4. C37.90 – IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus

B. IEEE:
   1. 4 – Standard Techniques for High Voltage Testing
   2. C37.14 – IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures
   3. C37.20.2 – IEEE Standard for Metal-Clad Switchgear
   4. C37.20.3 – IEEE Standard for Metal-Enclosed Interrupter Switchgear
   5. C37.23 – IEEE Standard for Metal-Enclosed Bus
   6. C37.30 – IEEE Standard for High-Voltage Switches
   7. C37.34 – IEEE Standard Test Code for High-Voltage Air Switches
   8. C37.41 – IEEE Standard Design Tests for High-Voltage Fuses, Distribution Enclosed Single Pole Air Switches, Fuse Disconnect Switches, and Accessories
   9. C57.12.91 – Test Code for Dry-Type Distribution and Power Transformers
   10. C57.13 – IEEE Standard Requirements for Instrument Transformers
   11. C57.18.10 – IEEE Standard Practices and Requirements for Semiconductor Power Rectifier Transformers IEEE
   12. C57.124 – IEEE Recommended Practice for the Detection of Partial Discharge and the Measurement of Apparent Charge in Dry-Type Transformers
   13. C62 – IEEE Surge Protection Standards Collection
   14. 450 – IEEE Recommended Practice for Maintenance, Testing and Replacement of Vented Lead-Acid Batteries for Stationary Applications

C. NEMA:
   1. AB-1 – Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures
   2. PE-5 – Utility Type Battery Chargers
   3. WC-57 – Standard for Control Cables
   4. WC-70 – Standard for Non-Shielded Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy

D. NIST

1.04 SUBMITTALS

A. The Contractor's overall Test Plan, Test Procedures, and Test Reports for the tests specified in this Section shall conform to the requirements herein. Six (6) copies of each test procedure shall be submitted to the Engineer for review, comment and approval prior to performing any tests.

B. Project Test Plan:
   1. The Contractor's Project Test Plan shall be used as the controlling document for all tests, and shall include the following information:
      a. Title of each test, with reference to the respective Section and Article number, in the Technical Provisions.
      b. Organization performing each test.
      c. Test location.
      d. Submittal date of each test procedure, test report, and certified test document.

e. Starting date of each test.
f. Completion date of each test.

C. Test Procedures:
1. The Contractor shall develop detailed test procedures for each test. Test procedures will not be required if such procedures are described in the applicable ANSI, IEEE, or NEMA standards, or other standards approved by the Engineer, provided that copies of the standard are submitted with the related test.
2. Test procedures shall be submitted together in heavy-duty 3-ring binders with a single table of contents, sequentially numbered pages, and index tabs provided for each major section.
3. Test procedures shall include detailed, sequential descriptions of all steps to be taken and the test equipment to be used.
4. Test procedures shall include forms for recording the test data. These forms shall be prepared in accordance with the following requirements, as a minimum:
   a. Forms shall have check and data entry boxes as required to record all data to be obtained during the test.
   b. Descriptions of equipment and devices to be tested and checked shall be filled-in on the forms and submitted for Engineer review and approval prior to testing.
   c. Forms shall contain all test quantities to be applied to equipment. These quantities shall be filled-in on the forms and submitted for Engineer review and approval prior to testing.
5. Test procedures will not be reviewed or approved until after the Project Test Plan has been approved.

D. Test Reports:
1. The Contractor shall prepare detailed test reports for each test to fully document all test results.
2. Test reports shall include the following information, as a minimum:
   a. Cover/transmittal letter summarizing the results of the tests and confirming that the equipment has passed all tests included in the test report.
   b. Table of contents referencing all documents contained in the report.
   c. Sequential, consecutive page numbering for all pages contained in the report.
   d. Comparison of the test results with the values permitted by the standards and specifications under which the equipment is being tested (pass/fail must be indicated for <u>each</u> test).
   e. National Institutes of Standard and Technology (NIST) traceable calibration dates and serial numbers for all test equipment used.
   f. Additional requirements as described below under equipment-specific tests.

E. Provide proof that similar tests, presently being used on extra heavy rail transit systems equipment, have developed a satisfactory operating history for a minimum of five (5) years.

1.05 QUALITY ASSURANCE

A. The Contractor shall submit evidence to the Engineer that the material furnished conform to the Contract Document requirements. The labeling of, or listing by UL will be acceptable evidence that material conforms to the requirements of UL. A certification or published specification data statement by a manufacturer, listed as a member of NEMA, to the effect that material conforms to the specified NEMA standards and to the Contract Documents will be acceptable evidence.

B. Electrical work shall conform to NFPA 70 (NEC).

C. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

ARTICLE 2 PRODUCTS

[NOT USED]

ARTICLE 3 EXECUTION

3.01 GENERAL

A. The Contractor shall provide at least twenty (20) days advance notice for the time, place and date on which tests are to be performed.

B. The Engineer reserves the right to witness all tests whether conducted by the Contractor, by an independent agency, or by the Contractor's suppliers. If the Engineer determines not to witness a test or tests, a written release will be provided to the Contractor. Test reports shall be submitted to the Engineer for approval.

3.02 FACTORY TESTS (DESIGN AND PRODUCTION)

A. Factory tests shall include design and production tests required by IEEE, ANSI, NEMA, and other alternative standards to which the equipment may be designed. Additional design tests may not be required where tests equal to, or more stringent than, those specified herein have been performed and documented by the Contractor on essentially identical equipment to that being used on this project. The Engineer will review certified documentation of previous tests, and where it concludes that the specified design test requirements are met, the Engineer, at its option, may waive certain design tests.

B. Minimum factory test requirements are described below. If the applicable standards indicate additional required tests, then these tests shall also be performed.

C. The list of tests, below, is for major equipment only. Contractor's Project Test Plan and Test Procedures shall address factory testing for all equipment to be furnished.

D. 23 kV Metal-Clad Switchgear Assembly:
   1. Design Tests:
      a. The tests described in IEEE C37.34 as "Design Tests" shall be, or shall have been, performed on one (1) 23 kV circuit breaker.
      b. The tests described in IEEE C37.20.3 as "Design Tests" shall be, or shall have been, performed on one (1) 23 kV ac Metal-clad switchgear assembly.
   2. Production Tests: All tests described in IEEE C37.20.3 as "Production Tests" shall be performed on all 23 kV ac metal-clad switchgear assemblies.

E. High Voltage AC Switchgear:
   1. Design Tests:
      a. All tests described in IEEE C37.09 as "Design Tests" shall be, or shall have been, performed on one (1) 23 kV circuit breaker.
      b. All tests described in IEEE C37.20.2 as "Design Tests" shall be, or shall have been, performed on one (1) 23 kV metal-clad switchgear assembly.
   2. Production Tests:
      a. All tests described in IEEE C37.09 as "Production Tests" shall be performed on all 23 kV circuit breakers.
      b. All tests described in IEEE C37.20.2 as "Production Tests" shall be performed on all 23 kV metal-clad switchgear assemblies.

F. Rectifier-Transformer:
   1. The Engineer will not accept a rectifier-transformer that has been damaged during testing.
   2. The rectifier-transformer test report shall include the following:
      a. Comparison of calculated values with measured values.
      b. Ratio and phase relation test results for all tap positions for the HV to LV1 (R1-R3-R5) and the HV to LV2 (R2-R4-R6) connections.
      c. Impedance and load loss test results for the HV to LV1 + LV2, the HV to LV1, and the HV to LV2 connections.
   3. Design Tests: The following factory tests shall be performed on one (1) rectifier-transformer, in accordance with IEEE C57.18.10:
      a. Temperature rise test ("heat run").
      b. Commutating reactance test.
      c. Short-circuit test.
      d. Impulse tests, per IEEE C57.12.91.
      e. Audible sound level test, per IEEE C57.12.91.
   4. Production Tests: The following tests, described in ANSI C57.18.10 as "Routine Tests" shall be performed on all rectifier-transformers:
      a. Resistance measurements of all windings at the rated voltage connection and at all tap connections.
      b. Ratio tests on the rated voltage connection and on all tap connections (both HV to LV1 and HV to LV2 connections).
      c. Polarity and phase relation tests on the rated voltage connection.

d. Excitation loss and excitation current at rated voltage on the rated-voltage connection.
e. Impedance and load loss test on the rated voltage connections (HV to LV1, HV to LV2, and HV to LV1+LV2 connections).
f. Applied potential tests.
g. Induced potential tests.
h. Partial-discharge tests in accordance with IEEE C57.124.

G. Rectifier:
1. Design Tests: The rated current test shall be performed on one (1) rectifier, in accordance with ANSI C34.2. This test may be combined with the rectifier-transformer unit design tests, described in Article 3.02 (H) of this Section:
   a. Thermocouples shall be applied to representative components, including diode cases, for purposes of temperature recording at intervals no farther apart than one (1) minute for the duration of the test. Ambient, supply air and discharge air temperatures shall be recorded, along with rectifier output, bridge and phase currents. Diode case temperature measurements shall be extrapolated to diode junction temperatures by the manufacturer; diode junction temperatures shall be included in the test report.
2. Production Tests: The following tests described in ANSI C34.2 shall be performed on all rectifiers:
   a. Dielectric strength.
   b. Rated voltage.
   c. Polarity: Perform tests to verify that all measuring and monitoring devices including shunts, transducers, meters and relays are correctly connected with the proper polarities.
   d. Controls sequence: Perform tests to verify that all control devices operate in the correct order.
   e. Control wiring continuity: Perform tests to verify correct wiring and of all control devices and circuits via operation of all control devices. For control devices and circuits that will connect to external devices, point-to-point continuity tests shall be performed.
   f. Mechanical Tests: Perform tests to verify the proper positioning and functioning of all mechanical devices including access doors, switches, interlocks, bolted connections, etc.

H. Transformer-Rectifier Unit Design Tests:
1. Design tests shall be performed on one (1) transformer-rectifier unit, including accessories and the bus duct connecting the transformer to the rectifier, in accordance with ANSI C34.2. Test circuit No.2, as described in Section 6.3.2.2. The tests shall verify efficiency, voltage regulation, harmonic voltage amplitude, current balance and displacement power factor at loads of zero, 50, 100, 150, 300, and 450 percent of the rated load.
2. After rectifier temperature stabilization at 100 percent load, the transformer-rectifier unit peak period loading cycle test shall be performed as specified in

Section 16230, "Traction Power Substation Transformer-Rectifier Units," Figure 16230-1, followed by a 6-hour 100 percent load cycle. Testing shall be in accordance with ANSI C34.2, Section 5.3.4.3. Test results shall prove that the temperature rise for the transformer at the end of the overload cycle does not exceed 149 degrees F, followed by a 6-hour 100 percent load cycle with a temperature rise at the end of the 6-hour limit, not to exceed 131 degrees F. Test shall also prove that rectifier diode junction temperature does not exceed the safe operating limit. The ac busduct temperature rise does not exceed 149 degrees F and 104 degrees F, for enclosure.

3. The Contractor shall be responsible for arranging and performing this test, and for providing all necessary equipment and expertise to obtain and document the test results.

I. DC Power Circuit Breakers:
  1. Design Tests: The tests described in IEEE C37.14 as "Design Tests" shall be, or shall have been, performed on one (1) dc power circuit breaker of each frame Ampere rating furnished.
  2. Production Tests: All tests described in IEEE C37.14 as "Production Tests" shall be performed on all dc power circuit breakers.

J. DC Power Switchgear Assemblies:
  1. Design Tests: All tests described in ANSI C37.20.1 as "Design Tests" shall be, or shall have been, performed on one (1) representative dc switchgear assembly.
  2. Production Tests: All tests described in ANSI C37.20.1 as "Production Tests" shall be performed on all dc switchgear assemblies.

K. Metal-Enclosed Bus:
  1. Design Tests: All tests described in IEEE C37.23 as "Design Tests" shall be, or shall have been, performed on one (1) representative metal-enclosed bus assembly.
  2. Production Tests: All tests described in IEEE C37.23 as "Production Tests" shall be performed on all metal-enclosed bus assemblies.

L. Negative Polarity Grounding Device:
  1. Design Tests: Perform all manufacturers' standard design tests.
  2. Production tests: Perform all manufacturers' standard production tests including wiring continuity and control and indications checks.

M. Molded Case Circuit Breakers:
  1. Design Tests: All tests described in NEMA AB-1 as "Design Tests" shall be, or shall have been, performed on each voltage class of molded case circuit breaker utilized in each substation.
  2. Production Tests: All tests described in NEMA AB-1 as "Production Tests," shall be performed on all molded case circuit breakers.

N. Relays, Meters, Instruments, Monitors and Annunciators:

1. Design and production tests for this equipment shall be performed in accordance with the standards to which they were manufactured and for the assemblies in which they will reside. All standard design and production tests shall be performed.

O. Station Battery:
   1. Design Tests shall be, or shall have been, performed on one (1) battery.
   2. Production Tests: All standard production tests described in IEEE 450 as "Acceptance Tests" shall be performed on all batteries.

P. Battery Charger:
   1. Design Tests: The tests described in NEMA PE-5 as "Design Tests" shall be, or shall have been, performed on one (1) battery charger.
   2. Production Tests: All tests described in NEMA PE-5 as "Production Tests" shall be performed on all battery chargers. In addition, the following production tests shall be performed on all battery chargers.
      a. Operation as a battery eliminator (with batteries disconnected).
      b. Manufacturer's standard production tests.
      c. Controls and indications check (all controls).
      d. Communications module functional tests.

Q. Auxiliary Power Transformer:
   1. Design Tests: Design tests, described in IEEE C57.12.90, shall be, or shall have been, performed on one (1) auxiliary power transformer.
   2. Production Tests: All production tests described in IEEE C57.12.90 as "Routine Tests" shall be performed on all auxiliary power transformers.

R. Wire and Cable;
   1. Production tests for 2,000 V feeder cable shall be performed in accordance with NEMA WC-70.
   2. Production tests for control cable shall be performed in accordance with NEMA WC-57.

S. Supervisory Control Interface and Auxiliary Power Cabinets:
   1. Design Tests (assembly): Not required for the assembly (individual components shall have design tests in accordance with their individual requirements).
   2. Production Tests (assembly):
      a. Wiring continuity
      b. Operation of all controls and indications

T. TPSS Assembly (Enclosure):
   1. All major substation equipment shall be assembled and interconnected in the factory: Ac switchgear, transformer-rectifier unit, dc switchgear, station battery system, negative polarity grounding device, SCADA interface terminal cabinet and auxiliary power system.

2. Perform TPSS assembly testing after temporary assembly of the substation has been completed. Factory assembly testing shall provide a measure of the overall quality of the completed product and shall be performed so that it simulates end product use and function. Tests shall include as a minimum the following, which shall be documented by procedural checklists:
   a. Energization of the substation
   b. Auxiliary power system functional test (all components)
   c. Annunciator functional test
   d. Breaker test cabinet tests
   e. SCADA/IFTC functional test (controls and indications)
   f. Lighting system functional test (normal and emergency)
   g. HVAC system functional test
   h. 120 Vac receptacle functional test
   i. ETS system functional check
   j. Operation of all other controls, interlocks and indications
   k. Verification of all alarms, including intrusion and blue and clear light systems

3.03 FIELD TESTS

A. The Contractor shall perform the following field tests after the TPSS enclosure has been installed on site and the Engineer has granted permission to test.

B. The list of tests below is for major equipment only. Contractor's Project Test Plan and test procedures shall address field testing for all equipment to be furnished.

C. 23 kV Metal-Clad Switchgear:
   1. Mechanical operation and alignment
   2. Insulation resistance (megger, hipot, megger)
   3. Controls and interlocks
   4. Protective relay settings in accordance with approved relay co-ordination study

D. Rectifier-Transformer:
   1. Insulation resistance
   2. Turns Ratio test on all taps
   3. Controls and interlocks
   4. Tap setting check (nominal tap)

E. Rectifier:
   1. Mechanical operation
   2. Insulation resistance
   3. Controls and interlocks

F. DC Switchgear:
   1. Alignment and mechanical operation checks
   2. Insulation resistance
   3. Controls and interlocks

G. Protective Relays:
   1. Calibration
   2. Setting per Contractor's recommended settings
   3. Operation checks

H. Meters and Tranducers:
   1. Verify the polarity and accuracy of all meters and transducers

I. Annunciator Panel:
   1. Verify correct operation of each alarm point and exterior white light operation.
   2. Verify correct operation of the annunciator serial Modbus communications interface and successful integration with the substation SCADA PLC and battery charger PLC.
   3. Verify correctness of all time-stamped alarm data.

J. Supervisory Control Interface Terminal Cabinet:
   1. Verify operation of each control and indication.

K. Station Battery System (Battery, Charger and Dc Panelboard):
   1. Using a load bank fully discharge the batteries. Turn on the charger and monitor charger performance. At the end of 8 hour period, demonstrate that cells have fully charged. Record voltage and specific gravity of each cell.
   2. Functional tests (controls, indications, communications).
   3. Wiring insulation tests.
   4. Verify correct operation of the battery charger serial Modbus communications interface and successful integration with the substation SCADA PLC and annunciator PLC.

L. Auxiliary Power System:
   1. Insulation tests for wiring and control power transformer.
   2. Functional tests for all components including inverters and ac distribution panel.

M. Wire and Cable (internal to enclosure):
   1. Perform insulation resistance test on all field-installed wire and cable in accordance with the applicable NEMA/ICEA standards.

N. 750 VDC Feeder Cables:
   1. Perform hi-pot test on each feeder cable in accordance with NEMA WC-70 and manufacturer's recommendations (feeder cable shall not be connected to the OCS during test).

O. Substation Grounding, in accordance with Section 16060, "Grounding and Bonding".

P. Traction Power Substation Assembly (Enclosure):

1. Water Leakage Test: After complete installation of the substation enclosure, perform a water leakage test by applying a uniform spray of water from hoses for 15 minutes to all surfaces to verify that the enclosure is completely watertight.
2. Verify correct operation of all miscellaneous traction power controls and indications.
3. Energization of all substation equipment from a Duquesne Light Company feeder.
4. Energization of catenary circuits with substation 650 Vdc output.

Q. Short-Circuit Tests:

1. Short Circuit on DC Feeder: Perform short circuit tests in the vicinity of North Shore TPSS substation to ensure capability of dc feeder breaker to trip and interrupt a close-in fault under maximum short-circuit conditions and to coordinate with cathode breaker forward trip. Apply a bolted fault at the tracks in the immediate vicinity of the substation between inbound OCS and a running rail. Demonstrate that the instantaneous trip element of the feeder breaker nearest to the fault in the substation initiate breaker tripping and rate-of-rise relay associated with the remote feeder breaker in the adjacent Gateway Tie Breaker station initiate breaker tripping and the cathode breaker and ac breakers and other dc feeder breakers does not trip improperly. Test with both rectifiers in operation and all dc feeder breakers closed. As part of the test, record the trip device which operates affected dc feeder breakers. Record current at each affected breaker with an oscillograph.
2. Remote Short Circuit on DC Feeder: The Contractor shall perform radial-feed remote fault tests for the new substation dc feeder breaker to verify the proper calibration and setting of the rate-of-rise relays to detect remote faults. Proper operation shall require the breaker feeding the faulted power section to trip via its rate-of-rise relay, and to indicate the correct track of the faulted section.
3. The aerial connections necessary for conducting the staged fault tests will be made by Authority.
4. Each low-level fault test shall be performed on an area of overhead contact system involving three (3) adjacent substations on the mainline and a single track. The tests shall be performed with the middle substation out of service and with its OCS section tie switches closed, to simulate emergency feeding conditions. A fault shall be applied near the riser pole at the opposite end of the test area from the feeding substation, with the dc breaker feeding the far end section open. This arrangement will provide a "radial feed" for the relay being tested (a section powered by only the circuit breaker under test).
5. The high-voltage ac circuit breaker and dc main and feeder breakers of the "feeding" substation shall be monitored simultaneously to show the status of each circuit breaker during and after each short-circuit application. Test results, such as steady-state fault current, voltage fault clearing time etc., shall be recorded on graphical data recorders or computers for further evaluation.
6. All equipment, including the substation enclosure, dc feeder breaker main contacts shall be inspected for damage, (if any) after each short-circuit test.

R. Simultaneous Train Start Tests:
   1. Authority will configure two (2) 2-car trains, with enhanced acceleration characteristics, to simulate the power draw of two loaded trains.
   2. With a single dc feeder breaker powering an OCS power section, Authority will operate one (1) train at maximum acceleration, and observe the breaker performance. If it trips, the trip settings will be recorded and analyzed.
   3. With the same power system configuration, two (2) trains will be operated at maximum acceleration in opposite directions, and breaker performance will be observed. If the breaker trips, the trip settings will be recorded and analyzed.
   4. Tests described in 3 and 4 (Section R – Short-Circuit Tests) will be performed on each feeder breaker.

S. Load Measuring Test:
   1. The Contractor shall prepare a test procedure for field-testing the load measuring systems of both feeder breakers in new substation and Tie-Breaker station. After obtaining Authority's approval for the procedure, the Contractor shall perform the tests and provide documented results. The automatic recloser system for both the near and remote fault shall be tested. Test the recloser system again for normal operating conditions.

3.04 ACCEPTANCE TESTS

A. The Contractor shall perform the following acceptance tests after satisfactory completion of all field tests.

B. Station Battery System:
   1. Verify the correct operation of the substation battery, battery charger and dc distribution system.
   2. Verify that battery charger serial communications interface communicates correctly between the charger and OCC.

C. High Voltage AC Switchgear:
   1. Energize equipment.
   2. Verify correct operation of all key interlocks.
   3. Verify correct operation of all controls and indications.

D. Auxiliary Power System:
   1. Verify the correct operation of the auxiliary power transformer.
   2. Verify the correct operation of the automatic transfer switches and inverters.
   3. Verify correct operation of all key interlocks.
   4. Verify correct operation of all controls and indications.

E. Grounding Systems:
   1. Verify the correct operation of the dc switchgear and rectifier hot and grounded structure relay functions and alarms.

2. Verify the continuity of the two bonding cables between each TPSS enclosure and the TPSS substation ground grid.

F. DC Main Circuit Breaker:
   1. Energize the dc switchgear.
   2. Verify correct operation of all key interlocks.
   3. Verify correct operation of all controls and indications.

G. DC Feeder Circuit Breakers:
   1. Verify correct operation of all key interlocks.
   2. Verify correct operation of all controls and indications.

H. Annunciator System and External Lights:
   1. Verify the correct operation of the blue and clear signal lights.
   2. Verify the correct operation of each alarm point.
   3. Verify that annunciator serial communications interface communicates correctly between the annunciator and OCC.

I. SCADA System:
   1. Verify the correct operation of each SCADA point, from the OCC control screen icons to the TPSS device.
   2. Verify the correct integration and operation of the TPSS SCADA PLC, the serial Modbus battery charger communications interface, and the serial Modbus annunciator communications interface.

3.05 INTEGRATED TESTING

A. The Contractor shall provide a secure and protect period for the substation, beginning on the day in which the substation passes all acceptance tests and ending on the day the substation is Finally Accepted and placed in service. Such securing and protecting shall include the Work site, the constituent electrical equipment within the Work site, and any ongoing cosmetic type construction activities such as landscaping. However, throughout this same secure and protect period, Authority will be responsible to operate and maintain the substation placed in service.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the Factory Testing portion of the work of this Section.

B. Item 16360.001 – Field Testing of Traction Power Substation Testing shall be measured as a lump sum unit, complete in place.

C. Item 16360.002 – Acceptance Testing of Traction Power Substation Testing shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. No separate payment will be made for the Factory Testing portion of the work of this Section. Payment for such portion(s) of the work shall be included in the payment for related portions of the Work.

B. Item 16360.001 – Field Testing of Traction Power Substation Testing will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

C. Item 16360.002 – Acceptance Testing of Traction Power Substation Testing will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 16430

LOW VOLTAGE METAL-ENCLOSED CIRCUIT BREAKER SWITCHGEAR

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for low voltage metal-enclosed circuit breaker switchgear.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Furnish and install Low Voltage Circuit Breaker Switchgear unit at the Gateway Station substation.
   2. Furnish and install Low Voltage Circuit Breaker Switchgear unit at the North Side Station substation.

1.02 RELATED SECTIONS

A. Section 16050, "Basic Electrical Materials and Methods."

B. Section 16060, "Grounding and Bonding."

C. Section 16081, "Electrical Testing."

1.03 REFERENCE STANDARDS

A. Equipment shall be designed, tested and manufactured according to the following:
   1. ANSI C37.20.1 – Metal Enclosed Low Voltage Power Circuit Breaker Switchgear
   2. ANSI C37.51 – Testing of Metal-Enclosed Low Voltage AC Power Circuit Breaker Switchgear.
   3. NEMA SG-5 – Power Switchgear Assemblies
   4. UL 1558 – Switchgear Assemblies

B. Main and Feeder Circuit Breakers used shall be designed, tested and manufactured to the following:
   1. ANSI C37.13- Low Voltage AC Power Circuit Breakers Used In Equipment
   2. ANSI C37.16- Preferred Rating, Related Requirement And Application Recommendations For Low Voltage Power Circuit Breakers and AC Power Circuit Protectors.
   3. ANSI C37.50- Testing of Low Voltage AC Power Circuit Breakers
   4. NEMA SG-3 - Low Voltage Power Circuit Breakers
   5. UL1066- Low Voltage Power Circuit Breakers

1.04 RATINGS

A. The ampacity of the Low Voltage Switchgear shall be determined by the loading of the feeder circuits.

System Ampacity

2500A – Gateway Station Substation

3000A – North Side Station Substation

B. The short circuit current rating of the system shall be determined by the available fault current at the Low Voltage Switchgear. All circuit interruption shall be accomplished by the circuit breaker and without the aid of limiter fuses. The Short time rating shall also be a function on the desired selectivity of the electrical system. Short time ratings shall be equal to interrupting ratings for systems delivering up to 85k amperes available fault current. RMS symmetrical amperes are as follows:

***Service Voltage* 480V**		**Short Time Rating**	**Close & Latch Rating**
Gateway	**65k**	**65k**	**65k**
North Side	**85k**	**85k**	**50k**

C. The assembly is designed for use on 60 Hz electrical systems up to 600 Vac. The assembly shall be properly braced to the ratings of the circuit breaker installed within the assembly.

D. Any items not specifically mentioned but which are obviously necessary for proper operation are implied in this specification.

E. Circuit breakers shall be drawout type with electronic trip units as specified on the associated drawings. Circuit breakers shall have interrupting, close and latch, and 30-cycle withstand ratings that meet the application requirements. Interrupting rating shall be 150 kA RMS amperes without fuses. Close and latch ratings to 65 kA available on all frame sizes. Thirty-cycle withstand rating available up to 100 kA to provide maximum coordination with downstream circuit breakers.

Circuit breakers shall be available in 800, 1600, 2000, 3200, 4000 and 5000 A frame sizes. An adjustable rating plug (range of 0.4 to 1 times the sensor plug value) and a field-replaceable sensor plug (available in standard amperage steps from 50% to 100% of the frame size) shall determine the ampere rating of the circuit breaker.

ARTICLE 2 PRODUCTS

2.01 MANUFACTURERS

A. Metal-Enclosed Low Voltage Power Circuit Breaker Switchgear shall be manufactured by:

MANUFACTURER	SWITCHGEAR	POWER CIRCUIT BREAKER
Square D	Power Zone 4	Masterpact NW
Cutler Hammer	Magnum DS	Magnum DS & DS11
General Electric	AKD-10	WAVE PO
Simens	RL	RL
ABB	K-Line	K-Line

2.02 STRUCTURE

A. General

1. Each steel section shall contain one or more individual circuit breakers, or instrumentation compartments, and a rear compartment for the buses and outgoing cable connections.
2. Rigid removable steel base channel shall be provided at the front and rear of each section.
3. The finish shall be gray ANSI #61.

B. Dimensions

1. Section widths should be 22, 30, or 36" wide dependent on the size of the circuit breakers being installed.
2. The lineup shall provide adequate wire bending space for mains and feeders breakers using up to 750 kcmil wires.
3. Section depth shall be 54" minimum when using 800A feeders. Additional depth to the lineup shall be for the sole purpose of additional wire bending and conduit space.
4. Adequate conduit space shall be provided to allow all conductors to exit the structure at the same end.

C. Moving and Handling

1. The Lineup shall be divided into shipping splits not to exceed 88" wide and shall be capable of being lifted overhead or by a forklift.
2. Each shipping split shall be provided with removable lifting straps
3. Removable Base Channels shall be provided with prying slots for ease of final positioning at the job-site.
4. For circuit breakers, an overhead or floor mounted lifter shall be provided to ease the installation or removal of circuit breakers in excess of 75 pounds.

2.03 BREAKER COMPARTMENT

A. Circuit Breakers

1. Each circuit breaker shall be mounted in its own barriered compartment.
2. Feeder circuit breakers rated 2000A or less shall be capable of being mounted in the uppermost compartment without derating.
3. Operational buttons on the circuit breaker as well as the trip unit and the display shall be accessible without opening the breaker compartment door.
4. Circuit breakers of like sizes and rated 1600A or less shall be interchangeable as standard. Circuit breakers of lower interruption ratings shall be mechanically prohibited from being placed in the cell.
5. Prepared spaces shall be totally complete, include the racking mechanism, bussing, and secondary contacts as necessary, so that a circuit breaker of the correct frame size can be installed with no modifications required.
6. Circuit Breaker and prepared space compartments shall be "keyed" such that a breaker cannot be incorrectly installed with respect to Interrupting Rating, Frame Size, or secondary connections

B. Secondary Connections

1. All customer secondary control and communications connections shall be made from the front of the switchgear lineup.
2. A dedicated wiring area accessible from the front shall allow easy access to all control or communications terminations
3. Control Connections shall be cage clamp terminals. All control wire shall be 14 gage SIS.
4. Dedicated conduit entry for control wires shall be provided at the top and bottom of each section, capable of landing up to 3 each 1 ½" conduits and accessible from the front.
5. All interconnections between sections at shipping splits shall use locking-pull apart terminal blocks.
6. All secondary and communication wiring shall be securely fastened to the switchgear without the use of adhesive backed wire anchors.

C. Instrumentation

1. Where additional space is required for instrumentation, CPT's, metering, etc., a barriered instrumentation compartment shall be used.
2. The instrumentation compartment shall not inhibit the routing of control or communication wires.
3. Individual component mounting surfaces and pans in the instrument compartments shall be painted white as standard.
4. Instrumentation shall be provided per the one line diagram.

2.04 BUSING AND CABLE COMPARTMENT

A. Busing
   1. All vertical and horizontal distribution bussing shall be rated for the full ampacity of the lineup.
   2. All bus joints shall consist of Grade 5 hardware and conical spring (e.g. Belleville) washers to withstand mechanical forces exerted during short circuits. All joints shall consist of a minimum of 2 bolts.
   3. Busing shall be plated along its entire length.
   4. Busing shall be braced to withstand the instantaneous interrupting rating of the main breaker(s) or 65kA minimum.
   5. Optional barriers shall be available to separate the busing and cable compartment.

B. Cable Compartment
   1. All incoming or outgoing power conductors shall be routed through this area.
   2. Feeder Breakers shall have adequate wire bending space regardless of the interrupting rating.
   3. Conduit area for each section shall be a minimum of 17" wide and provide adequate depth for all section conduits.
   4. Barriers to separate the busing and cable compartments shall be provided. Barriers to separate the cable compartment from an adjacent cable compartment shall be provided.

2.05 DIFFERENTIAL GROUND FAULT PROTECTION

A. 480Y/277V, 4 wire, connected equipment having multiple sources shall have a modified differential ground fault system (MDGF). The manufacturer shall complete the MDGF design prior to building equipment to insure that the proper main or tie breaker(s) operate properly during the following occurrences on the main bus.
   1. Insure the system will trip with the occurrence of a ground fault at any location in the switchgear.
   2. Insure system will <u>not</u> trip without ground fault and with normal current flow.
   3. Insure system will <u>not</u> trip due to large single-phase currents.
   4. Insure system will trip with combination of normal current flow and ground fault current flowing together.
   5. Insure system will <u>not</u> trip with circulating currents through the neutral due to multiple grounds and sources external to the immediate low voltage power sources.

B. The manufacturer shall be required to include additional CT's, ground fault relays, interlocks, wiring, components etc. to insure the ground fault systems operates without nuisance tripping on the main bus of the switchgear.

C. The manufacturer shall include a wiring diagram of the MDGF system along with a test procedure using high current injection equipment.

2.06 POWER CIRCUIT BREAKERS

A. Circuit Breakers
   1. Power Circuit Breaker shall be listed to UL 1066.
   2. Circuit breakers shall be suitable for the required instantaneous rating without the use of current limiting fuses.
   3. All circuit breakers shall have field interchangeable electrical accessories including shunt trip, spring release, electrical operator, auxiliary contacts, and Trip Unit.
   4. All secondary connections shall be made directly to the front of the circuit breaker cradle.
   5. Each Circuit breaker shall have built in contact temperature and contact wear sensors.

B. Padlocking provisions shall be furnished to receive up to three padlocks when circuit breaker is in the disconnected position, positively preventing unauthorized closing of the circuit breaker contacts.

C. Provisions for up to two key locks shall be furnished allowing locking in the disconnected position. Provisions for locking in the connected, test and disconnected positions by padlock or key lock shall be available as an option.

D. Located on the face of the circuit breaker shall be buttons, with optional lockable clear cover, to open and close the circuit breaker and indicators to show the position of the circuit breaker contacts, status of the closing springs, and circuit breaker position in the cell. An indicator shall show "charged–not OK to close" if closing springs are charged but circuit breaker is not ready to close. Circuit breaker racking system must have positive stops at the connected, test, disconnected and withdrawn positions.

E. Circuit breaker must be equipped with an interlock to discharge the stored energy spring before the circuit breaker can be withdrawn from its cell. Circuit breaker must provide a positive ground contact check between the circuit breaker and cell when the accessory cover is removed while the circuit breaker is in the connected, test or disconnected positions.

F. Circuit breaker shall provide long service life. The 3200 A circuit breaker frame and those of lower ratings must be certified to perform a minimum of 10,000 operations without maintenance. The 4000 A and 5000 A frames must be certified to 5,000 operations without maintenance.

G. Trip Units
   1. Circuit breaker trip system shall be an electronic trip unit.
   2. All trip units shall be removable to allow for field upgrades.
   3. Trip Units shall incorporate "True RMS Sensing", and have LED long-time pickup indications.

4. Trip unit functions shall consist of adjustable long-time pickup and delay, short-time pickup and delay, instantaneous neutral protection and ground-fault pickup and delay.
5. Adjustable long-time pickup (Ir) and delay shall be available in an adjustable rating plug that is UL Listed as field-replaceable. Adjustable rating plug shall allow for nine long-time pickup settings from 0.4 to 1 times the sensor plug (In). Other adjustable rating plugs shall be available for more precise settings to match the application. Long-time delay settings shall be in nine bands from 0.5–24 seconds at six times Ir.
6. Short-time pickup shall allow for nine settings from 1.5 to 10 times Ir. Short-time delay shall be in nine bands from 0.1–0.4 I2 t ON and 0–0.4 I2 t OFF.
7. Instantaneous settings on the trip units with LSI protection shall be available in nine bands from 2 to 15 times In. The Instantaneous setting shall also have an OFF setting when short-time pick-up is provided.
8. All trip units shall have the capability for the adjustments to be set and read locally by rotating a switch.
9. Trip unit shall provide local trip indication and capability to indicate local and remote reason for trip, i.e., overload, short circuit or ground fault.
10. Ground-fault protection shall be available for solidly grounded three-phase, three-wire or three-phase, four-wire systems. Trip unit shall be capable of the following types of ground-fault protection: residual, source ground return, and modified differential. Ground-fault sensing systems may be changed in the field.
11. Ground-fault settings for circuit breaker sensor sizes 1200 A or below shall be in nine bands from 0.2 to 1.0 times In. The ground-fault settings for circuit breakers above 1200 A shall be nine bands from 500 to 1200 A.
12. Neutral current transformers shall be available for four-wire systems.
13. Trip units shall be capable of communicating on MODBUS ® networks.
14. Trip units shall be available to provide additional protection by offering adjustable inverse definite minimum time lag (IDMTL). IDMTL provides optimized coordination by the adjustment of the slope of the long-time delay protection.
15. Trip units shall be available to provide real time metering. Metering functions include current, voltage, power and frequency.

H. A test shall be available to provide automatic function testing of the circuit breaker. No disassembly of circuit breaker shall be required.

I. Interlocking, Tripping and Operating Facilities
   1. On the LV Switchboard the two incoming supply circuit breakers shall be electrically interlocked with the bus-tie breaker so that only two out of the three can be closed at any one time. This interlocking shall be applicable in the 'Auto' and 'Manual' mode. All CT's shall be Class C as defined in IEEE Std C37.110-1996 and IEEE Std C57.13-1993.
      a. Supply Failure
         1) The incoming supply circuit breakers and the bus-tie circuit breaker shall be arranged to operate automatically on mains failure when the selector

switch is in the 'Auto' position. If the electronic protective circuitry detects a supply failure, after a time delay to be specified, the circuit breaker relating to the particular transformer shall trip and the bus-tie breaker shall close auntomatically.

2) The circuit breakers shall automatically return to their normal position after the full electricity supply has been restored after a pre-set time delay.
3) If the selector switch is in the 'Maunal' position, the automatic sequence shall be inhibited.
4) Should either of incomer MCCB's trip due to overcurrent or ground faults, the bus-tie MCCB shall not operate.
5) The bus section breaker shall not close if both main incoming supplies fail.

2.07 METERING AND INSTRUMENTATION

A. Main Metering
   1. Metering requirements that exceed the capabilities of the Circuit Breaker Trip Units shall use the Square D Powerlogic PM-850 series power monitoring system or equal.
   2. CT's shall be appropriately sized for use on the main.
   3. Separate low voltage HMI and display shall be mounted on the same door as the Main Circuit Breaker.
   4. Optional I/O and Ethernet communications card shall be provided as necessary.

ARTICLE 3 EXECUTION

3.01 INSPECTION

A. Examine area to receive switchgear to provide adequate clearance for switchgear installation

B. Check that concrete pads are level and free of irregularities.

C. Start work only after unsatisfactory condition are corrected.

3.02 INSTALLATION

A. Install switchgear in accordance with manufacturer's written guidelines, the NEC, and local codes.

3.03 FIELD QUALITY CONTROL

A. Inspect completed installation for physical damage, proper alignment, anchorage, and grounding.

B. Measure, using a Megger, the insulation resistance of each bus section phase-to-phase and phase-to-ground for one minute each, at minimum test voltage of 1000 Vdc; minimum acceptable value for insulation resistance is 1 megohms. NOTE: Refer to manufacturer's literature for specific testing procedures.

C. Check tightness of accessible bolted bus joints using calibrated torque wrench per manufacturer's recommended torque values.

D. Physically test key interlock systems to check for proper functionality.

E. Test ground fault systems by operating push-to-test button. [high current injection testing is required for modified differential ground fault testing.]

3.04 ADJUSTING

A. Adjust all operating mechanisms for free mechanical movement per manufacturers specifications.

B. Tighten bolted bus connections in accordance with manufacturer's instructions.

C. Adjust circuit breaker trip and time delay settings to values [indicated.] [as instructed by the Architect/Engineer.]

3.05 CLEANING

A. Touch up scratched or marred surfaces to match original finish.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16430.001 – Low Voltage Circuit Breaker Switchgear shall be measured per each, complete in place.

4.02 PAYMENT

A. Item 16420.001 – Low Voltage Circuit Breaker Switchgear will be paid at the unit price and shall include the cost of all work specified in this section.

END OF SECTION

SECTION16602

GENERAL REQUIREMENTS OVERHEAD CONTACT SYSTEM

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for overhead contact system, in accordance with the Contract Documents.

B. This Section includes general requirements associated with the procurement of materials, installation, construction, testing services, training, appurtenances and incidentals necessary to complete the work of the Overhead Contact System (OCS).

C. Furnish and install all necessary temporary material including poles, guys, insulators, splices, fittings, terminations and miscellaneous items

D. The North Shore Connector OCS shall also have compatible interfaces with the existing active Stage I OCS.

1.02 REFERENCE STANDARDS

A. UBC

1.03 SUBMITTALS

A. Detailed Shop Drawings.

B. Operating and Maintenance Manuals.

C. Training and Training Materials.

D. Qualifications of the OCS supplier.

E. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

1.04 DESIGN CRITERIA

A. OCS Distribution System:
   1. The overhead contact system shall be of the simple type, comprising one 500 kcmil stranded hard drawn copper messenger wire and one 350 kcmil hard drawn copper contact wire.
   2. The OCS is to be:
      a. Automatically tensioned (AT), in the portion outside of the tunnel section, using balance weights so that constant tension is maintained in the conductors

throughout the specified temperature range.
b. Fixed termination (FT) in the tunnel portions.

B. Contractor shall incorporate the hardware shown in the technical sheets, arrangement drawings and assembly drawings contained on the Contract Documents. The vendors called out on the Contract Drawings represent the quality and type required.

C. The OCS hardware, being all the material from the pole face out to, but excluding the conductors, shall primarily be supplied by one supplier. The supplier shall be an experienced manufacturer of OCS hardware. Typical experienced OCS hardware manufacturers are Brown Boveri, Dossert, Siemens, Impulse NC, Kummler + Matter, or approved equal.

D. Contractor shall be responsible for the form, fit and function of all components supplied for the overhead contact system. Detailed Shop Drawings shall be prepared to identify the form and fit of the proposed components.

E. Environment: The OCS equipment shall be capable of operating satisfactorily in an environment as follows:
1. Elevation: 1148 ft
2. Humidity: 5 to 100 percent.
3. Precipitation
   a. Maximum Rainfall Rate = 4 in/hr
   b. Maximum Snow Fall Rate = 5 in/hr
4. Ambient Temperature
   a. Highest recorded: 106 degrees F.
   b. Lowest recorded: minus 20 degrees F.
   c. Yearly average: 50 degrees F.
5. Design Climatic Conditions

		Operating Conditions			Non-Operating Conditions		
a.	Factor						
b.	Wind, mph	55	40	-	40	-	80
c.	Conductor Temperature, degrees F	77	-4	167	-4	32	77
d.	Ice	-	I	-	II	II	-

   e. Where Ice Loading I consists of radial ice of 1/2 in on the messenger and 1/4 in on the contact wire, and Ice Loading II consists of radial ice of 1/2 in on both the messenger and the contact wire.
6. Lightning: (Isokeraunic level): 28.
7. Seismic Withstand Criteria: Zone 1 (in accordance with UBC recommendations).
8. Conductor Temperatures
   a. Conductor temperatures for constant tension: 0 degrees F to 132 degrees F.
   b. Maximum conductor temperature: 167 degrees F.
   c. Minimum conductor temperature: -22 degrees F.

1.05 WARRANTY OF CONSTRUCTION

A. The warranty period for all goods, supplies, systems and equipment, except spare parts, shall be two years after Issuance of Certificate of Final Acceptance or twelve months after revenue service, whichever occurs first.

B. The warranty period for spare parts shall extend either twelve months from the placement of each spare part into revenue service or until two years after Issuance of Certificate of Final Acceptance, whichever occurs first. In the event it is necessary to place any spare parts into operation or service prior to the completion of the warranty period, the Contractor agrees to furnish and deliver free to Authority a replacement part for Authority's spare parts inventory.

ARTICLE 2 PRODUCTS

A. The supplier shall have not less than five years experience in the manufacture of OCS hardware.

ARTICLE 3 EXECUTION

3.01 CONSTRUCTION

A. Furnish and install all OCS poles and portal cross-beams.

B. Furnish and install OCS support systems including cantilevers, tunnel supports, headspan supports, and cross-span wire support pull-off and registrations on required poles.

C. Furnish, string, tension and insulate messenger and contact wires, including fabrication and erection of hangers and power feeder jumpers.

D. Furnish and install balance weight anchor tensioning assemblies, including insulation, tensioning and setting.

E. Furnish and install fixed termination anchor assemblies, including tensioning and insulation.

F. Furnish and install overhead and underground feeder cables and negative return cables, via the installed conduits and manholes/handholes.

G. Furnish and install OCS disconnect switches, and associated feeders and ground system.

H. Furnish and install mechanical section insulators, and overlap sectioning insulation.

I. Furnish and install warning signage.

J. Furnish and install grounding and bonding of the OCS structures as shown on the Contract Drawings.

K. Furnish and install surge arresters, with associated grounding.

L. Furnish and install switch heater power supply cables and associated hardware.

M. Furnish stagger and height gauges.

N. Furnish and install Contact Wire Heater System, to include all contact wire West of Allegheny Station.

O. Furnish mandatory and recommended additional spare parts.

P. Finish special tools and equipment for OCS maintenance.

Q. Furnish and install all necessary temporary material including poles, guys, insulators, splices, fittings, terminations and miscellaneous items required to enable the overhead contact system to be constructed in a manner consistent with Work sequences and the vehicle testing schedule.
   1. The temporary work should incorporate all requirements necessary to construct the OCS in various stages and be coordinated with other Authority contractors.
   2. The Contractor shall be aware that vehicle, system and integrated testing, and partial revenue service requires OCS energization of portions of the existing Authority Stage I mainline and the North Shore Connector extension.

R. Field Testing
   1. The Contractor shall obtain approval for the test plan and procedures as set forth in the Contract Documents prior to starting field testing.
   2. The Contractor shall perform all tests necessary to ensure that the OCS equipment performs according to the requirements of the Contract Documents.
   3. Test the OCS and furnish field support for start-up and integrated system testing in accordance with the requirements of the Contract Documents.

S. Provide operating and maintenance manuals for the equipment in accordance with the Contract Documents.

T. Provide training and training materials for Authority operating and maintenance personnel in accordance with the Contract Documents.

U. Provide maintenance support during integrated and pre-revenue service testing.

3.02 CONTRACTOR SUPPORT DURING INTEGRATED TESTING AND PRE-REVENUE SERVICE

A. Contractor shall provide sufficient personnel and equipment to support Authority's Integrated Testing Program and Pre-Revenue Service operations.

B. Integrated Testing is the testing of the Light Rail Vehicle and the designed functioning of traction power substations, OCS, communications and signals, in operating and emergency simulation modes. Certain tests will be developed to analyze the performance of the OCS under varying conditions.

C. Contractor shall support the Integrated Testing by operating their equipment in accordance with the Integrated Testing procedures and maintain the OCS at full performance.

D. In the event of any malfunctions to the OCS, the Contractor shall quickly identify the problem, repair or adjust and replace necessary items of equipment.

E. Pre-Revenue Service operations is the training runs of Authority's Operations and Maintenance personnel. All types of operational and emergency situations will be simulated. The Contractor shall support these tests and maintain the OCS at full performance.

3.03 SUPPORT DURING REVENUE SERVICE

A. It is Authority's intent to perform long term maintenance with its own forces. During initial Revenue Service, Authority's maintenance forces are considered trainees; thus Contractor will be required to provide technical assistance in troubleshooting, repair and maintenance. Contractor shall observe Authority's maintenance personnel and advise and assist them with necessary actions to provide a high level of quality maintenance.

B. Contractor shall provide up to 200 manhours of maintenance assistance to Authority during the six months following the opening of revenue service.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16602.001 - OCS Pole shall be measured per each, complete in place.

B. Item 16602.002 - OCS Portal shall be measured per each, complete in place.

C. Item 16602.003 - OCS Cantilever shall be measured per each, complete in place.

D. Item 16602.004 - OCS Wiring shall be measured per linear foot, complete in place.

E. Item 16602.005 - Balance Weight Anchor Assembly shall be measured per each, complete in place.

F. Item 16602.006 - Termination Assembly shall be measured per each, complete in place.

G. Item 16602.007 - Down Guy Anchor shall be measured per each, complete in place.

H. Item 16602.008 - Section Insulator shall be measured per each, complete in place.

I. Item 16602.009 - Disconnect Switch shall be measured per each, complete in place.

J. Item 16602.010 - Surge Arrester shall be measured per each, complete in place.

K. Item 16602.011 - Tunnel Support shall be measured per each, complete in place.

L. Item 16602.012 - Headspan shall be measured per each, complete in place.

M. Item 16602.013 - Dead End Bracket shall be measured per each, complete in place.

N. Item 16602.014 - Signage shall be measured per Lump Sum, complete in place.

O. Item 16602.015 – OCS Grounding shall be measured per Lump Sum, complete in place.

P. Item 16602.016 - OCS Electrical Testing, Acceptance and Revenue Support shall be measured per Lump Sum, complete in place.

Q. Item 16602.017 - Contact Wire Heater System shall be measured per Lump Sum, complete in place.

4.02 PAYMENT

A. Item 16602.001 - OCS Pole will be paid at the unit price and shall include the cost of all related work specified in this Section.

B. Item 16602.002 - OCS Portal will be paid at the unit price and shall include the cost of all related work specified in this Section.

C. Item 16602.003 - OCS Cantilever will be paid at the unit price and shall include the cost of all related work specified in this Section.

D. Item 16602.004 - OCS Wiring will be paid at the unit price and shall include the cost of all related work specified in this Section.

E. Item 16602.005 - Balance Weight Anchor Assembly will be paid at the unit price and shall include the cost of all related work specified in this Section.

F. Item 16602.006 - Fixed Termination Assembly will be paid at the unit price and shall include the cost of all related work specified in this Section.

G. Item 16602.007 - Down Guy Anchor will be paid at the unit price and shall include the cost of all work specified in this Section.

H. Item 16602.008 - Section Insulator will be paid at the unit price and shall include the cost of all related work specified in this Section.

I. Item 16602.009 - Disconnect Switch will be paid at the unit price and shall include the cost of all related work specified in this Section.

J. Item 16602.010 - Surge Arrester will be paid at the unit price and shall include the cost of all related work specified in this Section.

K. Item 16602.011 - Tunnel Support will be paid at the unit price and shall include the cost of all related work specified in this Section.

L. Item 16602.012 - Headspan will be paid at the unit price and shall include the cost of all related work specified in this Section.

M. Item 16602.013 - Dead End Bracket will be paid at the unit price and shall include the cost of all related work specified in this Section.

N. Item 16602.014 - Signage will be paid at the lump sum price and shall include the cost of all work specified in this Section.

O. Item 16602.015 – OCS Grounding will be at the lump sum price and shall include the cost of all work specified in this Section.

P. Item 16602.016 - OCS Electrical Testing, Acceptance and Revenue Support will be paid at the lump sum price and shall include the cost of all work specified in this Section.

Q. Item 16602.017 - Contact Wire Heater System will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16619

SURGE ARRESTERS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for surge arresters, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Surge arresters shall be installed in each of the following locations:
      a. At each OCS pole traction power feeder to OCS connection (switched or unswitched).
      b. At the OCS pole feed points for track switch heaters, if used.
      c. At locations as shown on the OCS Contract Drawings.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 01910, "Operations, Maintenance and Repair Data"

C. Section 16602, "General Requirements Overhead Contact System."

D. Section 16060, "Bonding and Grounding,"

1.03 SUBMITTALS

A. The following submittals shall be approved by the Engineer prior to fabrication:
   1. Complete manufacturer's descriptions, catalog data, and information including model number.
   2. Manufacturer's general, detail and arrangement Shop Drawings, and installation instructions.
   3. Schematic wiring and interconnection diagrams.
   4. Operation and maintenance manual, with list of spare parts.

ARTICLE 2 PRODUCTS

2.01 SURGE ARRESTERS

A. Surge arresters shall be of the metal oxide varistor type. Each surge arrester shall have an energy discharge capability of 3.2 kJ at 1280 VDC, for currents of 300A or less.

B. Each surge arrester shall be bonded to the grounding system by a No. 2 AWG copper wire with 2000V-rated insulation.

C. Bonding connections between the surge arresters and the grounding systems shall be of the exothermic weld type.

ARTICLE 3 EXECUTION

3.01 INSTALLATION REQUIREMENTS

A. Install surge arresters at locations as specified in Article 1.01B of this Section and as indicated in the Contract Documents.

B. Each surge arrester shall incorporate an individual ground connection that is separate from the OCS pole grounding, as per manufacturer recommendations.

C. Each grounding connection shall have a grounding resistance of 5 ohms or less or as specified by the surge arrester manufacturer for the type of unit supplied. Each location shall achieve the required grounding resistance recommended by the arrester manufacturer without additional costs to Authority.

D. Each grounding arrangement of the arrester shall be tested and approved individually in accordance with the testing procedures specified in Section 16060, "Grounding and Bonding," and as recommended by the arrester manufacturer.

E. Bonding cable connections between the surge arresters and the OCS, and between the surge arresters and the grounding system, shall be installed with a minimum number of bends.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16620

UNINSULATED CONDUCTORS AND CABLES

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for uninsulated conductors and cables, in accordance with the Contract Documents.

B. This Section includes, but is not limited to the following:
   1. Messenger Wire.
   2. Contact Wire.
   3. OCS Jumper Wire.
   4. Ground Wire.

C. Contractor shall supply and install all applicable bare conductors and wires for the 650 VDC overhead contact system in accordance with the requirements specified.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 01910, "Operations, Maintenance and Repair Data"

C. Section 16602, "General Requirements Overhead Contact System."

D. Section 16800, "Overhead Contact System Installation."

1.03 REFERENCE STANDARDS

A. ASTM
   1. B1 Hard-Drawn Copper Wire.
   2. B3 Soft or Annealed Copper Wire.
   3. B8 Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.
   4. B47 Copper Contact Wire.
   5. B105 Hard-Drawn Copper Alloy Wires for Electrical Conductors.
   6. B173 Rope-Lay-Stranded Copper Conductors having Concentric-Stranded Members, for Electrical Conductors.
   7. B193 Resistivity of Electrical Conductor Materials, Test Method.
   8. B229 Concentric-Lay-Stranded Copper and Copper- Clad Steel Composite Conductors.
   9. B258 Standard Nominal Diameters of Cross- Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors.

1.04 SUBMITTALS

A. Contractor shall submit Shop Drawings to the Engineer for approval to cable and wire manufacture. Included as a minimum shall be:
   1. Physical Characteristics and Parameters
      a. Size.
      b. Type.
      c. Material.
      d. Number of and diameter of individual wires.
      e. Overall diameter.
      f. Cross section area.
      g. Weight per foot.
      h. Rated breaking load.
   2. Electrical Characteristics
      a. Rated current carrying size (AWGkcmil)
      b. Resistance per unit length.

B. Contractor shall provide samples of conductors.

C. Contractor shall furnish certification from the manufacturer verifying that the conductors have been designed, manufactured, inspected and tested in accordance with applicable portions of the referenced standards, and the Contract Documents.

D. Contractor shall provide certified copies of manufacturer's test reports for the specific conductors furnished, which shall include but not limited to the following:
   1. Initial and Final Modulus of Elasticity (E).
   2. Coefficient of Thermal Expansion (CTE).
   3. Yield stress.
   4. Hardness values.
   5. Torsional twist test.

1.05 DELIVERY, STORAGE AND HANDLING

A. Ensure that all materials furnished are suitably packaged and protected against damage during delivery and transportation.

B. Store all products in accordance with the manufacturer's instructions, to ensure that all material is protected from damage and exposure.

C. Handle and otherwise use the wire and cable in accordance with the manufacturer's instructions, so as to ensure that the products are not damaged or misused prior to or during installation.

D. Any damage to the wire and cable shall be Contractor's responsibility, and all repairs and replacements shall be accomplished by Contractor in accordance with the manufacturer's instructions and with the approval of the Engineer, at Contractor's expense.

E. All wire and cable shall be shipped on reels suitable for the conductor type and weight carried.

1.06 WARRANTY

A. The conductors shall have a minimum in-service life expectancy of 30 years under operating conditions. The normal wear of the contact wire is an acceptable reason for its replacement prior to 30 years.

B. The conductors shall be unconditionally guaranteed by the manufacturer and/or supplier to be free from defects for a period not less than 2 years.

C. Contractor shall be responsible for the correct installation of all conductors specified herein, and any repairs and replacements shall be made by Contractor in accordance with the cable/wire manufacturer's instructions at Contractor's expense.

ARTICLE 2 PRODUCTS

2.01 MATERIAL

A. Conductor materials shall be of a composition, quality, and purity, such that the finished product shall have the properties and characteristics described in this Section. All conductors shall be of uniform size and shape.

B. The bare conductor particulars shall be in accordance with the parameters indicated on the Contract Drawings and specified herein.

C. Messenger Wire: 500 kcmil hard drawn copper cable, 37 strand, conforming to ASTM B1 and B8, Class AA, bare.

D. Contact Wire: 350 kcmil hard drawn copper cable, solid grooved, conforming to ASTM B47.

E. Equalizing In-Span Jumpers: 350 kcmil annealed copper cable, stranded, conforming to ASTM B3 and B8, Class C, bare.

F. Feeder and Continuity Jumpers: 500 kcmil annealed copper cable, stranded, conforming to ASTM B3 and B8, Class H, bare.

G. Stage I Yard Messenger Wire for Gateway crossover: 2/0 AWG Type G hard drawn copperweld -copper cable, 7 strand, conforming to ASTM B229.

2.02 PERFORMANCE

A. The physical, mechanical and electrical properties of the conductors shall conform to the requirements of the Contract Documents.

2.03 INSPECTION AND TESTING

A. Authority reserves the right to witness the manufacture, testing and packing of all conductors. The manufacturer shall notify the Engineer not less than 10 days in advance of manufacturing and testing operations.

B. All conductors shall be subject to factory quality control tests as required in the applicable Standards. Tests shall be performed on each reel prior to shipment. A certified copy of the test report for each reel shall be submitted to Engineer prior to shipment. A copy of the test report shall be packed with each reel.

C. Grooved contact wire supplied in accordance with ASTM B47 shall be subject to the twist test in addition to other required tests. The twist test shall be performed as specified for round wire, except that 6 twists shall be required. Contact wire not meeting this test will be rejected.

2.04 PACKAGING AND MARKING

A. All conductors shall be shipped on wooden reels, suitable for the weight of the conductors and shall be protected from damage. The diameter of the drum shall be sufficiently large so as to avoid difficulty with waves or kinks when the conductor is strung. The grooved contact wire shall be wound on the reel in such manner that the vertical axis of cross section shall be perpendicular to the axis of the reel with the contact surfaces facing inward and the top (grooved) side outward.

B. Each reel shall consist of one continuous, unspliced conductor, and shall have the required length of conductor so that no splices are required in the tension sections as installed.

C. Contact wire shall be permanently identified at intervals of 300 ft along its length on the surface of the top lobe, showing the manufacturer's mark, material, size in AWG and year of manufacture.

D. Each reel shall have a strong, weatherproof tag or marker securely fastened to it, showing the size and type of conductor as well as the ASTM designation, name and mark of the manufacturer, total reel length, and weight and manufacturer's special instructions.

E. A stripe in any contrasting color approximately 1 in wide shall be painted across the outermost layer on each reel. Any visible conductor shift at this line, upon receipt at the job Worksite, will be treated as indicating a relative wire movement during shipment, and is cause for reel rejection.

F. Splices in contact wire stock shall be marked with paint or dye prior to wire drawing. The marks shall be readily distinguishable after the wire drawing process.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Conductor installation shall be in accordance with Section 16800, "Overhead Contact System Installation."

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16622

INSULATORS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for insulators, in accordance with the Contract Documents.

B. This Section includes, but is not limited to the following:
   1. Cantilever Pipe Insulators.
   2. Tunnel Support Insulators.
   3. Messenger Support Insulators.
   4. Messenger In-Span and Termination Insulators.
   5. Contact Wire In-Span and Termination Insulators.
   6. Contact Wire Insulators, non-riding type without weathersheds.
   7. Feeder Line-Post and Termination Insulators.
   8. Headspan and Cross Span Wire Insulators.

C. All contact wire riding-type insulators for use on Section insulator assemblies are not part of this Section, and are specified in Section 16625, "Section Insulators."

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 16602, "General Requirements Overhead Contact System."

C. Section 16625, "Section Insulators."

D. Section 16800, "Overhead Contact System Installation."

1.03 REFERENCE STANDARDS

A. ANSI
   1. C2 National Electrical Safety Code.
   2. C29.1 Test Methods for Electrical Power Insulators.

B. ASTM
   1. A153 Zinc Coating (Hot-dip) on Iron and Steel Hardware.
   2. D149 Dielectric Breakdown Voltage and Dielectric Strength of Electrical Solid Insulating Materials at Commercial Power Frequencies.
   3. D229 Rigid Sheet and Plate Materials Used for Electrical Insulation, Method of Testing.

4. D256 Impact Resistance of Plastics and Electrical Insulating Materials, Test Methods.
5. D570 Water Absorption of Plastics, Test Method.
6. D624 Rubber Property Tear Resistance, Test Method.
7. D635 Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position, Test Method.
8. D638 Tensile Properties of Plastics, Test Method.
9. D651 Tensile Strength of Molded Electrical Insulating Materials, Test Method.
10. D695 Compression Properties of Rigid Plastics, Test Method.
11. D696 Coefficient of Linear Thermal Expansion of Plastics, Test Method.
12. D732 Shear Strength of Plastics by Punch Tool, Test Method.
13. D790 Flexural Properties of Plastics and Electrical Insulator Materials, Test Method.
14. D1149 Rubber Deterioration-Surface Ozone Cracking in a Chamber, Test Method.
15. D2303 Liquid-Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials, Test Method.
16. G21 Determining Resistance of Synthetic Polymeric Materials to Fungi, Practice.

C. NEMA
1. HV1 High-Voltage Insulators.
2. PH20 Galvanized Ferrous Insulator Clevises.

1.04 SUBMITTALS

A. Contractor shall submit Shop Drawings for approval to the Engineer prior to insulator manufacture, showing details and dimensions of the insulating and metal parts, describing the material composing the various parts, together with technical, mechanical and electrical characteristics and data.

B. Contractor shall prepare and submit an insulator device (assembly) and loading table for each type of insulator.

C. Contractor shall submit to the Engineer for approval details of the tests proposed for each insulator and the procedures and forms to be used during tests and inspection.

D. Certification: Contractor shall provide certificates of compliance for the following:
1. Steel analysis.
2. Hot dip galvanizing.
3. Adhesive materials.
4. Insulator materials.
5. In-service performance record of proposed insulators.
6. Certified Quality Control Procedures used in the manufacturing process.

E. Data to be furnished by Contractor, and approved by the Engineer prior to insulator installation:
   1. A complete set of assembly, component, and detail Shop Drawings showing dimensions, weights and form and fit functions of items.
   2. Storage, handling and installation instructions.
   3. Details of any specifications for materials included in the insulator assembly which are not covered in this Section.

F. Engineer shall be informed at least two weeks in advance of the date on which insulators will be ready for inspection and tests.

G. Contractor shall submit samples for approval by the Engineer of each type of insulator to be used on the Project.

H. The insulators shall be virtually maintenance free. If the manufacturer/supplier recommends specific maintenance procedures and data, they shall be submitted/approved without exception, prior to the supply of all insulators.

1.05 QUALITY ASSURANCE

A. Factory Quality Control: Factory tests shall be made as required by the Contract Documents. Test reports shall be submitted as detailed herein.

1.06 SYSTEM DESCRIPTION

A. Contractor shall supply and install all applicable insulators for the overhead wires and cables associated with the 650 VDC OCS, in accordance with the requirements specified.

1.07 DELIVERY, STORAGE AND HANDLING

A. Contractor shall ensure that all materials furnished are suitably packaged and protected against damage during delivery and transportation.

B. Contractor shall store all products in accordance with the manufacturer's instructions, to ensure that all material is protected from damage and exposure.

C. Contractor shall handle and otherwise use the insulators in accordance with the manufacturer's instructions, so as to ensure that the products are not damaged or misused prior to or during installation.

D. Any damage to the insulators shall be Contractor's responsibility, and all repairs and replacements shall be accomplished by Contractor in accordance with the manufacturer's instructions, at Contractor's expense.

1.08 WARRANTY

A. The insulators shall have a minimum in-service life expectancy of 30 years under operating conditions.

B. The insulators shall be unconditionally guaranteed in writing by the manufacturer and/or supplier to be free from operational and manufacturing defects for a period not less than 5 years.

ARTICLE 2 PRODUCTS

2.01 DESCRIPTION

A. The insulators covered by this Section are for use in the following applications, and are to be non-ceramic:
   1. OCS Insulators
      a. Cantilever Pipe and Tunnel Support Insulators - for the support and insulation of the cantilever and tunnel support pipe/tube frames, mounted to the poles and tunnel ceiling or wall. These shall be manufactured from glass fiber reinforced resin.
      b. Messenger Wire Support, In-Span and Termination Insulators - For the vertical and horizontal support, cut-in and dead ending of the main messenger wire which supports the hangers and contact wire. These shall be manufactured from glass fiber reinforced resin.
      c. Contact Wire In-Span and Termination Insulators - For the horizontal cut-in and dead-ending of the grooved contact wire for the Overhead Contact System. These shall be manufactured from glass fiber reinforced resin.
      d. Contact Wire Non-Riding Insulators - For the horizontal insulation of the grooved contact wire as a cut-in tension member used on overlaps where uplift may cause the pantograph to hit a normal weathershed insulator. These shall be manufactured from glass fiber reinforced resin without weathersheds.
      e. Feeder Termination and Line-Post Insulators - For the 650 VDC system feeder wires mounted on the OCS structures serving the tracks. These shall be manufactured from glass fiber reinforced resin.
      f. Headspan and Cross Span, Termination and In-Span Insulators - The horizontal insulation of the headspan and cross span wires shall be manufactured from glass reinforced fiber.

2.02 NON-CERAMIC INSULATOR MATERIALS

A. The non-ceramic insulator shall be a unit consisting of a rod, and end fittings. The rod shall be made of glass with its fibers running longitudinally through the rod length. The rod may be attached to the end fittings or hardware by a compression sleeve, wedge or adhesive. If adhesive is used, the adhesive shall encapsulate the rod in the end-fitting cavity and shall form a compressive wedge upon loading.

B. The non-ceramic insulator shall be constructed so as to be a light-weight, compact unit with high-impact strength. They shall be of a material that is vandal resistant insofar as being shatter-proof, thereby reducing vandalism damage.

C. The metal parts of the insulators shall be made of malleable iron, ductile iron, or forged steel and be galvanized in accordance with ASTM A153. Metal parts shall be galvanized prior to assembly to the rod.

D. The insulators shall be capable of withstanding service in an environment which includes exposure to ultraviolet radiation, moisture, surface discharges, ozone, temperature extremes, diesel engine exhaust fumes, and a diversity of contaminants such as industrial pollutants.

E. The insulators shall be designed to be capable of maintaining the integrity of the weathershedding material at all component interfaces. The interface between rod and weathershed shall, for the life of the insulator, remain void-free and dry. Color shall be ANSI Z55.1, color 61 light gray enamel. Minimum dry film thickness shall be one mil.

F. The resin-bonded glass fiber rod shall be sound and free from any defects or blemishes which may affect the life and performance of the insulator. It shall be of uniform quality throughout its length.

G. All non-ceramic material shall have a smooth, void-free finish. All adhesive coatings shall be sealed to the fittings to protect them against the ingress of moisture.

H. The design shall be such that stress due to temperature variation, and mechanical extension/contraction in any part of the insulator under load and normal handling, shall not lead to deterioration. The materials used shall not cause degradation by chemical interactions.

I. The end fittings attached to the fiberglass rod of the insulators shall ensure exact alignment with the rod and correct assembly in respect to each other to avoid torsional stress when the insulator is installed.

J. The insulators shall be so designed that no sparking or arcing shall occur on the surface of the insulator when energized at the maximum design voltage under clean and dry conditions.

K. The insulators shall be designed to suit the various wire systems and assembly arrangements, as shown.

L. Contractor may submit non-ceramic insulators of alternative design to the Engineer for approval. The alternative design shall meet or exceed all electrical, mechanical, dimensional, environmental, and other technical characteristics as specified herein, and all types shown have a proven in-service service history of not less than 5 years.

2.03 SPECIFIC REQUIREMENTS

A. All insulators shall include the fittings and connections for attachment to the pipe, pole, tunnel support, or steelwork, as shown in the Contract Documents.

B. The insulator shall be suitable for both horizontal and vertical mounting and installation, unless otherwise specified.

C. The insulators shall be formed to fit the specified conductors as shown on the Contract Drawings.

2.04 TECHNICAL CHARACTERISTICS AND DIMENSIONS

A. Insulator Characteristics

1.	Nominal Voltage	650 VDC.
2.	Insulation class	2 kV.
3.	BIL	3.7 kV AC, rms.
4.	Leakage Distance	1.88 in minimum.
5.	Dry Flashover	35 kV.
6.	Wet Flashover	18 kV.

2.05 MARKING

A. Each insulator shall bear the manufacturer's name or trademark and year of manufacture, clearly and permanently imprinted or attached without leaving any irregularity that would affect the electrical and mechanical performance of the insulator.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. The insulators shall be installed in accordance with the manufacturer's instructions, as shown on the Contract Drawings, and as specified in Section 16800, "Overhead Contact System Installation."

B. All tests shall be completed and all test reports accepted by the Engineer prior to shipment of any insulators.

3.02 PRODUCTION TESTS AND FABRICATION

A. The following tests shall be performed in accordance with ANSI C29.1
   1. Visual and Dimension Test
      a. The entire surface shall be smooth and free from defects.

b. If adhesives are used, the insulator shall be inspected to see that the fillet of adhesive provides a complete seal between the coating and end fitting.
c. The insulator shall be inspected to verify that both end fittings are in line after being assembled on the rod.
d. The insulator shall be in accordance with approved Shop Drawings and the Contract Drawings.

2. Routine Flashover: A sampling of not less than 5 percent of each type of insulators shall be subjected to a flashover test in accordance with ANSI C29.1. For this test, an electrode shall be placed at each side of, and adjacent to, the non-ceramic barrier. Should any test specimen fail, all insulators in the production batch of that specimen are subject to rejection. Alternatively, each insulator in the batch may be tested. Any insulators that puncture will be cause to have the insulator design rejected.

B. Proof Test: All insulators shall be subject to a mechanical strength proof test. The insulators shall be tested at room temperature for ten seconds to 120 percent of the designed tensile, compressive or bending load. Failure shall constitute rejection.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16625

SECTION INSULATORS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for section insulators, in accordance with the Contract Documents.

B. Section insulators are units in the OCS that achieve electrical isolation while allowing physical clearance for the passage of a pantograph. The Section Insulators shall be Arthur Flury 6.3670-7 or Authority approved equal.

C. Bridging type section insulators used for sectionalizing purposes, as shown, shall permit continuous current collection.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 16602, "General Requirements Overhead Contact System."

C. Section 16800, "Overhead Contact System Installation,"

D. Section 16622, "Insulators."

1.03 REFERENCE STANDARDS

A. ANSI

B. ASTM

C. IEEE

D. NEMA

1.04 SUBMITTALS

A. Furnish the following for approval by the Engineer
   1. Insulators
      a. Electrical
         1) Creepage length (in).
         2) Insulation level (impulse withstand test voltage, kV).
         3) DC test voltage (kV).
      b. Mechanical

1) Attachment centers and overall length (in).
2) Shed diameters (in).
3) Core diameters (in).
4) Breakdown of weights, insulator and fittings (lbs).
5) Tensile test withstand load (lbs).
6) Recommended maximum working tensile load (lb-ft).
7) Material (including end caps and touch- up insulator sealants).

2. Manufacturer's design safety factors.
3. Shop Drawings of hardware and components.
4. Listing and description of components and hardware.
5. Shop Drawings and specifications required for field forming and setting of contact wire into items, including gliders.
6. For assemblies, list values of BIL, ultimate tensile strengths, ultimate torsional strength, weights (including weight of components), and electrical characteristics.
7. Calculations to indicate maximum design loading occurring at each insulator location.

B. Instruction Manual: Instruction Manuals shall be furnished covering complete instructions for installation, operation, maintenance and testing. Complete replacement parts lists shall be included.

C. Test Reports: Reports of the following tests shall be furnished:
1. Prototype tests.
2. Production tests.
3. Field tests.

D. The manufacturer shall submit full information, with supporting documentation, on the in-service performance history of the proposed section insulators, in accordance with the Contract Documents.

1.05 DELIVERY, STORAGE AND HANDLING

A. Contractor shall ensure that all materials furnished are suitably packaged and protected against damage during shipping and storage.

B. Contractor shall store all products in accordance with the manufacturer's instructions, to ensure that all material is protected from damage and exposure.

C. Contractor shall handle and otherwise use the section insulators in accordance with the manufacturer's instructions, so as to ensure that the products are not damaged or misused prior to or during installation.

D. Any damage to the section insulators shall be Contractor's responsibility, and all repairs and replacements shall be accomplished by Contractor in accordance with the manufacturer's instructions, at Contractor's expense.

ARTICLE 2 PRODUCTS

2.01 PRODUCT CRITERIA

A. The section insulators shall be suitable for use in all styles and configurations of the OCS, including bi-directional traffic.

B. The section insulator shall be suitable to be positioned, in general, adjacent to a OCS support point, but shall also be compatible in-span, providing the span lengths are suitable and messenger heights are sufficient to allow for the extra sag. The arrangements showing the Section Insulator locations and requirements shall be as shown on the Contract Drawings.

C. The section insulators shall be capable of continuous operation at the nominal OCS voltage of 650 kVDC under all operational weather conditions specified for the project area. The section insulator shall be tested for dry flashover, wet flashover, low frequency dry and wet withstand, and impulse withstand tests. The tests shall be performed in accordance with applicable ANSI/IEEE Standards. Electrical criteria shall be the same as for other insulators on the project, as stated in Section 16622, "Insulators."

D. Assembly and component parts shall be designed for ease of maintenance, replacement, assembly, and disassembly with a minimum of specialized tools. Component parts shall be identified for this purpose.

E. To ensure continuous current collection during the passage of a pantograph, there shall be an riding overlap of the runners on bridging type assemblies.

F. The messenger insulation shall be of non-ceramic material in accordance with Section 16622, "Insulators."

G. The contact wire insulator shall be glass fiber reinforced synthetic resin or polymer and shall be 6 kV class insulation.

H. Stabilizing hangers (with suitable means of field adjustment) shall be provided from the messenger to restrict the rotational movement of the section insulator and to ensure correct alignment of the runners with respect to the pantograph. Loop or link insulators will be required in each stabilizing hanger.

I. The interface and connection of the contact wire insulator to the runners shall be designed so as to permit a smooth riding path without pantograph carbon damage and dynamic collector bounce. The mass of the connection and the skids shall be as small as possible. The skids shall be field adjustable to achieve alignment with the pantograph and the OCS.

J. The spacing of the runners on the section insulator shall be such that both sides are always in contact with the working portion of the pantograph.

K. The insulators and their end fittings shall be designed for the maximum working tensions of the conductors as shown on the Contract Documents. A factor of safety of 2.5 minimum shall be used for all components of the section insulator.

L. All components, particularly those associated with the contact wire, shall be as lightweight as possible.

M. The insulators should be capable of operating with multiple pantograph passes at speeds from zero to a maximum of 50 mph, without sustaining damage or causing OCS operational problems.

2.02 MANUFACTURER

A. The section insulator shall be supplied by the manufacturer complete in all respects suitable for installation.

B. Galvanizing: All steel and malleable or ductile cast iron fittings shall be hot-dip galvanized in accordance with ASTM Specification A-123, A-153, or A-386. Galvanizing shall be accomplished prior to assembly of the section insulator.

C. Testing
   1. All tests shall be conducted by the manufacturer. Authority reserves the right to attend the tests. Contractor shall inform the Engineer not less than 10 days in advance of testing operations. A certified test report shall be supplied whether or not the Engineer attends the tests.
   2. Contractor shall provide test data or reference applicable field operational experience for the same product in a similar application. This performance history shall demonstrate that for a 5 year in-service period, all weathershed material experiences no failure or detrimental effects for ultra-violet radiation and electrical tracking.
   3. The messenger insulators shall be tension-proof tested in accordance with the Contract Documents, and the contact wire units shall be tension-proof tested to 13,600 lbs.
   4. All test reports shall be submitted to and approved by the Engineer prior to shipment of any components.

ARTICLE 3 EXECUTION

3.01 GENERAL INSTALLATION REQUIREMENTS

A. Section insulators shall be installed as shown in the Contract Drawings and in accordance with the manufacturer's approved instructions.

B. All electrical connectors and clamps shall be prepared and protected externally and internally in accordance with the manufacturer's recommendations.

C. The method of installation shall assure there is no damage to the OCS wires. Any kinked contact wire shall be repaired as specified in Section 16800, "Overhead Contact System Installation," or replaced at Contractor's expense if the damage is prejudicial to good current collection.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16626

GALVANIZED STEEL WIRE AND WIRE ROPE

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for galvanized steel wire and wire rope, in accordance with the Contract Documents.

B. This Section includes, but is not limited to; all grades of galvanized steel wire, wire-strand terminations, wire assemblies, and wire rope for use as support wires, pull-off wires and down guys for the Overhead Contact System (OCS), as shown on the Contract Documents.

1.02 RELATED SECTIONS

A. Section 01300, “Administrative Requirements”

B. Section 01910, “Operations, Maintenance and Repair Data”

C. Section 16602, “General Requirements Overhead Contact System.”

1.03 REFERENCE STANDARDS

A. ASTM
   1. A475 Zinc-Coated Steel Wire Strand.

1.04 SUBMITTALS

A. Reports for each type of wire to be used containing the physical and mechanical properties of all components described in this Section shall be submitted. The conformance of components with the Contract Documents in the form of a manufacturer's certification shall be included. Include the following as a minimum:
   1. Size.
   2. Type.
   3. Material.
   4. Number of and diameter of individual wires.
   5. Overall diameter.
   6. Cross section area.
   7. Weight per unit length.
   8. Rated breaking strength.

9. Project use and application data.

B. Contractor calculations for attachment heights, span hanger lengths and loadings for cross-spans and headspans.

C. Operation (installation) and maintenance manuals shall be submitted for all down guy strands and specialized wire-strand terminations.

ARTICLE 2 PRODUCTS

2.01 DESCRIPTION

A. Components: The zinc-coated stranded wire shall be manufactured and tested in accordance with ASTM A475.

B. Performance: Physical properties of the zinc-coated stranded wire shall conform to the description in Table 1 of ASTM A475.

C. Materials: The material used for stranded steel wire and wire components shall conform to ASTM A475.

D. Zinc Coating: The weight of coating for zinc-coated steel wire shall not be less than that specified in Table 4, under Class C of ASTM A475.

E. Galvanized steel wire and wire rope shall be of the following types:
   1. Deadend, headspan and cross span wires: 1/2 inch diameter, high strength grade.
   2. Head guy and down guy wires: 3/4 inch diameter, extra high strength grade.

2.02 CERTIFICATION

A. Contractor shall provide certification that the galvanized steel wire and wire rope have been designed, fabricated, rated and tested in compliance with the Contract Documents.

ARTICLE 3 EXECUTION

3.01 DELIVERY AND MARKING

A. Materials shall be protected against damage in ordinary handling and shipping. Each reel shall have a strong, weatherproof tag securely fastened to it showing the physical and mechanical properties as well as the steel type designation, ASTM designation and the name and mark of the manufacturer.

3.02 INSTALLATION REQUIREMENTS

A. Galvanized steel wire and wire rope shall be cut and installed using tools and methods specified by the manufacturer.

B. Splicing of the galvanized steel wire and wire rope will not be permitted under any circumstances.

3.03 INSTALLATION OF CROSS-SPAN AND HEADSPAN ASSEMBLIES

A. Prior to installation of the cross-span and headspan assemblies, the Contractor shall record the following field details along the axis of the spans for review by the Engineer.
   1. Pole to pole, track to track, and track to pole centerline dimensions.
   2. Relative cross-track elevations of tops of foundations and tracks.
   3. Track superelevations and directions facing towards higher station numbers.

B. Contractor shall review and note all field changes from the Contract Drawings, and submit these changes together with the recommendations to the Engineer.

C. Wire sizes, location of turnbuckles, insulators, suspension assemblies, and hangers for the OCS shall be installed in accordance with the Contract Drawings.

D. The attachment heights, span hanger lenghts and loadings for cross-spans and headspans shall be fully developed by the Contractor in calculations for each location in accordance with standards shown on the Contract Drawings.

3.04 INSTALLATION OF DOWN GUYS

A. Down guys shall be installed before the OCS wires are strung. They shall be pulled taut, and secured in place with provisions for future adjustment as required to hold the structure in proper alignment after wires are installed to their final configuration and tensions.

B. Down guy terminations and attachments shall be installed as recommended by the manufacturer.

C. Guy guards shall be high luminous type installed as shown on the Contract Drawings, or as found necessary in the field, to protect the public from any potential danger imposed upon them by the guy wire.

D. Contractor shall make all final adjustments necessary to the down guys to compensate for initial stretch to insure the proper guying of structures.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16627

STAINLESS STEEL WIRE ROPE, STRAND, ROD AND STRIP

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for stainless steel wire rope, strand, rod and strip, in accordance with the Contract Documents.

B. This Section includes, but is not limited to the following:
   1. Stainless Steel Wire Rope
      a. Balance weight anchor assembly.
      b. Cantilever nose hanger wire.
      c. Bridle wires.
      d. Headspan and cross spans.
   2. Stainless Steel Wire Strand
      a. Span wire registration assembly.
      b. Messenger wire knuckle assembly.
      c. OCS hanger.
   3. Stainless Steel Strip
      a. OCS reduced length hanger.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 16602, "General Requirements Overhead Contact System."

1.03 REFERENCE STANDARDS

A. ASTM
   1. A276 Stainless Steel Bars and Shapes.
   2. A368 Stainless and Heat Resisting Steel Wire Strand.
   3. A492 Stainless Steel Rope Wire.
   4. A555 General Requirements for Stainless Steel Wire and Wire Rope.
   5. A580 Stainless Steel Wire.

1.04 SUBMITTALS

A. Certification: Furnish certification verifying that the stainless steel wire rope, strand and rod have been designed, manufactured, inspected and tested in accordance with the referenced standards and these Specifications.

B. Test Reports: Furnish copies of reports of all factory tests as required by these Specifications and referenced standards.

C. Manufacturer's Data: Furnish complete manufacturer's data.

D. Project Use: Furnish complete application data for all types of wire rope, strand, strip and rod used in for the OCS configurations.

1.05 SYSTEM DESCRIPTION

A. The stainless steel wire rope, strand, strip and rod shall be suitable for uses as shown, acceptable for use on a medium speed overhead contact system, and provide for a usable and maintainable wire arrangement.

1.06 DELIVERY, STORAGE AND HANDLING

A. The wire rope and strand shall be shipped on reels suitable for the weight carried.

B. The rod shall be shipped on reels suitable for the weight carried or in straight lengths, securely bundled. Rods shipped on reels shall be straightened prior to use.

C. The strips shall be shipped in bundles.

D. All material shall be protected against damage during handling and shipping. Each reel or bundle shall have a strong, weatherproof tag securely fastened showing the physical and mechanical properties as well as type designation, ASTM designation and the name and mark of the manufacturer, the total length and weight of the wire rope, strand or rod on each reel or bundle.

ARTICLE 2 PRODUCTS

2.01 MATERIALS

A. General
   1. Austenitic grade stainless steel.
   2. High corrosion resistance.
   3. Compatible with component items.
   4. Designed to carry maximum working loads with a factor of safety of 2.5 minimum based on yielding stress.

B. Stainless Steel Wire Rope
   1. Extra flexible.
   2. Manufactured, tested and in conformance with requirements of ASTM A368, A492, A555 and A580.

C. Stainless Steel Wire Strand
   1. Manufactured, tested and in conformance with requirements of ASTM A368, A555 and A580.

D. Stainless Steel Rod and Strip
   1. Round for rod, flat for strip.
   2. Manufactured, tested and in conformance with requirements of ASTM A276.

E. Stainless steel wire and wire rope shall be of the following types:
   1. Hangers: 3/16 inch diameter, 7x19 construction, 3700lbs breaking strength.
   2. Bridle Cables: 3/8 inch diameter, 7x19 construction, 10,000 lbs breaking strength.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Hangers shall be spaced as shown within a tolerance of ± 2 inches.

B. No damage to the interfacing components shall occur during installation.

C. Installation of wire rope and strand shall be as shown in the Contract Drawings and in accordance with manufacturer's recommendations

3.02 FABRICATION

A. Hanger lengths shall be fabricated within a tolerance of ± 1/4 inch of calculated lengths.

B. All material must be suitable for field adjustment.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16629

BALANCE WEIGHT ANCHOR ASSEMBLY

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for balance weight anchor assembly, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following:
1. Balance Weight Anchor System
2. Mounting Assembly to poles.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 16602, "General Requirements Overhead Contact System."

C. Section 16800, "Overhead Contact System Installation."

1.03 REFERENCE STANDARDS

A. ASTM
1. A27 Mild to Medium-Strength Carbon Steel Castings.
2. A36 Structural Steel.
3. A47 Malleable Iron Castings.
4. A123 Zinc Coating on Products Fabricated from Rolled, Pressed, and Forged Steel-Shaped Plates, Bars, and Strips.
5. A153 Zinc Coating (Hot Dip) on Iron and Steel Hardware.
6. A167 Stainless and Heat-Resisting Chromium Nickel Steel Plate and Strip.
7. A307 Carbon Steel Externally and Internally-Threaded Standard Fasteners.
8. A386 Zinc Coating (Hot Dip) on Assembled Steel Products.
9. A518 Corrosion-Resistant High-Silicon Cast Iron.
10. A536 Ductile Iron Castings.
11. A668 Steel Forgings, Carbon, and Alloy for General Industrial Use.
12. A711 Carbon and Alloy Steel Blooms, Billets, and Slabs for Forging.

B. ANSI

1.04 SUBMITTALS

A. Contractor shall furnish the following for approval by the Engineer:

1. A complete set of Shop Drawings showing the unit assembly, components, and bill of material giving dimensions, weights, and product data.
2. List of special tools required for assembly and installation of a single unit.

B. The supplier's certificate of compliance shall accompany each shipment. As a minimum, it shall contain the following:
1. Product Name.
2. Drawing Number and revision or date.
3. Serial Numbers (if required).
4. Quantity.
5. Purchase Order Number.
6. List of specifications to which the product was produced.
7. Supplier's name and address.
8. Signature and title of recognized quality authority.

C. Test reports shall be submitted to Authority for information.

D. Operation and maintenance data shall be provided.

1.05 SYSTEM DESCRIPTION

A. The balance weight anchor assembly automatically regulates the tension of the overhead contact system (wires) by compensating for the variations in conductor lengths resulting from changes in temperature due to ambient, solar and current heating variations.

1.06 DELIVERY, STORAGE, AND HANDLING

A. OCS balance weight anchor assemblies shall be packaged in a manner to allow stacking and outdoor storage until installation with no harmful effects.

ARTICLE 2 PRODUCTS

2.01 PERFORMANCE REQUIREMENTS

A. The assembly shall maintain constant tension in the conductors notwithstanding changes in ambient, solar or current heating temperatures. Changes in the lengths of conductors shall be compensated for by an equivalent change in stroke length of the unit. A high and low temperature stop device shall be furnished such that movement of the weights due to OCS behavior at conditions below 0 degrees F and above 122 degrees F is eliminated.

B. The balance weight assembly shall operate at a nominal pulley ratio of approximately 3:1 and within the range of 2.8:1 to 3.2:1.

C. The balance weight assembly shall have pulleys with a grease fitting, and shall be of the same type or equal as pulleys installed on Authority's Stage II LRT System.

D. The balance weight assembly shall operate freely under all climatic conditions within the temperature limits specified and shall function freely when a weight differential of ± 25 lbs is applied to the balance weight stack.

E. The balance weight assembly shall include a fall restraint system that will not allow the balance weights to fall from the superstructure to the ground below.

F. Balance weights shall be fabricated of cast iron, or other approved material, with a vandal-proof assembly.

G. Weight sets may be either one casting or made up from individual castings. If individual castings are used they shall be of an interlocking design to prevent slippage. The assembled stack of weights shall be as compact as possible. Maximum weight for an individual casting shall be 55 lbs.

H. Tolerance on the complete balance weight set shall be -0 lbs +50 lbs.

I. The balance weight assembly shall have a minimum design life of 30 years and shall not require preventative maintenance or inspection at intervals of less than 12 months. The design shall permit disassembly and reassembly of an in-place unit by standard maintenance crews.

J. Assemblies and component parts shall be designed for ease of maintenance, replacement, assembly, and disassembly, which shall be accomplished with a minimum of special tools. Component parts shall be properly identified for this purpose.

K. The assembly shall incorporate provisions for adjustment due to wire elongation (stretch).

L. All materials and the unit design shall have been proven by the manufacturer's experience to be suitable for the purpose for which they are intended. They shall be suitable for the loads and climatic conditions existing in the project.

M. All external ferrous parts shall be stainless steel or hot-dip galvanized in accordance with the appropriate ASTM specification. Any ferrous parts which are not stainless steel or cannot be galvanized shall be painted with an approved epoxy coating with color to match ANSI #61, light gray.

N. Each tensioning device shall bear the manufacturer's name or trademark and year of manufacture clearly and permanently imprinted.

2.02 TESTING

A. The assembly shall be inspected and tested to ensure that it satisfies the Contract Document requirements including dimensional accuracy and compatibility with mating components.

ARTICLE 3 EXECUTION

3.01 GENERAL INSTALLATION REQUIREMENTS

A. The assemblies shall be installed as shown on the Contract Drawings and as specified in Section 16800, "Overhead Contact System Installation." All wire rope shall be non-rotating stainless steel.

B. Adjustment and testing of the device shall be in conformance with the manufacturer's instruction manuals.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16640

OCS FITTINGS AND HARDWARE

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for OCS fittings and hardware, in accordance with the contract documents.

B. This Section includes, but is not limited to, the following:
1. Hanger components.
2. Cross contact bar assembly.
3. Wire splices.
4. Clevis-clevis fittings.
5. Wire terminations.
6. Parallel wire clamps.
7. Nuts, bolts, washers and cotter pins.
8. Messenger wire dead ends.
9. Links and eyebolts.
10. Messenger and contact wire terminations and turnbuckles.
11. Double clevis end fittings.
12. Thimbles.
13. Wire sleeves.
14. Messenger suspension clamps and span wire supports.
15. Span wire clamps.
16. Wire connectors.
17. Span wire adjustable straps.
18. Strain clamps.
19. Knuckle assemblies and wire spacers.
20. Trunion clamps.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 01910, "Operations, Maintenance and Repair Data"

C. Section 16602, "General Requirements Overhead Contact System."

D. Section 16800, "Overhead Contact System Installation."

1.03 REFERENCE STANDARDS

A. Ferrous Metals
   1. ASTM
      a. A27, Mild to Medium-Strength Carbon-Steel Castings.
      b. A47, Malleable Iron Castings.
      c. A153, Zinc coating (Hot-Dip) on Iron and Steel Hardware.
      d. A167, Stainless and Heat-Resisting Steel.
      e. A518, Corrosion-Resistant High Silicon Cast Iron.
      f. A536, Ductile Iron Castings.
      g. A668, Steel Forgings, Carbon and Alloy, for General Industrial Use.
      h. A711, Carbon and Alloy Steel Blooms, Billets, and Slabs for Forgings.
      i. A747, Steel Castings, Stainless, Precipitation Hardening.

B. Nonferrous Metal
   1. ASTM
      a. B26, Specification for Aluminum-Alloy Sand Castings.
      b. B148, Aluminum-Bronze Sand Castings.
      c. B179, Aluminum Alloys in Ingot Form for Sand Castings, Permanent Mold Castings and Die Castings.
      d. B248, General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strips and Rolled Bar.
      e. B249, General Requirements for Wrought Copper and Copper-Alloy Rod, Bar and Shapes.
      f. B557, Methods of Tension Testing Wrought and Cast Iron Aluminum and Magnesium – Alloy Products.
      g. B584, Copper Alloy Sand Castings for General Applications.
      h. B686, Specification for Aluminum Alloy Castings - High Strength.

1.04 SUBMITTALS

A. Shop Drawings: Contractor shall submit Shop Drawings for all components for approval by the Engineer prior to manufacture, showing details and dimensions, and giving designations of the materials comprising the various components together with technical, mechanical and electrical data as appropriate.

B. Samples of certain components shall be submitted to the Engineer for information as listed below and others that may be required by the Engineer:
   1. Messenger wire saddles and or clamps.
   2. Contact wire clamps.
   3. Hanger assembly.
   4. Wire splices.
   5. Messenger suspension clamps.
   6. Messenger span wire supports.
   7. Messenger and contact wire and pull-off terminations.
   8. Parallel groove wire clamps.

9. Jumper and feeder clamps.

C. Installation and maintenance data shall be provided, as required.

1.05 QUALITY ASSURANCE

A. For tension tests, a minimum of three test bars shall be poured from each lot of metal.

B. For chemical analysis each lot of castings shall be analyzed for conformance with the chemical composition specified in the referenced ASTM Standards.

C. A lot shall consist of all castings produced from one furnace melt.

1.06 DELIVERY, STORAGE AND HANDLING

A. The identification mark of the manufacturer or foundry and the pattern numbers assigned by the supplier shall be cast into all castings. Marks and numbers shall be readable size, clear characters and in such a position that they will not affect their electrical or mechanical performance.

B. Fittings and hardware shall be packed in accordance with the best commercial practice, adequate to ensure acceptance and safe delivery.

C. All shipping boxes, bags, or crates shall be properly marked showing the contents of each. If different materials are packaged in a box, bag or crate all items of a kind should be boxed, bagged or crated and properly marked or tagged prior to placement in the shipping vessel.

D. OCS fittings and hardware shall be packaged in a manner to allow stacking and outdoor storage until installation with no harmful effects.

ARTICLE 2 PRODUCTS

2.01 MATERIALS

A. Material for hardware and fittings shall comply with the applicable referenced standards. Hardware and fittings in contact with poles shall be compatible with the pole finish. Substitutions will be considered and approved if the requirements of the Contract Documents are satisfied. Contractor shall be responsible for form and fit of all OCS components and hardware, as shown on the Contract Drawings.

2.02 METAL CHARACTERISTICS

A. Malleable Iron: Fittings or components made of malleable iron shall be grade 32510 or better and shall conform to ASTM A47. All components and fittings shall be galvanized in accordance with ASTM A153.

B. Forged Steel: Material for forged steel shall comply with ASTM A711 or A668. All components and fittings shall be galvanized in accordance with ASTM A153.

C. Ductile Iron: Fittings or components requiring high yield strength shall be of ductile iron, grade 60-40-18 or better and shall conform to ASTM A536. All fittings and components shall be galvanized in accordance with ASTM A153.

D. Stainless Steel: Stainless steel hardware shall conform to ASTM A747.

E. Nonferrous Metals: Copper alloys for fittings and components shall conform with ASTM B584 and B148.

F. Copper: All copper components shall conform to ASTM B248 or B249.

G. Aluminum components shall conform to ASTM B26, B557 and B686.

H. All cotter pins, roll pins, spring clips and hitch pins shall be made out of stainless steel.

2.03 FABRICATION

A. The designated metals shall be produced by an approved method that will meet the requirements of the Contract Documents.

B. Castings shall be of uniform quality and shall be made in such a manner that the material of the casting conforms to the chemical and mechanical properties prescribed in the referenced ASTM standards.

2.04 WORKMANSHIP, FINISH AND APPEARANCE

A. The castings shall be free of adhering sand, voids, cracks, surface porosity and non-uniform dimensions.

B. Contractor shall be responsible for the dimensional accuracy of all fittings and hardware.

C. Repairs shall be permitted only to the extent allowed by the referenced ASTM standards. If welding or repair of a greater magnitude is required, the Contractor shall obtain approval prior to proceeding.

D. Malleable iron, ductile iron, forged steel and mild steel components in contact with the pole surface shall be painted to match the finish of the pole. Should the Contractor elect to furnish galvanized components, the paint system used shall be compatible with the galvanizing.

ARTICLE 3 EXECUTION

3.01 INSTALLATION REQUIREMENTS

A. Installation requirements for fittings and hardware shall be in accordance with the manufacturer's recommendations and as shown on the Contract Drawings and as specified in Section 16800, "Overhead Contact System Installation."

3.02 COMPONENT PERFORMANCE AND USABILITY

A. All fittings and hardware used for OCS assemblies shall be selected and made such that they can be reused after removal.

B. All fittings and hardware shall be designed for easy interface with the other components of the electrification system.

C. All fittings and hardware shall be designed and installed to provide a homogenous OCS hardware and assembly arrangement.

D. Components and assemblies shall be designed such that all fastenings and adjustments are accomplished with the same dimensional standards or tools (Metric or American standards shall be consistently used on the same part).

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16650

OCS BASIC ELECTRICAL MATERIALS AND METHODS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for OCS basic electrical materials and methods, in accordance with the Contract Documents.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data"

B. Section 16602, "General Requirements Overhead Contact System."

1.03 REFERENCE STANDARDS

A. ANSI

B. ASTM

C. FS

D. NEMA

E. NBC

F. NEC

G. NFPA

H. UBC

I. UL

1.04 SUBMITTALS

A. Manufacturer's description, Shop Drawings, installation and operational manuals.

B. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

1.05 QUALITY ASSURANCE

A. Materials specified shall meet the requirements of the Contract Documents.

B. Production tests shall be performed on materials and certified by the Manufacturer.

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Materials furnished shall be standard products of manufacturers regularly engaged in the production of materials specified.

2.02 GALVANIZED RIGID STEEL (GRS) CONDUIT AND ACCESSORIES

A. Conduits, Couplings, Elbows, Bends and Nipples shall be hot-dip galvanized and meet the requirements of ANSI C80.1 and UL 6.

B. Conduit Straps, Clamps, Back and Spacers - Hot-dip galvanized malleable iron.

C. Conduit Fittings and Accessories shall be galvanized steel and meet the requirements of FS, W-F-408.

2.03 CONDUIT EXPANSION FITTINGS:

A. The end couplings shall be of the same material as those of the conduits to be coupled.

B. Neoprene sleeves attached to the end couplings by stainless steel bands shall accommodate an axial expansion or contraction from normal of 3/4 inch minimum in either direction, parallel misalignment of the axis of coupled conduit runs, in any direction, parallel misalignment of the axis of coupled conduit runs, in any direction, of 3/4 inch minimum, and an angular misalignment of the axis of coupled conduit runs, in any direction, of 30 degrees minimum.

C. A tinned flexible copper braided bonding jumper, integral with the expansion fitting, shall be attached to the end couplings to provide electrical continuity for all metal conduits.

2.04 GROUNDING AND BONDING MATERIALS

A. Grounding and bonding materials shall comply with UL 467.

B. Ground Conductors: ASTM B3, Class B stranded annealed copper and sized as indicated on the Contract Drawings.

C. Connectors: Buried ground connections shall be exothermic welded as indicated on the Contract Drawings.

2.05 INSULATED WIRE, CABLE AND ACCESSORIES

A. Unless otherwise specified, conductors for general use shall be soft or annealed copper complying with ASTM B8, Class B stranded. Insulation level shall be 2,000V NEC type XHHW conforming to NEMA WC 7 or type RHW conforming to NEMA WC8.

B. All terminations and cable terminal connections shall meet or exceed the capacity and insulation voltage ratings of the wire or cable terminated.

C. All feeder cable and insulated wire runs shall be identified at each end of the run, and also at all manholes pull boxes and handholes. Wire identification markers/tags shall be water resistant, self-laminating vinyl with opaque-blank write-on section. Permanent ink markers shall be used to complete these tags. A transparent adhesive wrap shall be used to secure and protect the tag on the cable.

D. Wire ties shall be a heavy-duty nylon type strap with stainless steel locking barb sized to suit application, and ultraviolet ray (sunlight) resistant.

E. Wire ties shall not be used to support cables on the cantilevers. Cables shall be supported with "Minerallac" conduit hangers or approved equal.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Installation work shall be in accordance with applicable requirements NFPA 70 and shall comply with the regulations of NEC and UBC.

B. Materials and equipment shall be applied, installed, and connected as recommended by the manufacturer.

3.02 CONDUIT, FITTINGS, AND ACCESSORIES

A. Embedded Conduits
1. The ends of conduits shall be capped or covered prior to concrete placement.
2. Embedded conduits shall be properly supported and paced prior to concrete placement or backfilling.
3. Conduits shall be pitched to provide moisture drainage to the manhole, pull box or handhole.
4. Conduits shall be rodded, or wire brushed, and swabbed prior to cable installation, to remove foreign matter. After cleaning, conduit ends shall be recapped until cable pulling commences.
5. Where conduits cross structural expansion joints, conduit expansion fittings, as specified, shall be installed at the expansion joints.
6. The ends of field cut conduits shall be reamed to remove rough edges.

B. Exposed Conduits
1. Unless otherwise noted, exposed conduits shall be GRS conduit.

2. Conduit runs shall be made with approved couplings and unions. Right angle bends, offsets and change-in-direction bends shall be made with standard elbows, conduit fittings and pull boxes. Runs shall be straight and true; with elbows and bends uniform and symmetrical. Bends with kinking and deformed cross-sectional contours are not acceptable and will be corrected without additional costs.
3. Conduits entering outlet boxes, pull boxes, enclosures, cabinets and similar equipment enclosures shall be attached to the box or enclosure with a locknut on both the outside and inside, each tightened. Conduits shall be provided with end bushings.
4. Conduit clamps and supports shall be used on all runs elbows, and ends to securely fasten the conduit to the pole or support structure. They shall be suitable for the conduit size intended and act to secure the conduit during the wire pulling operations.
5. All conduit runs shall be cleared and swabbed to remove foreign matter after final installation, prior to pulling in wire and cable. The Contractor installing the conduit runs shall provide this function without exception.

3.03 GROUNDING

A. Buried Ground Conductors
   1. Conductor splices, joints, and connections shall be made by the exothermic copper oxide reduction weld method.
   2. Finish welds shall be cleaned and coated with an approved cold applied bituminous resin compound. Primer shall be as recommended by the coating manufacturer.

B. Connections Above Ground
   1. Above grade (exposed) grounding connections shall be accomplished using fittings and clamps expressly manufactured for grounding use. Connectors shall be compatible to and listed for their attachment, including connection to wires, cables, equipment, support hardware and OCS components and/or steelwork.
   2. Acceptable connectors include bolted, compression, wedge driven and grounding clamps. Connections made using the exothermic copper oxide reduction weld method are also acceptable means of accomplishing above grade connections.

3.04 INSULATED WIRE, CABLE AND ACCESSORIES

A. General
   1. Wire and cable shall be installed by means of equipment, devices, and methods recommended by the manufacturer. High voltage cable terminations shall be performed by qualified personnel.
   2. Wiring and cabling shall be terminated and connected by means of connectors, lugs, and other methods specified.
   3. Cables installed with conduit hangers on cantilevers shall be installed to allow for movement of the cantilever. Installation procedures shall be approved by the Engineer.

B. Power Cabling

1. DC circuits consisting of multiple single conductors shall be grouped and pulled together in the designated conduit or duct. Conductors shall be continuous from end to end without splices. Adequate slack shall be provided at terminations and in pull boxes, handholes and manholes.
2. Cables shall be identified by individual permanent tags at each end of circuit and at any intermediate pull box, handhole, or manhole by specified markers.

3.05 WIRING DEVICES

A. Wire Termination: Power wiring shall be terminated with approved connectors. Provide adequate slack wire, one loop minimum, to prevent strain on termination.

3.06 FIELD TOUCH-UP

A. Galvanized Metal Surfaces: Coat damaged surfaces to meet the finish of the original coating, with polystyrene organic rich compound containing not less than 91 percent by weight metallic zinc powder in dried film.

B. Painted Metal Surfaces: Clean, treat, and coat damaged surfaces with required rust inhibiting undercoating and finish coat paint system in accordance with manufacturer's instructions.

C. Fiberglass Reinforced Polyester Enclosures: Repair minor damaged surface with materials and methods as recommended by manufacturer. Major damage shall require complete component replacement as directed by the Engineer at no additional costs to Authority.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16700

COMMUNICATIONS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for communications, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to the following activities:
   1. Communications systems and equipment:
      a. Contractor shall install all communications systems and equipment including the fiber optic and copper inside and outside cable plant, carrier transmission system, VMS/PA system, radio equipment, emergency telephone equipment, PAAC telephone equipment, digital IP video cameras and mountings, UPS and DC power systems, SCADA equipment and Remote PBX Modules at locations shown on the Contract Drawings and Reference Drawings for Construction Contract NSC-010, "Gateway Station Finishes," Construction Contract NSC-011, "North Side Station Finishes," and Construction Contract NSC-012, "Allegheny Station Finishes" as listed in Section 00200, "Instructions to Bidders." Additional modifications required by Contractor's design must be approved by the Engineer.
      b. Contractor shall furnish and install equipment described in the Contract Documents in three new NSC communications rooms:
         1) Allegheny Station Communications Room
         2) North Side Station Communications Room
         3) Gateway Station Communications Room
      c. Contractor shall furnish and install equipment described in the Contract Documents to provide radio and emergency telephone service along the right of way.
      d. Contractor shall provide a Digital Video System at Pitt Tower to augment the existing analog CCTV system at Pitt Tower. The new digital system shall monitor, record and control the new digital IP video cameras to be installed at the NSC stations.
      e. Contractor shall provide a Portal Surveillance Detection system at each end of the bored tunnel. The detection system shall send an intrusion alarm signal to the video management system for annunciation on designated video management workstations at Pitt Tower.
      f. Contractor shall upgrade and replace the existing UPS system at Pitt Tower with a larger UPS system, which shall be able to provide sufficient power for both the existing analog CCTV system and the new Digital Video System.
      g. Contractor shall furnish and install the fiber optic and copper cable plant and associated hardware as described in the Contract Documents required to

interconnect all new and existing communications facilities.

h. Contractor shall make modifications to the existing Gateway Station communications room allowing for all retired equipment to be removed while providing for the continued reliable operation of the remaining equipment.

C. Contractor shall furnish all labor, material, equipment, supervision, transportation, and miscellaneous services, whether or not explicitly identified herein, to provide a completely tested and fully operational communication system.

D. The work includes the installation of two diversely routed 96 strand fiber optic cables between the current end of the existing fiber optic cables at the Gateway Station and the communications room at the Allegheny Station including interconnection to the existing Authority fiber optic cable plant as shown on the Contract Drawings.

E. The work also includes the installation of two 18 pair local distribution telephone cables between the new Gateway Station communications room and the end of the aerial structure as shown on the Contract Drawings.

F. The work also includes the installation of the trackside (Blue Light) emergency telephones between the new Gateway Station and the end of the Elevated Structure as well as the termination of the 18 pair local distribution cables at each emergency telephone set as shown on the Contract Drawings.

G. The work also includes the installation of the leaky coaxial cable (Radiax) in the tunnels, Gateway Station, North Side Station and interior spaces of the Allegheny Station as shown on the Contract Drawings.

H. The work also includes all communications equipment in the new Gateway Station communications room including the carrier transmission system, UPS and DC power supplies, VMS/PA controller and amplifier, CCTV Gigabit Ethernet Switch, SCADA Remote Terminal Unit (RTU), Remote PBX Module, BDA units, as well as all miscellaneous equipment including, but not limited to, fiber and cable termination equipment, racks, cabinets, patch cables, patch panels, and other hardware required to outfit the communications room as described in the Contract Documents.

I. The work also includes all communications equipment to be installed in the new Gateway Station platform and entrance levels as shown on the Contract Drawings including, loudspeakers, ambient noise microphones, patron emergency telephones on platforms, PAAC telephones, Radiax cable, VMS signage, CCTV fixed and PTZ dome cameras, and all interconnecting cables necessary to furnish a working system that meets the requirements of the Contract Documents.

J. The work also includes all cables required to interconnect the tie-breaker station RTU, MCC RTU, signal CTC equipment, and TWC equipment located at the Gateway Station to the new Gateway Station communications room as shown on the Contract

Drawings and the Reference Drawings from Construction Contract No. NSC-010, "Gateway Station Finishes."

K. The work also includes modifications to the existing Gateway communications room including the removal of all PA/VMS and CCTV equipment that is to be retired from service concurrent with the discontinuance of service to the existing Gateway Station. Contractor shall assure that all equipment to remain in service including, but not limited to, the carrier transmission system, UPS and DC power supplies, SCADA RTU and other associated equipment will continue to function in a safe and reliable manner. All equipment to be retired shall be returned to Authority in good condition.

L. The work also includes all communications equipment in the North Side Station communications room including the carrier transmission system, UPS and DC power supplies, VMS/PA controller and amplifier, CCTV Gigabit Ethernet Switch, SCADA Remote Terminal Unit (RTU), Remote PBX Module, BDA units, as well as all miscellaneous equipment including, but not limited to, fiber and cable termination equipment, racks, cabinets, patch cables, patch panels, and other hardware required to outfit the communications room as described the Contract Documents.

M. The work also includes all communications equipment to be installed in the North Side Station platform, mezzanine and entrance levels as shown on the Contract Drawings including, loudspeakers, ambient noise microphones, patron emergency telephones, PAAC telephones, Radiax cable, VMS signage, CCTV fixed and PTZ dome cameras, and all interconnecting cables necessary to furnish a working system that meets the requirements of the Contract Documents.

N. The work also includes all cables required to interconnect the traction power substation RTU, MCC RTU, signal CTC equipment, and TWC equipment located at the North Side Station to the new North Side Station communications room as show in the Contract Drawings and Reference Drawings from Construction Contract No. NSC-011, "North Side Station Finishes."

O. The work also includes all communications equipment in the Allegheny Station communications room including the carrier transmission system, UPS and DC power supplies, VMS/PA controller and amplifier, CCTV Gigabit Ethernet Switch, SCADA Remote Terminal Unit (RTU), Remote PBX Module, BDA units, radio base stations, combiners, air interface units, as well as all miscellaneous equipment including, but not limited to, fiber and cable termination equipment, racks, cabinets, patch cables, patch panels, and other hardware required to outfit the communications room as described in the Contract Documents.

P. The work also includes all communications equipment to be installed in the Allegheny Station platform, mezzanine and entrance levels as shown on the Contract Drawings including, loudspeakers, ambient noise microphones, patron emergency telephones, PAAC telephones, Radiax cable, VMS signage, CCTV fixed and PTZ cameras, and all interconnecting cables necessary to furnish a working system that meets the requirements of the Contract Documents.

Q. The work also includes all cables required to interconnect the circuit breaker room RTU, signal CTC equipment, and TWC equipment located at the Allegheny Station to the new Allegheny Station communications room as shown on the Contract Drawings and Reference Drawings from Construction Contract No. NSC-012, "Allegheny Station Finishes.".

R. The work also includes the installation of a radio antenna to be installed at the Allegheny Station as shown on the Contract Drawings.

S. The work also includes modifications and additions to the existing OCC to support the facilities and equipment added as part of the Project including, but not limited to:
   1. The design, construction, delivery, installation, testing, placing into revenue operations, and warranty for the upgraded OCCS.
   2. Surveying and providing documentation of the OCCS.
   3. Update of OCCS Overview Display including, but is not limited to: design of graphical depiction of NSC track layout and SCADA monitor/control points, modification of overview display screen layout to create space for the NSC portion of the track diagram, and updating OCCS system configuration data to implement the necessary overview display modifications.
   4. Update of OCCS Console User Display includes, but is not limited to: design of graphical depiction of NSC track layout and SCADA monitor/control points and updating OCCS system configuration data to implement the necessary console display modifications.
   5. Upgrade the carrier transmission system to include a head-end SONET multiplexer, T1 multiplexer (channel bank), Ethernet Switches, DACS, DSX Panel, and ancillary equipment to support the new NSC SONET Ring.
   6. Update of OCCS External Interfaces includes, but is not limited to: installation of cable to provide additional RS-232C physical connections between the OCCS and CTS to support the new code system interfaces to Project field units, updating OCCS system configuration data to implement the new code system interfaces, and testing the new code system interfaces.
   7. Replace existing PBX with a new redundant head-end PBX server to support telephone communications to all existing telephones and all new telephones being serviced by the Remote PBX Modules at the NSC stations.

1.02 RELATED SECTIONS

A. Section 01400, "Quality and Product Reference."

B. Section 01777, "Construction Certification Program"

C. Section 01910, "Operations, Maintenance and Repair Data."

D. Section 16701, "Fiber Optic Outside Plant."

E. Section 16702, "Copper Outside Plant."

F. Section 16703, "Carrier Transmission System."

G. Section 16705, "Communications System Power Supply."

H. Section 16721, "Telephone System."

I. Section 16722, "Radio Communications System."

J. Section 16741, "Variable Message Sign/PA System."

K. Section 16742, "SCADA System."

L. Section 16750, "Digital Video System."

M. Section 16901, "Communication System Inspection and Test."

N. Section 16950, "Operations Control Center System (OCCS) Upgrade."

1.03 RFERENCE STANDARDS

A. EIA-310, "Cabinets, Racks, Panels, and Associated Equipment" and EIA RS-359, "Colors for Color Identification and Coding.".

B. NFPA 130, "Fixed Guideway Transit Systems" and NFPA 70, "National Electric Code."

C. Military Standards MIL-W-16878/1, "Wire, Electrical, Polyvinyl Chloride Insulated", MIL-STD-810, "Environmental Test Methods and Engineering Guidelines", and MIL-STD-461, "Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference."

D. CFR, Title 47, Part 15. Part 80 to END.

E. ANSI/TIA/EIA-568, "Commercial Building Telecommunications Cabling Standard."

F. UL Standard 467, "Grounding and Bonding Equipment," Standard 50, "Enclosures for Electrical Equipment" and Standard 797, "Electrical Metallic Tubing."

G. ASTM B187, "Standard Specification for Copper Bar, Bus Bar, Rod and Shapes" and A 53 "Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless."

H. NEMA Standard 250, "Enclosures for Electrical Equipment," TC2, "Electrical Polyvinyl Chloride (PVC) Tubing and Conduit" and TC3, "PVC Fittings for use with

Rigid PVC Conduit and Tubing."

I. Electronic Industry Association/Telecom Industry Association (EIA/TIA 603)

J. Rural Utilities Services (RUS) Specification Standard 7 CER 1755.390 (Formerly PE-39)

K. ANSI/ICEA S-80-576, "Communications Wire and Cable for Premises Wiring."

L. ANSI C80.3, "Specification for Zinc Coated Electrical Metallic Tubing."

M. ASA Standard for Paint Colors.

N. Telcordia SR-332, "Reliability Prediction Procedures for Electronic Equipment" and GR-3013, "Generic Reliability Assurance Requirements for Optoelectronic Devices Used in Short-Life, Information-Handing Products and Equipment".

1.04 SUBMITTALS

A. Contractor shall make the following submittals related to the Communications System:
   1. Design Definition Document as defined in this Section.
   2. Integration Plan: This submittal is a detailed description of integration of all systems that will send or receive communications through the Communications System. This includes utility requirements.
   3. Staging, Commissioning and Closeout Plan: This submittal is a complete description of the process of transitioning the NSC Communications System with the Existing Communications System creating a fully integrated communications system. This includes detailed procedures necessary to install all software and hardware to place the Communications System in a fully operational state.
   4. Labeling Definitions Table: This submittal is a list of symbolic or index-labeling definitions used with each site's installation.
   5. Parts List as defined later in this Section.

B. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

C. Submittals as defined below shall be made for each communications subsystem as indicated in the relative Technical Provision:
   1. System Design: Text and diagrams that define and describe each subsystem. Includes, but is not limited to, block diagrams. This identifies the inter-relationship between all major subsystem elements and the interfaces to other systems and subsystems.
   2. Product Data, Shop Drawings and Specifications: Information about all products and manufacturers to be used in each subsystem. Includes, but is not limited to, a list of proposed manufacturers, qualifications of proposed manufacturers, product technical data and specifications, product manuals and application guides, manufacturers' catalogue sheets, reliability, availability and maintainability

information, manufacturers' Quality Assurance Plans, and manufacturers' warranty information.

3. Installation Plan: Installation Shop Drawings and all mechanical details necessary to install new elements and move existing elements as necessary. Provide this submittal for all Communications System elements, including conduits, junction boxes, cabinets, equipment racks and cable racks. Contractor shall not begin installation prior to approval of the Installation Plan by the Engineer.
4. Software and Firmware Plan: A functional description of all software and firmware, list of names and version numbers of all commercial products, copies and source code where required.
5. Allocation and Provisioning Plan: A complete listing of the configuration and all settings required for every Communications System element. This includes all equipment, programmable and configurable parameters and a listing of all plug-in modules.

D. Submittals defined below shall be made for each site where Communications System equipment is located:
   1. Functional Site Block Diagram: Provide one for each site, showing all systems and subsystems at the site, the relationships between elements, and interfaces to other systems and subsystems. Circuit types shall be identified; for example, DS-1, 4W E&M. Signal levels shall be identified; for example, 0 dBm. Functional Site Block Diagram shall include SCADA input and output points.
   2. Arrangement Plan: Provide this submittal for all locations, showing arrangement of all equipment, racks and cabinets, in plan view (floor plan) and elevation view. Include dimensions to identify locations and clearance between components.
   3. Site Wiring Plan: This submittal details all wiring and connections for the Communications System, including but not limited to point-to-point cable routing and cable makeup, cable identification number, conductor size, conduit identification, cable rack identification, junction box identification, pull box identification, manhole identification, duct identification, and splice locations. The Wiring Plan shall include wiring for grounding and all system inputs and outputs. For fiber optic and copper cables, the Wiring Plan shall include the entire outside plant. Copper Cable Schedules are intended as a starting point for Contractor in its design, and in particular the development of Site Wiring Plans.
   4. Power Wiring Plan: Provide this submittal for each site, showing electrical and power wiring for all Communications System elements.
   5. UPS Sizing Calculations: Provide calculations to support the sizing of each UPS system including spare reserve capacity.
   6. As-Built Documents: Provide as-built documents, CD files and reproducible drawings and O&M documentation.

1.05 DEFINITIONS

A. The Existing Communications System: Communications subsystems and components that are in place at the beginning of the Work shall be referred to as the existing Communications System in the Contract Documents.

B. The NSC Communications System: All subsystems and components of Authority's Communications System that are installed as part of the Work shall be referred to as the NSC Communications System in the Contract Documents. The term NSC Communications System shall include changes to the Existing Communications System that are made as part of the work.

C. The Communications System: All communications subsystems and components that are in service at the completion of the Work shall be referred to as The Communications System. The Communications System shall include subsystems and components of the Existing Communications System that are not replaced and removed by the Work.

D. Communications Equipment Room (CER): Any room that contains communications equipment is referred to herein as a communications equipment room.

1.06 CONTRACT DRAWINGS AND SPECIFICATIONS

A. The Contract Drawings provide block diagrams and typical examples of how the communications facilities provided as part of the project are to be configured. Not all required circuits and design details are shown. Contractor shall provide a final design using the Contract Drawings and Specifications as a guide for methodology, not content.

B. Station communications equipment locations and conduit routes are provided in the architectural drawings which are referenced into the Contract Drawings for the communications work.

1.07 GENERAL REQUIREMENTS

A. Contractor shall design, supply, and install all wiring/cabling for all communications subsystems in accordance with the wiring requirements defined in NFPA Standard 130, "Standard for Fixed Guideway Transit Systems." and NFPA 70, "National Electric Code."

B. Contractor's work shall include all and including, but not limited to, racks, cabinets, cable, antennas, cable ladder, main distributing frames, pull boxes, conduit, fiber optic slack enclosures, fiber optic patch panels, patch cords as well as system material, modification to the existing communications systems, any ancillary systems, and all equipment, hardware and software necessary to provide a complete, and working system.

C. Contractor's work also includes modifications to one existing communications room, the provisioning of the SONET system. The work also includes site preparations, and all permits, and licenses necessary to install and operate the communications system equipment.

D. Contractor shall support the phased installation and testing of the new systems on the existing operating portions of Authority's LRT System. Integrated testing of the radio system requires the use of a Light Rail Vehicle as outlined in Section 16901, "Communication System Inspection and Test." Contractor shall support these tests and maintain the radio system at full performance during the testing stage. In the event of any malfunctions in the systems under test, Contractor shall quickly identify the problem and repair, adjust or replace necessary items or equipment.

E. Any use of materials not covered under these NSC specifications, shall be submitted to the Engineer for approval prior to use and installation.

F. Contractor shall provide a proven and modern Communications System in all respects. The communications system provided shall be completely compatible with the existing systems in place; all equipment shall be equal or similar in all functional aspect.

G. Contractor shall supply all documentation, training, and spare parts, as indicated in the Contract Documents.

H. Contractor shall become familiar with Authority's existing LRT System, contractor shall be responsible for ensuring a complete systems understanding and all aspects are understood.

I. Contractor is advised that all drawings and exhibits furnished as part of the Contract Documents are provided as illustrations for reference and to convey design concepts only, and are not to be utilized for manufacture of equipment or construction of the Communications System. Contractor shall be responsible for design of the Communications System.

J. All equipment, materials and products provided under this Contract shall require approval of the Engineer.

K. Contractor shall review the Contract Documents in their entirety.

L. Contractor shall bear total system responsibility for all work and for specified additions and changes to Authority systems. Contractor has the responsibility to integrate all elements of the work to meet overall specification goals.

M. All Contractor provided systems, equipment and services shall perform and be suitable for their intended purpose, be provided in accordance with best commercial practices, and be in compliance with all applicable Section requirements.

N. Contractor shall assume total responsibility for the configuration of equipment, parts, interconnecting wiring, software, and other materials and services furnished. Systems provided by Contractor that do not meet these Specifications shall be modified at Contractor's expense. Any modifications to approved system designs shall be subject to prior approval by the Engineer.

O. At no additional cost to Authority, Contractor shall assume total responsibility for the correction of any degradation in the performance of existing Authority systems or equipment, which results from any system or equipment interface installed by Contractor. The Engineer will determine if it is Contractor's responsibility to correct any degradation in performance. If Contractor must replace a device in Authority's existing system, and that device is no longer in production, then Contractor shall obtain engineer's approval to provide an equal substitute.

P. Although the Engineer will review Contractor's system and component configuration and products selected, Contractor retains responsibility to comply with all Contract requirements.

Q. Contractor shall provide sufficient personnel and equipment for the integrated testing program and pre-revenue service operations to verify that the completed system operates properly.
   1. Integrated testing includes the testing of the traction power substations, ventilation fans, overhead contact system, radio, telephone, visual and fiber optic communications and signal systems, in operating and emergency simulation modes. In the event of any malfunctions in the Communications System, Contractor shall quickly identify the problem and repair, adjust or replace the necessary items of equipment. Contractor shall provide an acceptable integration and cutover plan that addresses the integration to the existing functional systems without any adverse effect on revenue operations.
   2. Pre-revenue service operations includes the training of Authority's Operations and Maintenance personnel. All types of operational and emergency situations will be simulated. Contractor shall support these tests and maintain all the Communications System at full performance.

R. During initial revenue service, Contractor shall provide technical assistance in troubleshooting, repair and maintenance. Contractor shall be responsible for all maintenance of the provided system until the terms of the warranty turnover process have been met.

1.08 DESIGN REQUIREMENTS

A. General Design Requirements
   1. The Communications System shall be maintainable and accessible.
      a. All test points, indications and components requiring adjustment or replacement shall be visible and accessible while mounted in their normal position, without disassembly of other components
      b. Test points shall be clearly and permanently labeled and shall be provided wherever required for troubleshooting and routine maintenance, and be capable of accepting probes and connectors used with standard test equipment. Accessible points shall be provided and labeled where signals need to be injected for testing.
      c. Built in indicators or meters shall be provided where observations or

adjustments are necessary. All indicators shall be labeled.

d. All audio circuits shall have line, equipment, and monitor jacks at every communications equipment room to facilitate testing.

2. Assemblies and components that perform identical functions within the Communications System shall be mechanically and electrically interchangeable. Standardized, commercially available components of multiple sources shall be used whenever possible, particularly for items which require replacement at predictable intervals.
3. No part of the Communications System shall project into the vehicle clearance envelope as shown in the Contract Drawings.
4. All equipment and material shall be commercial off the shelf (COTS), standard products of manufacturers regularly engaged in the production of communications equipment and material.
5. All equipment installed under this Contract shall be properly and sufficiently protected from surges caused by lightning strikes and/or power surges.
6. Authority Rail Operations are centralized in the Operations Control Center (OCC) at South Hills Village. Authority Rail Operations rely on the Communications System to remotely control its signal system, traction power system and ventilation fan system. Public Address, Variable Message Signs, Radio, and CCTV are used to transmit the information required for daily rail operations. It is critical that all facets of the Communications System be available for operation with no downtime. Contractor shall protect and save harmless all Authority systems, facilities and property.
7. All local wire and cable shall be protected by conduit or other suitable raceway outside of communications equipment rooms.
8. Contractor shall review and be familiar with all Contract Documents. Contractor shall be alert for inaccuracies that exist on the Drawings, including reference drawings, and take necessary precautions to protect all existing facilities.

B. Vibration Design Requirements

1. Components that are sources of vibration shall be sufficiently damped to eliminate externally audible resonance or their affect on the integrity of other internal components.
2. Equipment shall be designed to withstand shock and vibration caused by the passing of LRVs as well as emergency braking of fully loaded LRVs.
3. Communications equipment shall meet the vibration requirements for facilities located near rail lines as stated in MIL-STD-810, "Environmental Test Methods and Engineering Guidelines" or Engineer approved equivalent.

C. Environmental Design Requirements

1. Radio Frequency (RF) communications equipment supplied under this Contract shall be in compliance with MIL-STD-810, "Environmental Test Methods and Engineering Guidelines."
2. All systems and equipment shall perform reliably, properly and without damage when subjected to dust, moisture, electromagnetic interference, power fluctuations, vibration, and other adverse conditions as well as under the

following conditions, singularly and in any combination:

a. Sunlight: None to full, direct.
b. Ambient Temperature Range: –40 to +120 degrees F.
c. Temperature fluctuations: up to plus or minus 30 degrees F in two hours.
d. Relative Humidity Range: 30 to 95 percent, non-condensing.
e. Rainfall: up to 8 inches per hour.
f. Wind speed: up to 120 mph.
g. Freezing precipitation: up to 3 inches per hour.

D. EMC-Related Design Requirements

1. The Communications System shall be designed to operate in the electromagnetic environment of the LRT system and not cause interference to other systems. Communications system shall be in compliance with MIL-STD-461-E, "Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference."
2. Equipment shall be designed, selected, and installed with consideration given to the electromagnetic environment, which includes but is not limited to traction power supply, AC power distribution systems, vehicle propulsion systems, signal systems, adjacent railroads, electric utility lines, information and data systems, and communications systems, including radio.
3. Equipment installed under this Contract shall operate without being adversely affected by or emitting electromagnetic interference and shall not be adversely affected by nor cause interference to other Authority services, including, but not limited to signal systems, power systems, information and data systems, automatic equipment identification, and radio communications.
4. Equipment installed under this Contract shall meet the requirements of the CFR, Title 47, Part 15.80 to END.

E. Power Requirements

1. All Communications System components shall be powered from 120 VAC or –48 VDC.
2. Power to all Communications System components shall be from the Communications System Power Supply as described in Section 16705 "Communications System Power Supply" unless otherwise specified in the Contract Documents.
3. Contractor shall submit plans for powering all Communications System components to the Engineer for approval as part of the Communications System design.
4. All equipment installed in cabinets must have adequate space around the equipment to allow for air movement and heat dissipation.

F. Reliability and Availability

1. Contractor shall design, provide, install, integrate and commission the New Communications System as a reliable, available and maintainable system.
2. Reliability and availability of the New Communications System shall be calculated by Contractor. The calculations shall demonstrate that the New

Communications System reliability and availability shall both be at least 99.999% for redundant (i.e. backed up) circuits and 99.7% for non-redundant circuits. Reliability and availability calculations shall be based upon a period of ten years. Calculations of reliability and availability shall be based upon Telcordia standards, unless an alternate method is submitted by Contractor to the Engineer and the Engineer approves the alternate method.

3. Any item furnished as part of the work is considered a system element. A system element can be hardware or software. Examples of system elements are a modem, a length of fiber optic cable, a distribution frame, and a SONET multiplexer.
4. A circuit is considered to be the equipment necessary to communicate a user's application from its origin to its destination. For reliability and availability estimates, circuits are considered as originating and terminating on equipment that is furnished and installed as part of the Work. An example of a circuit is a telephone circuit that originates at the interface point to Authority's PBX, is then routed through the CTS, terminating on a telephone instrument in a substation.
5. Any circuit that is operated with a parallel circuit to which the application will be transferred upon failure of the circuit is considered to be a redundant circuit. Any circuit that is operated with at least one system element that is a single point of failure is considered to be a non-redundant circuit.
6. When a system element experiences a cessation of the ability to perform a specific function or functions that are necessary for the proper operation of any circuit using that element, that system element has experienced a failure. A failure is a condition that is beyond the adjustment of controls available to the system's user during normal operation.
7. For the purposes of the Communications System, Mean Time Between Failures (MTBF) is the predicted average time between failures of a population of specific system elements. Applicable Telcordia standards include TR-332, "Reliability Prediction Procedures for Electronic Equipment" and TA-418, "Generic Reliability Assurance Requirements for Fiber Optic Transport Systems." Contractor shall state the MTBF for every population of specific elements. Contractor shall present data that justifies its MTBF figure for each population.
8. For purposes of the Communications System, Mean Time to Repair (MTTR) is the predicted average time during which a population of system elements with detected failures can be repaired. MTTR includes diagnosis and physical repair time. Contractor shall state the MTTR for every population of specific elements. Contractor shall present Data that justifies that MTTR figure for each population.
9. For purposes of the Communications System, Mean Logistical Delay Time (MLDT) is the predicted average time between detection of a system element failure and the initiation of repair. Contractor shall coordinate with the Engineer and Authority to obtain MLDT figures to use in Contractor's calculation.
10. Contractor shall convert the MBTF for each system element into reliability estimates. System element reliability is ten years divided by that element's MTBF, expressed as a percentage.
11. Contractor shall convert the MBTFs, MTTRs, and MLDTs for each system element into availability estimates. System element availability is MTBF divided

by the sum of its MTBF, MTTR and MLDT, described as a percentage.

12. Contractor shall identify each unique type of circuit in the system and estimate its network reliability and availability. Circuit uniqueness shall be based on both the type and quantity of network elements. Contractor shall estimate the System reliability and availability estimates using standard probability theory for independent serial and parallel failure events.
13. First Year Failure Rates shall be estimated in accordance and compliance with Bellcore standards and reported by Contractor for all system elements. If the actual failure rate of any system element during the Guarantee Period of this Contract exceeds the First Year Failure Rate estimated by Contractor, Contractor shall supply at no cost to Authority sufficient replacements to support the element over ten years. The number of sufficient replacements shall be the actual failure rate in the first year times ten.

1.09 GUARANTEE

A. Contractor shall be responsible for obtaining technical assistance from the equipment manufacturers and/or suppliers in cases where programming, operational or adjustment difficulties are encountered.

B. Contractor shall be responsible for providing additional training to Authority on any communications equipment if new or unusual problems/repairs are discovered during the guarantee period.

C. Contractor shall be required to arrive on site within 24 hours to any service call during the guarantee period.

D. Contractor shall be required to support the system reliability and availability levels approved at the Final Design Review as described in Article 3.05 of this Section.

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. Contractor shall provide and install all equipment, materials and products necessary for the complete Communications System, including but not limited to the items listed below.

B. All equipment, materials and products provided by Contractor shall require approval of the Engineer and shall meet the requirements stated in this Section. Contractor shall submit to the Engineer for approval Product Data, Shop Drawings, and/or specifications for all products provided under this Contract.

C. Contractor shall give special attention to long lead time items, such as fiber optic cable, and shall order such items sufficiently early to avoid installation delays.

2.02 ELECTRICAL SUPPORTING DEVICES

A. Channel and angle support systems, hangers, anchors, sleeves, brackets, fabricated items and fasteners shall be designed to provide secure support from the building structure for electrical components.
    1. Material: Steel, except as otherwise indicated, protected from corrosion with zinc coating or with treatment of equivalent corrosion resistance using approved alternative finish or inherent material characteristics.
    2. Metal items for use outdoors or in damp locations: Hot-dip galvanized steel, except as otherwise indicated.

B. Steel channel supports have 9/16 inches diameter holes at a maximum of 8 inches on center outside circumference, in at least one surface.
    1. Fittings and accessories mate and match with channels and are from the same manufacturer.

C. Raceway and Cable Supports: Manufactured clevis hangers, riser clamps, straps, threaded C-clamps with retainers, ceiling trapeze hangers, wall brackets, and spring steel clamps or "click"- type hangers.

D. Sheet-Metal Sleeves: 0.0276 inches or heavier galvanized sheet steel, round tube, closed with welded longitudinal joint.

E. Pipe Sleeves: ASTM A 53, Type E, Grade A, Schedule 40, galvanized steel, plain ends.

F. Cable Supports for Vertical Conduit: Factory-fabricated assembly consisting of threaded body and insulating wedging plug for nonarmored electrical cables in riser conduits. Plugs have number and size of conductor gripping holes as required to suit individual risers. Body constructed of malleable iron casting with hot-dip galvanized finish.

G. Expansion Anchors: Carbon-steel wedge or sleeve type.

H. Toggle Bolts: All-steel springhead type.

I. Powder-Driven Threaded Studs: Heat-treated steel.

2.03 MOUNTING HARDWARE

A. Unless otherwise specified, all attachment hardware used in the tunnels and aerial structure including, but not limited to, hangers, brackets, clamps, bolts, nuts, or washers shall be hot-dip galvanized. The zinc coating shall be of commercially pure zinc and shall be continuous and through with at least 2 ounces of zinc per 1 square foot of galvanized surface. Plating shall not scale, blister, or be removed by any process of handling during installation. All material shall be cut, formed, or drilled prior to plating

2.04 EQUIPMENT RACKS

A. Equipment racks shall conform to EIA-310.

B. Equipment racks shall be floor mounted, stand alone, double sided type. Mounting holes shall be tapped for 12-24 screws and have EIA Universal hole pattern, 5/8 inches - 5/ 8 inches - ½ inch.

C. Racks shall be 23 inches and 19 inches, and sized to accommodate Contractor's proposed equipment.

D. The rack support channels shall be a minimum of 16-gauge steel.

E. Equipment racks shall have holes in side of rack for joining racks or mounting ladder end guards.

F. Contractor shall provide all hardware for securing the rack to the floor, walls or ceiling.

G. Contractor shall supply rack accessories and hardware such as guard rails, mounting hardware, cable brackets, mounting screws and rack fasteners.

H. Each rack shall be finished in ASA 61 gray enamel.

2.05 CABLE RACKS (CABLE TRAYS)

A. Cable racks shall be ladder type.

B. Cable rack side bars shall be 1.5 inches minimum. Cable rack post height shall be 5 inches minimum. Spacing between posts shall be 9 inches minimum. Cable rack width shall be 10 inches minimum.

C. Contractor shall supply all drop-offs, junctions, clips, clamps, splices, braces, risers, supports, hangers, framing bars, channel, hardware and other material necessary to install a complete cable rack system.

D. Cable racks shall be finished in ASA 61 gray enamel.

2.06 ELECTRONIC EQUIPMENT CABINETS

A. Electronic equipment cabinets shall be designed to house electronic equipment. NEMA Type 1 cabinets shall be used for indoor environment and Type 4 for outdoor environment.

B. Side covers shall be 0.04 inch thick minimum aluminum alloy or steel. Side covers shall be removable.

C. Top cover shall be minimum 0.04 inch thick and equipped with louvers for ventilation.

D. Equipment cabinets shall be supplied with integral equipment mounting rails.

Mounting rails shall be steel with a minimum thickness of 12 GA; recessed a minimum of 2.4 inches from the front of the cabinet.

E. Holes in mounting rails shall be tapped to 12-24 thread and arranged in the EIA Universal hole pattern, 5/8 inches - 5/ 8 inches - ½ inch.

F. Equipment cabinets shall be 23 inches and 19 inches, and sized to accommodate Contractor's proposed equipment.

G. All exterior seams shall be smooth and sealed weather-tight.

H. Cabinets shall be equipped with ground stud.

I. Cabinets shall be equipped with hinged doors on the front and back. Doors shall be equipped with latching mechanism and door locks. Doors shall have provision for securing in open position.

J. Cabinets shall be equipped with AC power strips.

K. Cabinets shall be equipped with a forced air fan system. Fan system shall be as follows:
   1. Designed so that air enters through an intake grille and filter at the bottom of the cabinet and is discharged into the cabinet.
   2. Designed so that water dripping onto the top of the cabinet shall not enter the cabinet.
   3. Air shall be exhausted through a grille and filter at the top of the cabinet.
   4. Thermostatically controlled with accessible temperature control.
   5. Operate on 115 volt AC, 60/50 Hertz, single phase input power.
   6. Deliver a minimum of 275 cubic feet per minute of air at zero static pressure.
   7. Permanently lubricated and require no maintenance other than changing filters.
   8. Operate properly in the temperature range 15 to 115 degrees F.
   9. Produce minimal noise.
   10. Rated to operate continuously for a minimum of 20,000 hours.
   11. UL listed.
   12. Filters shall be easily accessible for changing.
   13. Filters shall be efficient, durable, environmentally friendly, and moisture resistant. Filters shall have no sharp edges, resist damage during handling, have high dust holding properties, and cause minimal air pressure drop.
   14. All equipment installed in enclosed racks or cabinets must have adequate space around the equipment to allow for air movement and heat dissipation. Filters shall be capable of being cleaned and reused, general foam rubber filters are unacceptable due to the deterioration of the material.

2.07 GROUNDING MATERIALS

A. Ground Wire: Minimum No. 6 AWG stranded copper ground wire shall be furnished.

B. Ground Bus: Hard drawn pure copper having a minimum conductivity of 98 percent per ASTM B187. The minimum dimensions of the buses shall be 18 inches by 2 inches by 1/4 inches thick.

C. Mechanical connections to ground bus bars shall be of the same type used throughout the installation.

2.08 TOUCH-UP PAINT

A. For Equipment: Provided by equipment manufacturer and selected to match equipment finish.

B. For Non-equipment Surfaces: Matching type and color of undamaged, existing adjacent finish.

C. For Galvanized Surfaces: Zinc-rich paint recommended by item manufacturer.

D. Paints shall be a recognized approved brand.

ARTICLE 3 EXECUTION

3.01 DESIGN DEFINITION DOCUMENT

A. Upon completion of the site inspection, Contractor shall prepare a Design Definition Document. This document shall include text and Shop Drawings and shall state Contractor's understanding of the requirements of the Contract Documents and the result of the site inspection. The Design Definition Document shall include, but not be limited to the following:
   1. Design approach for the Communications System and subsystems.
   2. Overall Communications System layout and design philosophy, total system functional description, system overview and conceptual designs, and system interfaces. The Design Definition Document shall demonstrate that all requirements of the Contract Documents shall be met.
   3. Reliability and Availability: Provide estimates for Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), and first year failure rates for all major communications system elements.

3.02 DESIGN REVIEWS

A. There shall be three formal design review meetings prior to the Engineer's acceptance of the final design of the Communications System. The required design reviews are:
   1. Conceptual Design Review
   2. Preliminary Design Review
   3. Final Design Review

B. Each design review has a purpose, with specific documents and issues that are to be reviewed, resolved, and approved before proceeding to the next step.

C. Before each design review meeting, the following shall be distributed by Contractor to those attending at least 21 days before the meeting:
   1. Date, time, and place of meeting
   2. List of invited attendees
   3. Agenda listing purpose of the meeting, objectives to be achieved, and items to be discussed
   4. Submittals pertaining to the design review
   5. List of any open items to be discussed from previous meeting

D. Design review meetings shall be included in the Project Schedule.

E. The Contractor shall publish minutes of the design review meetings.

3.03 CONCEPTUAL DESIGN REVIEW (CDR)

A. The purpose of the CDR is to ensure Contractor has a full understanding of Authority's operations and system requirements, and to give Contractor the opportunity to explain how its proposed design meets those requirements.

B. The following submittals shall be distributed before the CDR:
   1. Design Definition Document.
   2. Integration Plan
   3. Staging, Commissioning, and Closeout Plan
   4. Labeling Definitions Table
   5. Complete listing and samples of CAD standards and sample documentation format.
   6. Most recent update of the Project Schedule
   7. Quality Assurance Program and other submittals required by Section 01400, "Quality and Product Reference."
   8. Inspection and Test Plan. Refer to Section 16901, "Communication System Inspection and Test."
   9. Design documents for each subsystem developed to the conceptual level of completion. The design documents shall include, but not be limited to:
      a. System Design
      b. Product Data, Shop Drawings and specifications
      c. Functional Site Block Diagram
   10. Copper Cable Report. Refer to Section 16702, "Copper Outside Plant."
   11. HVAC requirements for each Communications Room.
   12. Grounding Report and Proposed Test Method.

C. At the CDR, the following issues shall be discussed:
   1. Contractor's understanding of the design requirements.
   2. Contractor's familiarity with the Existing Communications System, related systems and maintenance environment of Authority
   3. Contractor's strategies, process and schedule that shall be used to develop and implement the design

4. Site conditions
5. Contractor's proposed Quality Assurance Program
6. Information needs and decisions required
7. Submittals distributed before the CDR

3.04 PRELIMINARY DESIGN REVIEW (PDR)

A. The purpose of the PDR is to:
   1. Assess the progress, consistency, and technical adequacy of the design.
   2. Check the compatibility of the design with functional and performance requirements.
   3. Verify the compatibility of the interfaces between the software, hardware, and final product.

B. The following submittals shall be distributed before the PDR:
   1. Integration Plan.
   2. Staging, Commissioning, and Closeout Plan.
   3. Preliminary Parts List.
   4. Inspection and Test Plan. Refer to Section 16901, "Communication System Inspection and Test."
   5. Training Program Plan. Refer to Section 01910, "Operations, Maintenance and Repair Data."
   6. Preliminary Recommended Spare Parts List and List of Special Tools and Test Equipment.
   7. Reliability and availability estimates.
   8. SCADA Point Chart as described in Section 16742, "SCADA System."
   9. Design documents for each subsystem developed to the preliminary level of completion. Preliminary level shall mean that all major design decisions are made. With the exception of fiber optic cable or other long leadtime items approved by the Engineer, Contractor shall order no hardware, material or service until acceptance of the Preliminary Design has been issued by the Engineer. The design documents shall include, but not be limited to:
      a. System Design.
      b. Product Data, Shop Drawings and specifications.
      c. Functional Site Block Diagram.
      d. Arrangement Plans.
      e. Installation Plan.
      f. Wiring Plan.
      g. Power Wiring Plan.
      h. Software and Firmware Plan.
      i. Allocation and Provisioning Plan.

C. Contractor is encouraged to submit PDR information incrementally to reduce the duration of the formal meeting. Ideally, the formal PDR meeting should be limited confirmation of previously reviewed, commented on, and approved-in-principle submittals and resolution of open items.

D. At the PDR, the following issues shall be discussed:
   1. Overall system design and operation.
   2. Hardware components to be supplied under the Contract.
   3. System interfaces, both internal and external.
   4. How design meets requirements for installation, reliability, availability, and maintainability.
   5. Training program, including training materials, facilities, products, classes, and schedule.
   6. Special tools and test equipment.
   7. Impact of design decisions on the Project Schedule.
   8. Information needs and decisions required.

3.05 FINAL DESIGN REVIEW (FDR)

A. The purpose of the FDR is to verify that the detailed design meets performance and technical requirements before implementation.

B. The following submittals shall be distributed before the FDR. Each submittal shall be developed to the 100 percent level and shall include mechanical and electrical details.
   1. Final Integration Plan.
   2. Final Staging, Commissioning, and Closeout Plan.
   3. Parts List.
   4. Recommended Spare Parts List and List of Special Tools and Test Equipment. Refer to Section 01840, "Spare Parts and Test Equipment."
   5. Final Inspection and Test Plan.
   6. Final reliability and availability estimates, verified by Contractor.
   7. Final design documents for each subsystem:
      a. System design.
      b. Product Data, Shop Drawings, and specifications.
      c. Functional Site Block Diagrams.
      d. Arrangement Plans.
      e. Installation Plan.
      f. Wiring Plan.
      g. Power Wiring Plan.
      h. Software and Firmware Plan
      i. Allocation and Provisioning Plan.

C. Contractor is encouraged to submit FDR information incrementally to reduce the duration of the formal meeting.

D. At the FDR, the following issues shall be discussed and demonstrated:
   1. Complete system satisfies the performance and design requirements.
   2. Interfacing to internal and external systems meets requirements.
   3. System maintenance, the effects of system maintenance on hardware and software components, and the role of Authority maintenance personnel.
   4. Plan for conducting system integration tests.

5. Plan for transition from the existing system to the new system.
6. Plan for providing system support.
7. Impact of design decisions on the Project Schedule.
8. Information needs and decisions required.

3.06 POST-FDR CHANGE CONTROL

A. After completing the FDR, system design is frozen. From this point on, if an engineering change is required, the Contractor shall be required to develop and implement design change control procedures so as to document any changes to the design.

3.07 PARTS LIST

A. Contractor shall submit a preliminary parts list at PDR, and a final parts list at FDR for all equipment furnished under the Contract.

B. The list shall include manufacturer serial numbers and model numbers for replaceable components, circuit boards, assemblies, consumable items, meters and instruments, electrical fittings, nameplates, tags and all comparable items.

C. The listing shall include component name, drawing reference, description, rating, accuracy class, tolerance, part number, supplier or source and any other essential data.

D. The parts list shall be provided in a matrix form that shows the quantity of each item used at each location.

E. This matrix shall be the basis of the Recommended Spare Parts List as described in Section 01840, "Spare Parts and Test Equipment."

3.08 EQUIPMENT INSTALLATION REQUIREMENTS

A. Contractor shall be responsible for all engineering and support services and furnishing all elements of the New Communications System, as presented in the Contract Documents.

B. Contractor shall consult the Contract Drawings for locations of the equipment. If exact location is not given, information shall be obtained from the Engineer prior to installation. Measurements shall be verified in the field.

C. Components and equipment shall be installed to provide the maximum possible headroom where mounting heights or other location criteria are not indicated.

D. Items shall be installed level, plumb, parallel, and perpendicular to other building systems and components except where otherwise indicated.

E. Equipment shall be installed to facilitate service, maintenance, and repair or replacement of components. Connect for ease of disconnecting, with minimum interference with other installations.

F. Contractor shall obtain Engineer's approval before relocating any raceways or piping systems installed by others.

G. Power distribution panel shall be mounted above all other apparatus mounted on racks.

H. Contractor shall permanently label all equipment utilizing permanent machine printed labels including, but not limited to the following:
   1. Equipment Cabinets.
   2. Equipment Racks.
   3. Equipment interfaces.
   4. Equipment displays.
   5. Cable connections.
   6. Cable racks.
   7. RF directional ports on equipment and directional connections on cables.
   8. Power Connections.

I. Contractor shall provide copies of a table of symbolic or index labeling definitions used at each site. For each site, one copy shall be mounted on each cabinet, rack, or standalone piece of equipment. In addition, one copy shall be provided to the Engineer.

J. Contractor shall seal all openings in conduits, ducts, equipment shelters, equipment rooms, enclosures and junction boxes where cables enter. A resilient sealing compound made expressly for this purpose shall be installed after the cables are in place.

K. Contractor shall remove and properly dispose of all material that is replaced or otherwise made redundant by the Work. Authority shall be given the option of retaining any replaced electronic equipment.

L. Work shall present a neat and coordinated appearance.

3.09 ELECTRICAL SUPPORTING METHODS

A. Contractor shall conform to manufacturer's recommendations for selecting supports.

B. Strength of Supports: Adequate to carry all present and future loads times a safety factor of at least four. The minimum design load is 200 lb per square foot.

3.10 ELECTRICAL INSTALLATION

A. Miscellaneous Supports: Metal channel racks shall be installed for mounting cabinets, pull boxes, junction boxes, and other devices except where components are mounted directly to structural features of adequate strength.

B. Fastening: Unless otherwise indicated, electrical items and their supporting hardware shall be secure if fastened to the building structure. Fastening shall be performed according to the following:
   1. Fasten by means of wood screws or screw-type nails on wood, toggle bolts on hollow masonry units, concrete inserts or expansion bolts on concrete or solid masonry, and by machine screws, welded threaded studs, or spring-tension clamps on steel.
   2. Depth of drilled holes in concrete shall not exceed three (3) inches in bored tunnel.
   3. Threaded studs driven by a powder charge and provided with lock washers and nuts may be used instead of expansion bolts, machine screws, or wood screws.
   4. In partitions of light steel construction, sheet-metal screws shall be used.
   5. Fasteners shall be selected so the load applied to any fastener does not exceed 25 percent of the proof-test load.

3.11 CUTTING AND PATCHING

A. Contractor shall cut, channel, chase and drill floors, walls, partitions, ceilings, pavement, curbing and other surfaces necessary for electrical installations. Cutting shall be performed by skilled mechanics of the trades involved.

B. Disturbed surfaces shall be repaired to match adjacent undisturbed surfaces.

3.12 CLEARANCE

A. Contractor shall provide adequate clearance in relation to LRV dynamic outline, catenary structure clearance, signal sighting distances, line of sight to LRV and pedestrian crossings, obstructions and access by maintenance personnel.

3.13 PAINTING

A. Contractor shall follow paint manufacturer's written instructions for surface preparation and for timing and application of successive coats.

B. All exposed electrical equipment, conduit and fittings shall be painted to match background.

C. No paint shall be applied on wet, damp, frosted or dirty surfaces, or when the temperature is below 54 degrees F or when in the opinion of the Engineer conditions are otherwise unsuitable for painting.

D. Surfaces required to be painted that will be inaccessible after installation or erection shall be given two additional coats of paint before installation or erection.

E. If any painted surface is damaged prior to the completion of the work under this Contract, such damaged surface shall be cleaned, touched-up or completely repainted by Contractor without additional compensation.

F. Contractor shall furnish Authority 2 gallons of touch up paint for each finish color at the end of the work.

3.14 JUNCTION BOXES

A. Installation of junction boxes shall meet the applicable requirements of Section 16130, "Raceways and Boxes" of the Specifications.

3.15 EQUIPMENT RACKS

A. Wherever possible, communications equipment shall be mounted on equipment racks.

B. A minimum of 36 inches clearance shall be maintained in front of and in back of all equipment racks.

C. Racks to be mounted in the same row shall be of the same height.

D. Contractor shall submit for approval to the Engineer a fully detailed Arrangement Plan for each equipment room. This Arrangement Plan shall include:
   1. Floor plan to scale of all communications equipment rooms showing size and arrangement of all racks, rack mount enclosures and equipment to be installed and/or moved.
   2. Rack view to scale of all communications equipment racks and equipment in their permanent locations.

E. Equipment racks and communications equipment shall be installed according to approved Arrangement Plan.

F. All equipment cabinets and racks shall be permanently connected to a common ground point.

3.16 CABLE RACKS

A. Contractor shall provide and install cable racks in all communications equipment rooms to provide overhead routes for all wire and cable.

B. Contractor shall provide and install cable racks where necessary in existing communications equipment rooms.

C. Contractor shall submit for approval to the Engineer a fully detailed Arrangement Plan showing all proposed cable rack installations. The Arrangement Plan shall show:
   1. All parts of cable rack.
   2. Size of cable racks.

D. Cable racks shall be installed according to approved Arrangement Plan.

E. All cable racks shall be permanently connected to a common ground point.

3.17 ELECTRONIC EQUIPMENT CABINETS

A. Communications equipment that is being installed within station communications equipment rooms and existing communications equipment that will remain in service shall be rack mounted inside electronic rack cabinets.

B. Electronic rack cabinets shall be included and indicated in the Arrangement Plan to be submitted to the Engineer for approval.

C. Contractor shall size electronic equipment cabinets to accommodate the proposed communications equipment. Standard rack widths of 19 inches or 23 inches shall be used. Cabinets to be mounted in the same row shall be of the same height and exterior finish.

3.18 WIRE AND CABLE

A. Outside plant copper communications cables include all copper communications cables that run between two locations, such as between two communication equipment rooms, or between a communications equipment room (CER) and any location that is not contained in the same building or structure as the CER. For example, a copper cable between a CER and a wayside emergency telephone is an outside plant copper communication cable. A copper cable from the main distribution frame (MDF) to an equipment rack where the equipment is housed in the same room as the communications equipment is not an outside plant copper communications cable. Refer to Section 16702, "Copper Outside Plant."

B. Copper communications wire and cable that does not exit the room that houses the communications equipment is referred to herein as inside communications wire and cable.

C. Copper communications wire and cable that exits the CER but runs within the location or station area is referred to herein as local communications wire and cable. Examples of local communications cables are cables between a station's CER and PA speakers, VMS signs, patron phones, and ticket vending machines located at that station.

D. Inside and local communication wire and cables are considered part of the subsystem that uses them, and are specified in the subsystem's Section. Contractor shall furnish and install new inside and local cable as necessary to provide all required connections. Contractor shall furnish and install the type of cable that provides the functionality required. As an example, cable to SACS locations must provide a data connection for the RTU and a telephone connection for the telephone. This may require two separate cables, an extended distance data cable and a telephone cable.

E. Contractor shall terminate all local communications wire and cable on protection blocks equipped with protection modules on the new MDF. From the protection blocks, the local cables shall be connected to cross connect blocks. At the far end, all local cables shall be terminated on terminal blocks.

F. Inside communications cables and wires shall be terminated on cross connect blocks on the new MDF. Installation of the MDF is described in Section 16702, "Copper Outside Plant." Inside communications cable shall be connectorized wherever possible, using industry standard connectors. Contractor shall include connector type as part of the wiring plan to be submitted to the Engineer for approval. Connections between cable and wire conductors shall be made using cross connect wire on the MDF.

G. Contractor shall submit to the Engineer for approval a fully detailed Wiring Plan that:
   1. Includes the naming convention used in the Contract Documents.
   2. Indicates the type of wire or cable, and the number of pairs or conductors for each wire or cable run.
   3. If necessary, includes cable and wire types not specified in the Contract Documents. Wire and cable types not specified must be submitted to the Engineer for approval as part of the Wiring Plan, with explanation of why they are required.
   4. If a new run of cable is to be used to extend, or otherwise connect to an existing cable, the new cable shall be consistent with the existing cable. Color code, pair count, size of conductors, etc. shall be the same.

H. Wire and cable shall be installed according to the approved Wiring Plan.

3.19 GROUNDING

A. Conduits and connections to electrical equipment shall be installed to make a continuous ground in accordance with Section 16060, "Grounding and Bonding.

B. General Requirements
   1. The grounding system shall preclude any closed loop grounding arrangement.
   2. Ground connection to the track rails or use of the neutral conductors of the local power utility company or AC signal supply system shall not be permitted.
   3. The grounding of entrance racks and instrument racks shall be accomplished using the ground bus as specified herein. All racks shall be electrically connected to the ground bus by means of a minimum No. 6 AWG stranded wire. Means shall be provided at each rack to isolate the rack from ground for test purposes. Cable racks shall be isolated from the racks and grounded separately.
   4. All other individual apparatus not located on racks or herein specified to be grounded shall have individual insulated minimum No. 6 AWG extra-flexible ground connections to the ground bus. These connections shall be designed to be of the shortest possible distance consistent with good workmanship and the layout of the communications equipment room.
   5. Sharp bends in grounding conductors used with surge protection equipment shall be avoided.
   6. The resistance between any equipment or rack grounds and the ground bus shall

be 0.5 ohms or less.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16701

FIBER OPTIC OUTSIDE PLANT

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the fiber optic outside plant, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to the design coordination and implementation of the following activities:
   1. Contractor shall furnish all labor, material, equipment, supervision, transportation, and miscellaneous services, whether or not explicitly identified herein, to provide a completely tested and fully operational fiber optic cable plant.
   2. Furnishing and installing diversely routed 96 strand fiber optic cables from the existing communications room in Gateway station to three new communications rooms located in the new Gateway Station, North Side Station and Allegheny Station. The fiber optic outside plant consists of fiber optic cable and ancillary equipment as required for a fully operational system as specified herein and as shown on Contract Drawings CM004 to CM007 and Cable Routing (CR) Drawings:
      a. One 96 strand fiber optic cable shall be run between the existing Gateway Station communications room and the new Gateway Station communications room.
      b. One 96 strand fiber optic cable shall be run between the new Gateway Station communications room and the Allegheny Station communications room.
      c. One 96 strand fiber optic cable shall be run between the Allegheny Station communications room and the North Side Communications Room.
      d. One 96 strand fiber optic cable shall be run between the North Side Station communications room and the existing Gateway Station communications room where it will be cross connected to the existing fiber optic cable between the existing Gateway Station communications room and the Wood Street Station communications room.
   3. The work also includes the installation of the signal fiber optic cable spans as listed below:
      a. One 12 strand fiber optic cable shall be run from the new Gateway Station signal relay room to the North Side Station signal relay room as shown on Contract Drawings SG020-SG021.
      b. One 12 strand fiber optic cable shall be run from the new North Side Station signal relay room to the Allegheny Station signal relay room as shown on Contract Drawings SG021-SG023.
   4. The work also includes the installation in conduit provided by the station finish contract, of 6 strand fiber optic cable between the IP Video cameras and the

communications room at the three NSC stations as indicated on Contract Drawing CM028. The location of the IP cameras is shown on the "Also" drawings within the Contract Package.

5. All 96 strand communications fiber optic cables shall be diversely routed to the extent possible. Wherever possible, Contractor shall avoid running redundant fiber optic cables in common raceways, conduits, or cable troughs.
6. The work also includes the installation of all necessary conduit to complete the fiber optic cable installation as shown in the cable routing (CR) drawings and SG020 through SG023.
7. The work also includes the installation of the fiber termination panels in equipment cases located in the existing Gateway Station communications room, new Gateway communications room, the North Side Station communications room, the Allegheny Station communications room, the new Gateway Station signal room, the new North Side Station signal room and the Allegheny Station signal room.
8. The work also includes the installation of all conduit, pull boxes, splice enclosures, slack enclosures cable ladder, patch panels, connectors, pigtails and other miscellaneous hardware required to provide a functional, reliable and maintainable fiber optic cable communications system.

C. The Contractor shall perform a site survey of the existing fiber optic plant to record and document all fiber optic link losses and splice losses required for the new fiber optic rings specified herein. Contractor shall also prepare a fiber optic map of the existing and new fiber to be installed as part of the NSC work to record all existing and projected losses in each of the new fiber optic rings as shown on CM005 & CM006.

Contractor shall calculate and prepare a document for approval showing the total fiber optic ring losses for the NSC SONET & Gigabit rings along with the projected transmission loss margins for the fiber optic equipment in each ring.

D. The Contract Documents provide the performance parameters and design criteria to complete the fiber optic outside plant. The Contractor shall be responsible to provide a complete design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16700, "Communications."

B. Section 16901, "Communication System Inspection and Test."

1.03 REFERENCE STANDARDS

A. ANSI Standard C2.

B. ANSI/EIA Standard 472.

C. Telcordia Standard GR-20, Generic Requirements for Optical Fiber and Optical Fiber Cable.

D. EIA/TIA Standards 568 and 598.

E. NEMA Standards LRT-006 16701-2 Conformed January 26, 2001

F. NFPA Standard 130, "Standard for Fixed Guideway Transit Systems"..

G. Rural Utilities Service Specification, 7 CFR 1755.900, (Formerly REA PE-90)

1.04 SUBMITTALS

A. System Design to include the following in addition to the requirements stated in Section 16700, "Communications":
   1. Optical loss budget plan and analysis with supporting design calculations. This plan shall show the calculated optical loss between all connected nodes.

B. Product Data, Shop Drawings and specifications to include the following in addition to the requirements stated in Section 16700, "Communications":
   1. Include full technical data for all products to be used, including fiber optic cable, conduits, fiber slack enclosures (FSEs), fiber distribution panels (FDPs), fiber optic connectors, pigtails, patch cords, equipment racks, and splice trays.
   2. Documentation and certifications that the jacket meets the physical requirements of Rural Utilities Service Specification, 7 CFR 1755.900, is of low smoke zero halogen construction, and meets the requirements of all local, state, federal and other regulatory agencies.
   3. List of installations supplied by each proposed manufacturer, indicating a minimum of five years experience in supplying fiber optic cables and fiber optic outside plant equipment as described in this Section.
   4. List of fiber optic cable and outside plant installations provided by the Contractor, indicating a minimum of five years experience in supplying fiber optic cables and fiber optic outside plant equipment comparable in size and complexity to this Project as described in this Section.
   5. Sample specimens in 4 feet lengths for each proposed manufacturer's cable.

C. Functional Site Block Diagram by node locations.

D. Arrangement Plan.

E. Installation Plan containing detailed installation plans, prior to commencement of any such work, for approval by the Engineer. These plans shall include the following in addition to the requirements stated in Section 16700, "Communications":
   1. Detailed cable routing; splicing, installation methods; termination plans; conduit, and cable rack details; and proposed length of duct and conduit to be installed.
   2. Cable pulling tension calculations, proposed method of monitoring cable tension, and execution plan for pulling and installing all fiber optic cable.

3. Cable bending radius plan.
4. Specific location plan and exact mounting arrangement of fiber slack enclosures.
5. Plan for using one type of optical connector throughout Project.
6. List of fiber optic plants installed by proposed fiber optic cable installers, as described in this Section.

F. Fiber Optic Outside Plant Wiring Plan detailing all wiring and connections to include the following in addition to the requirements stated in Section 16700, "Communications":
   1. Summary of identification schemes.
   2. Wiring diagrams of all terminations, distribution frames, equipment racks, and any other portion of the Fiber Optic Outside Plant System.

G. Inspection and Testing submittals
   1. Completed and signed test report prior to shipment of each batch of fiber optic cable.
   2. Attenuation report with each reel of fiber optic cable as described in this Section.
   3. Contractor shall submit for approval by the Engineer evidence that Contractor has experience and expertise in performing required field tests.
   4. Format of the Splice Log used to document all splices to fibers in the Fiber Optic Outside Plant. The Splice Log shall be used by Contractor to maintain a record of all splices and shall include, but not be limited to, the following information:
      a. Site location.
      b. Equipment room, signal/relay room, etc.
      c. Each fiber in the splice shall have the following information recorded:
         1) Fiber cable designation.
         2) Buffer tube and fiber identification within the cable.
         3) Distribution panel and fiber number (if applicable).
         4) Description of the fiber function such as NSC OC-12 Ring Primary, NSC OC-12 Ring Secondary, Gigabit Ethernet Ring Primary, Gigabit Ethernet Ring Secondary, etc.
      d. Time and date of when the splice was made.
      e. Name of the person who performed the splice.
      f. Initials of the person who performed the splice.
      g. Notes or comments regarding the splice.
   5. Final Attenuation Report of the installed cable as described in this Section.
   6. Fiber Layout Maps shall be provided for all new and existing fiber cables.

1.05 DELIVERY, STORAGE AND HANDLING

A. All cable shall be shipped on reels and adequately protected from damage in shipment. Contractor shall be responsible for correction of any defect in the cable occurring in transit.

B. Each length of cable shall be wound on a separate reel. Reels shall be designed and constructed to withstand handling and shall be so designed that both ends of the cable will be secured and accessible but protected from injury. If the inner end of the cable projects through the flange of the reel, the inner end shall be protected by a suitable cover of metal having rounded ends and sides and securely fastened in place to protect cable end. Both ends of cable on the reel shall be secured in place to prevent their becoming loose in transit or handling of the reel.

C. The radius of the reel drum shall be larger than the minimum dynamic bending radius of the cable to prevent damage to the cable during reeling. The arbor hole shall admit a spindle 2.5 inch in diameter without binding. The reels shall be designated and constructed as non-returnable when drum size and cable weight and volume permit.

D. After acceptance of factory tests, the cable shall be effectively sealed against the entrance of moisture. Both ends of each length of cable shall be protected by suitable means approved by the Engineer. The use of friction tape, other than as an external mechanical protection over an adequate rubber and/or plastic tape, shall not be accepted. The cable end protection shall be adequate to protect the cable in shipment and prolonged external storage in the weather, without regard to the position of the reel while so stored.

E. Each layer of cable on the reel shall be closely and tightly wound in a uniform manner.

F. An arrow shall be painted on one head of each reel pointing the opposite direction from the outer end of the cable with the words "Roll This Way." The words "Roll This Way" shall not be less than 0.75 inch in height and the arrow shall not be less than 6 inch in length and 0.5 inch in width.

G. Each reel of cable shall be identified with a unique number that can be used to trace relevant information about the cable, such as manufacturer's batch, date of manufacture, and factory location where manufactured. This cable reel identifier shall be referred to in the attenuation report provided with each reel of cable.

1.06 QUALITY ASSURANCE

A. The cable shall be manufactured in compliance with a Quality Assurance Program that meets the intent of ISO 9001:2000 Quality management systems – Requirements.

B. Contractor shall furnish to Authority, within 30 days after Notice To Proceed, 2 samples in 4-foot lengths identical the cable Contractor intends to supply. Specimen samples shall remain the property of Authority.

1.07 QUALIFICATIONS

A. The manufacturer shall have a minimum of five years of experience in supplying fiber optic cables and fiber optic outside plant materials comparable to those specified herein.

B. The manufacturer shall have supplied a minimum of five systems comparable in size to the system specified herein. Each of these systems shall have been in service and operating satisfactorily for a minimum of 12 months. The manufacturer shall provide a list of these systems to the Engineer. The list shall include names, addresses, and telephone numbers of operating personnel who may be contacted and who are responsible for the maintenance of the system. Demonstration of the systems shall be arranged upon request.

C. The manufacturer shall be submitted for approval of the Engineer.

D. All entities participating in the installation of the fiber optic cable shall have a minimum of five years experience in installing fiber optic cable and appurtenances and shall have installed a minimum of five fiber optic outside plants comparable in size to the plant specified herein. Each of these plants shall have been in service and operating satisfactorily for a minimum of 12 months. Contractor shall provide a list of these systems to the Engineer. The list shall include names, addresses, and telephone numbers of operating personnel who may be contacted and who are responsible for the maintenance of the system. Demonstration of the plants shall be arranged upon request.

E. The proposed installer shall be submitted to the Engineer for approval.

1.08 PROVISIONING

A. The following shall be used as a guideline in determining the quantities of major materials required for the Fiber Optic cable plant:
   1. Single-Mode LSZH Fiber Optic cable shall be installed in conduit between NSC stations and existing communications room in Gateway Station as indicated on the Cable Routing (CR) Drawings.
   2. Fiber Optic cable (96 strands) shall be installed in GRS Conduit and cable troughs on both the inbound and outbound sides of the Gateway/North Side Station tunnel as indicated on the Cable Routing (CR) Drawings.
   3. Fiber Optic cable (96 strands) shall be installed in cable troughs on both the inbound and outbound sides of the section from North Side Station to the Allegheny Station as indicated on the Cable Routing (CR) Drawings.
   4. Fiber Optic cable (12 strands) shall be installed in GRS Conduit and cable trough in one tunnel between the new Gateway Station signal relay room and the North Side Station signal relay room.
   5. One Fiber Optic cable (12 strands) shall be installed in cable trough between the North Side Station signal relay room and the Allegheny Station signal relay room.
   6. Fiber Optic cable (6 strand) shall be installed in conduit at the NSC stations between the IP Video cameras and the communications equipment rooms.
   7. One Fiber Distribution Panel and one Fiber Slack Enclosure shall be installed on each end of all fiber cables installed between station CERs and signal relay rooms.

B. Contractor shall determine fiber optic cable and conduit lengths, and the quantity of Fiber Distribution Panels, and Fiber Slack Enclosures and other hardware based upon information shown on the Contract Drawings. Actual quantities to be installed depend upon contractor's design, and may therefore vary from the quantities shown on the Contract Drawings.

1.09 WARRANTIES

A. Contractor shall guarantee that 100 percent of the fibers meet or exceed Contract requirements. Contractor may elect to provide this guarantee by providing a percentage of fibers in excess of those specifically required; however, these additional fibers shall be provided at no additional cost to Authority.

ARTICLE 2 PRODUCTS

2.01 FIBER OPTIC CABLE

A. General
   1. Cable with jacketing materials capable of a 40-year average service life shall be provided.
   2. Cable shall be suitable for installation at minus 5 degrees F.
   3. All fiber optic cable shall be provided with low smoke zero halogen jackets, and meet all of the Fire, Smoke and Smoke Toxicity requirements of this Section.

B. The fiber optic cable shall meet or exceed the requirements of the latest issue of Telcordia GR-000020 "Generic Requirement for Optical Fiber and Optical Fiber Cables", ANSI/EIA-472 "Generic Specification of Fiber Optic Cables," and RUS (Rural Utilities Service) "Specification, 7 CFR 1755.900: Specifications for Totally Filled Fiber Optic Cables," and appropriate sectional specifications thereof.

C. Unless otherwise shown on the Contract Drawings, the fiber optic cables shall contain 6, 12 or 96 optical fibers designed and fabricated for single mode optical transmission.

D. The fiber optic cable shall be constructed entirely from dielectric material.

E. The fiber optic cable shall be Low-smoke, zero halogen, fire retardant cable produced in conformance with local, NEC, NFPA and other binding regulations. This cable shall be suitable for direct installation into a cable trough or conduit affixed directly to tunnel walls. This type shall be referred to as the "LSZH cable" in the Contract Documents.

F. The fiber optic cable shall be of loose tube construction with buffer tubes wrapped around a dielectric central strength member. All fibers shall be contained within buffer tubes, and each buffer tube shall have an inside diameter much greater than the total diameter of the fibers it supports.

G. Each fiber or group of fibers shall be free-floating within the tubes such that all mechanically or environmentally induced stress placed upon the cable is de-coupled from the fibers.

H. The fiber optic cable shall contain materials that will prevent entry by water and migration of water through the cable core.

I. Fibers and buffer tubes shall be color coded to facilitate easy individual fiber identification without use of special equipment or instruments. Color-coding shall conform to latest issue of EIA/TIA-598, or be approved by the Engineer.

J. Fibers shall be equally distributed among buffer tubes as far as practicable.

K. An inner jacket shall be provided to protect the buffer tubes from environmental and mechanical stresses.

L. The cable shall be provided in continuous lengths. Each fiber shall be pulled from the same optical waveguide form and shall be free of splices.

M. The fiber optic cable shall be marked in accordance with ANSI Standard C2, including a visual identifier to identify the cable as a telecommunications cable. The sheath shall have permanent marking that shows the manufacturer's name, the month and year of manufacture, and the words "fiber optic cable" or "optical cable." A numerical sequence shall be marked on the outer jacket, at intervals no greater than 10 feet, to facilitate determination of length of cable and amount of cable remaining on the reel.

N. The outer jacket shall be constructed of black, durable, abrasion resistant plastic, with a minimum thickness of 0.06 inch. Jacketing material shall be applied directly over the tensile strength members and flooding compound. The outer jacket shall be ultra-violet ray and fungus resistant. In addition to these requirements, LSZH cable shall have a type of outer jacket that is specifically formulated and manufactured for low smoke, zero halogen, and low flame spread classification.

O. Cable construction method other than as specified shall be approved by the Engineer. The LSZH cable shall meet or exceed the optical and mechanical specifications found below in Tables 16701-1 and 16701-2:

TABLE 16701-1
Optical Specifications

Attribute	Requirement
Operational Wavelength	1,310 nm and 1,550 nm
Maximum Optical Attenuation @ 1,310 nm	0.40 dB/km
Maximum Optical Attenuation @ 1,550 nm	0.30 dB/km
Maximum Attenuation Point Discontinuity @ 1,310 nm	0.1 dB
Maximum Attenuation Point Discontinuity @ 1,550 nm	0.1 dB

TABLE 16701-1 Optical Specifications	
Attribute	**Requirement**
Maximum Cutoff Wavelength	1260 nm
Maximum Optical Dispersion @ 1,310 nm	3.2 psec/nm-km
Maximum Optical Dispersion @ 1,550 nm	20 psec/nm-km
Zero Dispersion Wavelength	1310 nm +/- 12 nm
Maximum Zero Dispersion Slope	0.092 ps/nm-nm-km
Nominal Fiber Core Diameter	8.3 um
Fiber Coating Diameter	250 um +/- 15 um
Fiber Cladding Diameter	125 um +/- 1 um
Maximum Core/Cladding Concentricity Error	1.0 um
Maximum Cladding Non-Circularity	1.0 %
Mode Field Diameter	9.3% +/- 0.5 % @ 1,310 nm
Nominal Refractive Index Difference	0.37 +/- 0.5%

TABLE 16701-2 Mechanical Specifications	
Attribute	**Requirement**
Crush Resistance	5,000 N/m, over length of cable
Nominal Cable Outside Diameter	20 mm (0.79 inch) +/- 5%
Minimum Bending Radius, Installation	20 times the cable diameter
Minimum Bending Radius, Static	10 times the cable diameter
Operational Temperature	-40 to 150 degrees F
Storage Temperature (on reel)	-40 to 150 degrees F
Humidity	0 to 100%
Impact Resistance	Minimum 20 impact cycles
Cyclic Flexing	Minimum 20 cycles
Minimum Proof Strength	100 kpsi
Attenuation at Water Peak	Maximum 2.1 dB/km @ 1383 +/- 5 nm
LSZH Cable – Tensile Strength Short Term	600 lbf
LSZH Cable – Tensile Strength Long Term	135 lbf

2.02 FIBER OPTIC CONNECTORS

A. Only one type of connector shall be used on the Project, and it shall be the same type as supplied by the manufacturer of the optical multiplexers, fiber modems, and all other equipment supplied that interfaces with optical fibers. The single mode optical connectors furnished under this Contract for installation on FDPs, optical patch cords and pigtails shall be type ST connectors. All connectors shall conform to the latest issue of EIA/TIA-568 for ST connector performance and physical characteristics. All optical connectors shall be factory installed on patch cords and pigtails. No field installation of connectors shall be permitted.

B. The connectors shall meet or exceed the specifications listed below in table 16701-3:

TABLE 16701-3 Connector Specifications	
Attribute	**Requirement**
Attenuation (Average, 3 readings, 120 degrees spacing)	Less than or equal to 0.7 dB
Mechanical Stability	Less than or equal to 0.3 dB change
Tensile Stability	Less than or equal to 0.3 dB change
Thermal Stability [5 cycles, -10 to +45 degrees C (-15 to 110 degrees F)]	Less than or equal to 0.4 dB change
Nominal Insertion Loss (mated pair)	0.25 dB
Maximum Insertion Loss (mated pair)	0.50 dB
Reflectance	Less than – 55 dB

2.03 OPTICAL PATCH CORDS AND PIGTAILS

A. The optical patch cords furnished under this Contract shall consist of a section of single fiber, jacketed cable equipped with optical connectors at both ends.
   1. Patch cords for connections from FDP to FDP shall be equipped with approved connectors on both ends of the patch cord.
   2. Patch cords for connections from FDP to optical equipment shall be equipped with an approved connector on one end. The optical connector on the other end of these patch cords shall be compatible with the connectors furnished on the optical equipment.

B. The optical pigtails furnished under this Contract shall consist of a section of single fiber, jacketed cable, equipped with an Engineer-approved connector at one end. The other end shall be stripped and prepared for fusion splicing.

C. The approved connectors furnished as part of optical patch cords and pigtails shall meet or exceed the requirements for approved connectors specified herein.

D. The fiber portion of each patch cord and pigtail shall be a single, single mode, jacketed fiber, with optical properties identical to the Outside Plant (OSP) cable furnished under this Contract. The fiber jacket shall be an Engineer-approved low smoke, low toxicity, and flame-retardant sheath. The jacketed fiber shall have a tensile strength in excess of 20lbf.

2.04 FIBER DISTRIBUTION PANELS (FDPS)

A. FDPs shall be furnished and installed at the locations shown on the Contract Drawings.

B. Contractor shall provide the required FDPs, at each location. Each FDP shall consist of two parts: a splice shelf and an optical patch panel.
   1. Splice Shelf
      a. The splice shelf shall house and protect fusion splices of OSP fibers to single mode fiber pigtails. The pigtails shall have minimum length of 13 feet.
      b. The fiber pigtail slack shall be neatly coiled and secured in a manner that does not allow the minimum operational bending radius of the pigtail to be exceeded.
      c. Each splice tray shall be capable of storing and protecting a maximum of 12 fusion splices with heat shrink protection, and shall include a clear plastic tray cover.
      d. Splice shelves installed in CERs shall have a minimum capacity of 8 trays (96 splices) and be capable of adding trays up to a maximum of 16 (192 splices) as required at the location.
      e. Splice shelves installed in signal relay rooms shall have a minimum capacity of 2 trays (24 splices and be capable of adding trays up a maximum of 4 trays (48 splices).
      f. The splice shelf shall be rack-mountable on a standard 19 or 23 inch equipment rack.
   2. Optical Patch Panel
      a. The optical patch panel shall house and protect the approved connectors on each pigtail, and fiber optic patch cords.
      b. The approved type single mode connectors on the end of each pigtail shall screw into a sleeve securely mounted to a patch panel within the FDP enclosure. The maximum optical loss across the connection shall not exceed 0.7 dB.
      c. The optical patch panels shall be modular units whereby each module shall have a capacity of 6 ports (pigtails). The optical patch panel shall have the capability of adding modules to achieve the required capacity. Each optical patch panel shall have the capacity (number of ports) to accommodate each fiber terminated at the FDP, plus 100% spare ports.
      d. Each optical patch panel shall have removable hinged front and rear doors with a flipcard to facilitate record keeping.
      e. Each optical patch panel shall be rack-mountable on a standard 19 or 23-inch equipment rack.

C. The FDP housings shall be rack mounted, as shown on Contract Drawing CM095. The housings shall have OSP cable entrances with cable sheath strain relief.

2.05 FIBER OPTIC SPLICES

A. All permanent optical splices in the system shall be of the fusion type.

1. There shall be no mid-span splices of the fiber optic cable. All fiber optic cables must originate and end at an optical node, fusion spliced to a fiber distribution panel or to another cable run.
2. A factory fabricated fusion splice kit containing materials necessary for quality fusion splicing shall be provided for each fiber splice.
3. Splices made with the factory fabricated single mode fusion splice kits shall lose no more than 0.05 dB at 1310 nm.
4. An emergency restoration kit shall be provided to perform temporary splices. This kit shall include all necessary tools and materials to perform mechanical splices. Each mechanical splice kit shall lose no more than 0.1 dB at any wavelength.
5. Contractor shall keep a log of all splices and splice testing.

2.06 FIBER SLACK ENCLOSURES (FSE)

A. FSEs shall be provided and installed as part of this Contract, in every communications equipment room as shown on the Contract Drawings.

B. FSEs shall house and protect fiber optic cable slack, in a manner that allows maintenance personnel access to the cable slack so they may implement moves and changes to the fiber optic cable plant without disruption to its integrity.

C. FSEs shall be NEMA (National Electrical Manufacturers Association) type 3R; wall mounted or pole mounted and suitable for indoor and outdoor application. They shall provide for weatherproof entry and exit of cable from the bottom sides of the FSE.

D. FSEs shall be equipped with an Engineer-approved padlock provided by Contractor.

E. FSEs shall be sized to house a minimum of 328 ft of cable slack within the enclosure and be no less than 35 in high, 20 in wide, and 8 in deep.

F. FSEs shall have provisions for entrance of the fiber optic innerduct, including compression fittings, seals, and other incidentals required for proper installation of the innerduct. The FSE shall be designed such that the cable can be released and uncoiled from the enclosure via the front of the enclosure.

G. The method used for storage of fiber slack within the FSE shall not allow the minimum operational bending radius of the cable to be exceeded at any time.

2.07 FIBER OPTIC CONDUIT (INNERDUCT)

A. The fiber optic conduit shall be orange in color for ease of identification, and shall have a pre-installed pull rope or pull tape to facilitate cable pulling.

B. The fiber optic conduit shall be sized to assure that the maximum pulling tension of the fiber is not exceeded during installation.

C. The fiber optic conduit shall be made from low smoke, zero halogen, low toxicity, fire retardant material, and shall be free of pinholes, voids, or other imperfections. When used in tunnel applications it shall conform to local, NEC, NFPA, and other binding regulations. The conduit shall be made from material that is approved by the Engineer.

D. The words "FIBER OPTIC CABLE" shall be permanently imprinted along the conduit at 16-foot intervals.

ARTICLE 3 EXECUTION

3.01 FIBER OPTIC CABLE INSTALLATION REQUIREMENTS

A. Contractor shall perform a pre-installation survey of the entire fiber optic cable route as part of the Site Inspection. Site Inspection shall include inspection of relevant ducts, ductbanks, conduits, cable trays, and cable troughs as well as entrances to the communications equipment rooms and signal rooms.

B. The route of the 96 strand communications fiber optic cables shall be as physically diverse as possible; there shall be the widest separation of distance between portions of the cable forming the loop as shown in Contract Drawing CM004. Therefore, Contractor shall, to the greatest extent possible, assure that the 96 fiber cables installed between Gateway and Allegheny stations are located on opposite sides of the tunnels and aerial structures.

C. Contractor shall coordinate the installation of the fiber optic cable with Authority.

D. The installation plan shall indicate areas where conduit is to be installed directly to the walls of tunnels. The proposed method of attaching the conduit to the wall of the tunnel shall be detailed in the plan.

E. Contractor shall perform the cable installation in accordance with the approved plan. Any deviations from the approved plan must be submitted in writing to the Engineer for approval.

F. Contractor shall pull a pull cord whenever installing cable in ducts. A minimum of 2 feet of pull cord shall be left at each end of conduit run, with ends of the pull cord secured.

G. Contractor shall verify raceway conduit is free of obstructions by pulling a suitable wire brush, swab, and mandrel through raceway conduit to remove extraneous matter.

H. Contractor shall ensure raceway conduit is dry before installation of cable and use lubricant approved by cable manufacturer to facilitate pulling cable.

I. Maximum cable lengths and pulling tensions shall be determined to avoid excessive pulling tensions or more bends than manufacturer's recommendations.

J. Contractor shall assure that the minimum bending radius of the fiber optic cable is not compromised during the installation of the cable.

K. Exposed cable will not be permitted along the wayside.

L. All exposed cables entering or leaving equipment housings, junction boxes, slack enclosures, and equipment racks shall be protected from abrasion. Chase nipples shall be provided in drilled or punched openings in housings and junction boxes. Openings in equipment enclosures and junction boxes shall have split ring plastic grommets. All cables shall be identified by permanent labels indicating "to" and "from" information.

M. All openings in equipment enclosures and junction boxes where exposed cables enter the enclosure or box shall be sealed. A resilient sealing compound made expressly for the purpose shall be installed after the cables are in place.

N. Fiber optic patch cables between individual equipment shall be neatly arranged, bundled, and secured in a manner that will not compromise the minimum bending radius.

O. Cable installed in conduit, regardless of length, shall not exceed the maximum fill recommendations of the manufacturer and the requirements of the NEC and local codes. Where the aforementioned codes do not apply, the maximum fill shall not exceed 60 percent.

3.02 FIBER DISTRIBUTION PANEL (FDP)

A. The fiber optic cable shall be brought into a FSE at each node location.

B. The OSP cable shall be run from the FSE to the FDP located in each communications equipment room.

C. Within the FDP, each fiber that terminates at that node, shall be fusion spliced to a single mode fiber pigtail pre-wired to a multi-port connector module. The optical loss specifications of the fusion splice shall be identical to those described elsewhere in this Section.

D. Minimum of 13 feet of slack in each fiber pigtail shall be coiled within the FDP.

E. Minimum of 6.6 feet of slack for each strand of the through-splice shall be provided and protected in the appropriate splice trays within the FDP.

F. Fibers that do not terminate at a node shall be fusion spliced through to the outgoing cable.

3.03 FIBER SLACK ENCLOSURE (FSE)

A. Fiber slack enclosures shall be installed at communications equipment rooms and at other locations as shown on the Contract Drawings. Contractor shall submit to the Engineer for approval a detail drawing showing the exact mounting locations for fiber slack enclosures prior to commencement of cable installation.

B. 100 feet of cable slack shall be coiled in each FSE.

C. Fiber cable coiled in the FSE shall be coiled in a Figure-8 manner, and then folded over for placement in the FSE. The minimum bend radius of the cable shall not be exceeded at any time.

D. The cable shall be supported within the enclosure in a manner to minimize the stress to the cable.

E. The cable shall be secured in all FSEs to prevent the cable from spilling out of the enclosure when accessed via the front panel.

3.04 FIBER OPTIC SPLICING

A. Fiber optic splicing shall be performed in a clean dust-free environment.

B. All splices shall be tested for loss and reflection. Any splice that does not meet the performance specifications described herein shall be redone, at no additional cost to Authority.

C. All fiber optic splices shall use the fusion processes.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16701.001 - Fiber Optic Outside Plant shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16701.001 - Fiber Optic Outside Plant will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16702

COPPER OUTSIDE PLANT

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, material, tools, equipment, and incidentals necessary for the copper outside plant, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to the design coordination and implementation of the following activities:
   1. Contractor shall furnish all labor, material, equipment, supervision, transportation, and miscellaneous services, whether or not explicitly identified herein, to provide a completely tested and fully operational copper outside plant.
   2. Contractor's design shall provide outside plant copper communications wire and cables as shown on the Contract Drawings CM007, CM011 to CM013, Cable Routing (CR) Drawings, and as specified herein.
   3. The Work includes the installation of all necessary conduits to complete the copper cable installation to the trackside emergency telephones as shown in the Cable Routing (CR) Drawings.
   4. The Work also includes the furnishing and installation of all two (2) pair cables between the communications rooms and Remote Terminal Units (RTUs), patron emergency telephone sets and PAAC telephone sets as indicated on Contract Drawings CM011 through CM013, and as shown on the referenced drawings as indicated below;
      a. Gateway Station Finishes Construction Contract No. NSC-010
      b. North Side Station Finishes Construction Contract No. NSC-011
      c. Allegheny Station Finishes Construction Contract No. NSC-012
   5. The Work also includes the furnishing and installation of all RTU control and indication wiring and cabling.
   6. The Work also includes the installation of all pull boxes, splice enclosures, slack enclosures cable ladder and other miscellaneous hardware required to provide a functional, reliable and maintainable communications system.
   7. The Work also includes furnishing and installing two 18 pair 22AWG copper communications cables between the new communications room in the new Gateway Station and the end of the aerial track section. Both copper communications cables will also terminate in the new communications rooms at North Side Station and at Allegheny Station. The 18 pair copper cables shall terminate in each trackside emergency telephone set as shown on Contract Drawings CM038 to CM040 and the Cable Routing (CR) Drawings.
   8. Furnishing and installing the copper communications cable in tunnels and on aerial structures, conduit, pull boxes, splice enclosures, terminations and distribution frames, patch panels, connectors and other miscellaneous hardware

necessary to provide a reliable, maintainable communications system that meets the requirements of the Contract Documents.

C. The Contract Documents provide the performance parameters and design criteria to complete the copper outside plant. The Contractor shall be responsible to provide a complete design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16700, "Communications."

B. Section 16721, "Telephone System."

C. Section 16741, "Variable Message Sign/PA System."

D. Section 16742, "SCADA System."

E. Section 16901, "Communication System Inspection and Test."

1.03 REFERENCE STANDARDS

A. ASA Standard for Paint Colors.

B. Telcordia GR-136, "Generic Requirements for Distribution Frame Wire".

C. EIA Standard RS-359, "Standards Colors for Color Identification and Coding."

D. ICEA Standards S56-434 and S45-434.

E. Rural Utilities Service (RUS) Specification Standard 7 CFR 1755.390 (Formerly PE-39)

F. ASTM Standard B3.

G. NFPA Standard 130, "Standard for Fixed Guideway Transit Systems".

H. ANSI/ICEA Standard S-80-576.

I. ANSI/ICEA Standard S-85-625-1996

J. UL-497

1.04 SUBMITTALS

A. System Design to include the following in addition to the requirements stated in Section 16700, "Communications."
   1. Application of all suggested cables runs, whether for voice or data.

B. Product Data, Shop Drawings and specifications.

C. Functional Site Block Diagram.

D. Arrangement Plan.

E. Cable manufacturer qualifications and cable installer qualifications as specified within this Section.

F. Installation Plan containing detailed installation plans, prior to commencement of any such work, for approval by the Engineer. Plan shall include installation details of copper cable and termination/splicing equipment, including conduit plans, location of all splices, and identification of all underground utilities. Proposed length of ducts and conduits shall be stated.

G. Copper Outside Plant Wiring Plan detailing all wiring and connections to include the following in addition to the requirements stated in Section 16700, "Communications."
   1. Wiring diagrams of distribution frames, equipment racks, and the copper outside plant cable.
   2. List of proposed runs of outside plant copper communications cable.

1.05 DELIVERY, STORAGE AND HANDLING

A. All cable shall be shipped on reels and adequately protected from damage in shipment. Contractor shall be responsible for correction of any defect in the cable occurring in transit.

B. Each length of cable shall be wound on a separate reel. Reels shall be designed and constructed to withstand handling and shall be so designed that both ends of the cable will be secured and accessible but protected from injury. If the inner end of the cable projects through the flange of the reel, the inner end shall be protected by a suitable cover of metal having rounded ends and sides and securely fastened in place to protect cable end. Both ends of cable on the reel shall be secured in place to prevent their becoming loose in transit or handling of the reel.

C. The radius of the reel drum shall be larger than the minimum dynamic bending radius of the cable to prevent damage to the cable during reeling. The arbor hole shall admit a spindle 2.5 inch in diameter without binding. The reels shall be designated and constructed as non-returnable when drum size and cable weight and volume permit.

D. After acceptance of factory tests, the cable shall be effectively sealed against the entrance of moisture. Both ends of each length of cable shall be protected by suitable means approved by the Engineer. The use of friction tape, other than as an external mechanical protection over an adequate rubber and/or plastic tape, shall not be accepted. The cable end protection shall be adequate to protect the cable in shipment and prolonged external storage in the weather, without regard to the position of the reel while so stored.

E. Each layer of cable on the reel shall be closely and tightly wound in a uniform manner.

F. An arrow shall be painted on one head of each reel pointing the opposite direction from the outer end of the cable with the words "Roll This Way." The words "Roll This Way" shall not be less than 0.75 inch in height and the arrow shall not be less than 6 inch in length and 0.5 inch in width.

G. Each reel of cable shall be identified with a unique number that can be used to trace relevant information about the cable, such as manufacturer's batch, date of manufacture, and factory location where manufactured. This cable reel identifier shall be referred to in the attenuation report provided with each reel of cable.

1.06 QUALITY ASSURANCE

A. Control Testing: The following control tests shall be performed during manufacture.
   1. Voltage and insulation resistance tests on cables in accordance with ICEA S-95-658, modified as follows:
      a. Test potentials for both AC and DC as specified herein.
      b. All immersion tests after 24 hours minimum immersion.
      c. Individual conductors of multiple conductor cables tested before assembly as specified for single conductor cables.
   2. Shield isolation test on all combinations of pairs and over-all shield. After one minute at 500 volts, minimum resistance shall be 0.1 megohms per 1 foot.
   3. Conductor resistance test on all cables in accordance with ICEA S-95-658.
   4. Physical characteristic tests on at least one sample from each type and size of cable in accordance with ICEA S-95-658.

B. AC voltage withstand test on each shipping reel of finished cable at the test insulation voltage for 1 minute prior to shipment.

1.07 QUALIFICATIONS

A. Manufacturer Qualifications: Manufacturer shall have 15 years of documented experience in supplying cable to the telecommunications and rail transit industry for use in installations similar to those required by this Contract. A certification letter shall be submitted by the Contractor.

B. The Manufacturer shall be submitted for approval of the Engineer.

C. All entities participating in the installation of all communication cable, whether Contractor, Subcontractor, or a combination, shall have a minimum of five years experience in the installation of communication cable and appurtenances and shall have installed a minimum of five copper outside cable plants comparable in size to the plant specified herein. Each of these plants shall have been in service and operating satisfactorily for a minimum of 12 months. Contractor shall provide a list of these systems to the Engineer. The list shall include names, addresses, and telephone numbers of operating personnel who may be contacted and who are responsible for the maintenance of the system. Demonstration of the plants shall be arranged upon request.

D. The proposed installer shall be submitted to the Engineer for approval.

1.08 EXISTING CONDITIONS

A. Gateway Station is being replaced. A new communications equipment room serving the new Gateway Station will be built which will require new copper cabling to serve the new station. The existing communications room will remain in service to serve existing equipment not removed as part of the station replacement.

1.09 PROVISIONING

A. Contractor shall determine cable and conduit lengths, and the quantity of Main Distribution Frame (MDF) terminal blocks, and pull boxes, and other hardware based upon information shown on the contract drawings. Actual quantities to be installed depend upon contractor's design, and may therefore vary from the quantities shown on the Contract Drawings.

ARTICLE 2 PRODUCTS

2.01 WIRE AND CABLE

A. Outside plant communications cables shall be Low Smoke, Zero Halogen (LSZH) and conform to the latest requirements of ICEA S56-434.
   1. Outside plant cables shall be 18 pair.
   2. The conductors shall be No. 22 AWG and meet the following requirments:
      a. Resistance – 85.5 ohms/wire mile, nominal
      b. Resistance – 171 ohms/loop mile, nominal
      c. Insulation Resistance – 10,000 Megohm, minimum
      d. Dielectric Strength – 3,600 Volts DC between conductors, 10,000 Volts DC between conductor and shield.
      e. Attenuation – 1.79 dB/mile at 1000 Hz
      f. Average Mutual Capacitance - .083 mf/mile
      g. Capacitive unbalance 25 pf/1000 ft.
   3. Conductors shall be individually insulated with a color coded thermoplastic insulation. The conductor insulation color shall be in accordance with ICEA S56-434 and shall comply with the requirements of EIA Standards RS-359.
   4. The insulated conductors shall be twisted into pairs with varying lay lengths to minimize crosstalk and provide low susceptibility to noise pick-up. The length of pair twists shall be designed to meet ICEA S45-434.
   5. A non-hydroscopic core tape is applied over the cable core as a dielectric and heat barrier.
   6. Extended thermoplastic rubber type filling compound shall be applied to the cable core in such a way as to provide as near to 100 percent fill of the available air

space within the core as is commercially practicable. The filling compound shall be applied in a manner to fill all voids and conductor interstices between pairs and under the core tape to restrict the migration of moisture. The filling compound shall be compatible with the insulation and other cable compounds.

7. The filled core shall be completely covered with a layer of non-hydroscopic, non-wicking dielectric tape applied longitudinally with overlap over the cable core to ensure high dielectric strength from cable core to shield.
8. A 0.005 inch thick coated copper shield shall be applied over the core. The tape shall be applied longitudinally with overlap.
9. The space between the core tape and the shield, including its overlap, and between shield and jacket shall be filled with a flooding compound designed to prevent moisture and/or water entry and migration.
10. The outer jacket shall be resistant to abrasion, moisture, weather and environmental cracking and meet the requirements of ICEA S73-532. The overall jacket shall be sequentially marked at 2 feet intervals with cable type, year of manufacture, footage, pair count, conductor size, and manufacturer. The jacket shall be free from holes, splits, blisters, or other imperfections and shall be smooth and concentric.
11. All copper outside plant communications cable used in tunnels or below ground areas shall conform to NFPA Standard 130.

B. Station Telephone Cable
1. UL Listed Type MPR/CMR, conforming to ANSI/ICEA S-80-576.
2. Conductors shall be solid tinned annealed copper.
3. Insulation shall have color code that complies with the requirements of EIA RS-359.
4. Minimum specifications:
   a. Conductor gauge: 24 AWG.
   b. Shield: foil around each pair with drain wire.
   c. Capacitance: 22 pF per ft.
   d. Resistance: 45 ohms per 1000 ft.
   e. Insulation: plenum rated, low flame, no smoke.
   f. Jacket: plenum rated, low flame, no smoke.
   g. Pairing: two twists per foot.
   h. Temperature rating: 220 degrees F.
   i. Voltage rating: 300 volts.

C. Low Level Cable
1. 1 Twisted pair.
2. Minimum specifications.
   a. Conductor gauge: 20 AWG.
   b. Shield: aluminum polyester, tinned copper drain wire.
   c. Insulation: plenum rated, low flame, no smoke.
   d. Jacket: plenum rated, low flame, no smoke.
   e. Temperature rating: 220 degrees F.
   f. Voltage rating: 300 volts.

D. Cross Connect Wire
   1. Suitable for voice and high speed data communications up to 16 Mbps.
   2. UL Listed and conform to Telcordia GR-136, "Generic Requirements for Distribution Frame Wire.
   3. Minimum Specifications:
      a. Conductor gauge: 24 AWG.
      b. Maximum resistance: 29 ohms per 1000 ft
      c. Insulation: Plenum rated, low flame spread, no smoke.
      d. Maximum capacitance: 0.15 mF per 1000 ft

2.02 COPPER DISTRIBUTION FRAMES/FIELDS

A. Main Distribution Frame (MDF)
   1. The MDF shall be rack mounted, or mounted in a terminal cabinet, located in the communications equipment rooms.
   2. The MDF shall contain cross-connect blocks, cable trays, ground bus, wiring, and connections.
   3. The MDF shall serve as the termination point, inside the communications equipment room, of all copper outside plant connections.
   4. The MDF shall also serve as a connection point between elements within the communications equipment room, connected by a copper wire. Such connections include, but are not limited to:
      a. Connection between channel banks and RTU.
      b. Connection between channel banks and VMS/PA controller.
      c. Connection between channel banks and telephones.
      d. Connections between the RTU and contact closures for local alarms.
      e. Connection between RTU and PA System speaker line monitoring circuit.
      f. Connections between channel banks and PA pre-amplifier.
   5. Proposed use of any existing distribution frame, cable protection, and grounding shall be part of the Copper Cable Report to be submitted to the Engineer for approval. Copper Cable Report shall include the condition of any distribution frame, cable protection, and grounding to be used, which shall include MDF equipment at Gateway Station and the OCC.

B. Protection Blocks
   1. Contractor shall provide protection blocks for termination of copper outside communications cable. Protection blocks shall protect personnel and equipment from abnormal voltages and currents on incoming cable pairs.
   2. Protection blocks shall be designed to mount on conventional central office distribution frames.
   3. Protection blocks shall be equipped with a 22 AWG cable stub of minimum length of 20 feet.
   4. Protection blocks shall be equipped with a ground conductor.
   5. Protection blocks shall be capable of terminating a minimum of 25 cable pairs.
   6. Protection blocks shall be equipped with standard test fields that require no special test gear.

7. Protection blocks shall be equipped with protector modules. Protector modules shall be telephone industry standard 5 pin plug-in footprint and meet the requirements of this Specification as listed below.

C. Cross Connect Blocks
   1. Contractor shall provide cross connect blocks that provide quick, simple installation, and easy access for maintenance.
   2. Cross connect blocks shall be equipped with connectors to accept inside communications cable connector. Cross connect side of cross connect blocks shall accept 20-26 AWG insulated conductors and 18-19 AWG skinned conductors.
   3. Cross connect block shall be equipped with a fanning strip on cross reconnect side to organize jumpers.
   4. Cross connect blocks shall be UL listed.

2.03 SPLICE CLOSURES

A. Where copper outside plant cables are spliced to a cable stub on the protection block, the splice shall be contained in a splice closure.

B. Splice closures shall meet the following requirements:
   1. Non-metallic, re-enterable type.
   2. Splice closures shall be moisture and chemical resistant and fire retardant.
   3. Splice closures shall be sized to accommodate the required number of copper splice connectors. Sizing shall be shown in wiring diagrams to be submitted to the Engineer.

2.04 SPLICE CONNECTORS

A. Contractor shall provide copper splice connectors for splicing copper cables. Connectors shall meet the following requirements:
   1. Capable of joining insulated conductors in 17 through 26 AWG, without stripping the insulation.
   2. Encapsulated to prevent the ingress of moisture.
   3. Capable of providing splice, bridge, and half-tap options, in either foldback or in-line configurations.

B. The splice connector shall meet the following additional requirements:
   1. Dielectric Strength 3.0 KVAC
   2. Contact Resistance 1 in 10,000 failures at .001 ohm
   3. Temperature -40 to +65 degrees C (-40 to 150 degrees F)
   4. Humidity 10 to 90% relative
   5. Insulation Resistance > 20 x 10^9 ohms at 1000 VDC

C. Contractor shall provide all necessary tools and appurtenances to properly splice or terminate all telephone cables furnished as part of the Work.

D. The splice connector provided shall be used in the splice closure, specified elsewhere.

2.05 PROTECTOR MODULES

A. All outside cable plant cable pairs shall be terminated in protection blocks equipped with protection modules. All cable pairs shall be protected, whether active or inactive.

B. Protector modules shall be telephone industry standard 5-pin plug-in footprint protector modules for primary protection.

C. Cable pairs to be cross connected to digital electronic equipment shall be protected by solid state protector modules. Nominal breakdown voltage shall be 300 VDC.

D. All other cable pairs shall be protected by 3 element gas tube protector modules. Nominal breakdown voltage shall be 300 VDC.

E. The DC holdover of the protector module shall be in excess of 150 volts.

F. Protector modules shall provide current protection via heat coils and sneak fuses.

G. Protector modules shall be UL Listed.

2.06 TERMINAL CABINETS

A. Contractor shall provide a terminal cabinet for all outside plant cable termination locations where a rack-mounted termination is not available.

B. Furnished with a 3/4inch thick marine plywood back panel, all wood surfaces painted with two coats of ASA 161 gray paint before mounting.

C. Constructed of industrial grade fiberglass with a hinged door or cover.

D. Sized to accommodate the required number of copper pairs to be terminated. Sizes and locations of terminal cabinets shall be included in wiring diagrams to be submitted to the Engineer for approval.

E. Provided with the required termination and protection blocks per location. Termination and protection blocks shall be included in wiring diagrams to be submitted to the Engineer for approval.

2.07 LUBRICANT

A. Temperature use range: -20°F to 110°F.

B. Cable compatibility: No deleterious effects on physical or electrical properties of cable jackets.

C. Toxicity: No-toxic and non-sensitizing.

D. Flammability: Lubricant has no flash point and dried residue is non-flammable.

E. Cleanup: Complete cleanup possible with water.

F. Lubricant such as Polywater® Lubricant WF manufactured by American Polywater Corporation or approved equal.

2.08 CABLE IDENTIFICATION LABELS

A. Permanently attached to cable. Resistant to oil, water and solvents.

B. Minimum letter height 0.12 in.

C. Label shall identify all cables with a tag showing "To" and "From" information, which correlates with the cable identification shown on Wiring Plans.

D. Cable Identification Labels such as Brady Worldwide, Inc. self laminating vinyl or approved equal.

ARTICLE 3 EXECUTION

3.01 GENERAL COPPER COMMUNICATIONS CABLE INSTALLATION

A. The installation of the copper cable shall be conducted in a proper manner. Contractor shall make every effort to protect the cable during construction and installation, including protection from vandalism.

B. Contractor shall perform a pre-installation survey of the entire copper outside plant route as part of the Site Inspection. Site Inspection shall include inspection of relevant ducts, ductbanks, conduits, cable trays, and cable troughs as well as entrances to the communications equipment rooms.

C. The installation plan shall indicate areas where conduit, if required, is to be installed directly to the walls of tunnels. The proposed method of attaching the conduit to the wall of the tunnel shall be detailed in the plan.

D. Contractor shall perform the cable installation in accordance with the approved plan. Any deviations from the approved plan must be submitted in writing to the Engineer for approval.

E. Contractor shall verify conduit and ducts are free of obstructions by pulling a suitable wire brush, swab, and mandrel through the conduit or duct to remove extraneous matter.

F. Contractor shall ensure that the conduit or duct is dry before installation of cable and use lubricant approved by cable manufacturer to facilitate pulling cable.

G. Maximum cable lengths and pulling tensions shall be determined to avoid excessive pulling tensions or more bends than manufacturer's recommendations.

H. All cables shall be grounded ONLY ONCE on the inbound termination end of the cable. The outbound end shall be left ungrounded. All cable splice and/or drop points shall extend the ground through to the inbound end. Grounding shall be shown on installation plans to be submitted to the Engineer for approval.

I. Contractor shall terminate all outside plant cable connections, between two locations, on protection blocks equipped with protection modules, as specified herein, at each location. This shall include, but not be limited to, all copper cable installed between the communications equipment room and any of the following:
1. Trackside Emergency Telephones
2. Traction power substation
3. Traction power tie-breaker station
4. Signal/Relay Room

3.02 DISTRIBUTION FRAMES

A. The distribution frames shall be rack-mounted or mounted in a terminal cabinet at each communications room.

B. Contractor shall make cross-connections only from the cross-connect side of each cross connect block.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16702.001 - Copper Outside Plant shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16702.001 - Copper Outside Plant will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16703

CARRIER TRANSMISSION SYSTEM (CTS)

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the carrier transmission system (CTS), in accordance with the contract documents.

B. The work of this Section includes, but is not limited to, the design coordination and implementation of the following activities:
   1. The installation of new CTS equipment in the equipment rooms at the three NSC stations, Pitt Tower, and at the OCC.
   2. The CTS upgrade shall consist of creating a new NSC SONET Ring to support OCC communications to the new NSC stations.
   3. Modifications to the CTS in the existing Gateway Station to ensure continued service to any equipment that is to remain in that location.
   4. Coordination with PAAC personnel for the testing and commissioning of the new CTS equipment.

1.02 RELATED SECTIONS

A. Section 01300, "Submittals."

B. Section 01840, "Interfaces."

C. Section 16901, "Communication System Inspection and Test."

1.03 REFERENCE STANDARDS

A. Telcordia Technologies
   1. TR-NWT-000170, "Digital Cross-Connect System (DSC 1/0) Generic Criteria."
   2. GR-436, "Digital Network Synchronization Network Plan."
   3. GR-253, "SONET Transport System: Common Generic Criteria."
   4. GR-63, "Network Equipment Building System (NEBS) Requirements: Physical Protection."
   5. TR-TSY-000009, "Asynchronous Digital Multiplexers, Requirements and Objectives."
   6. GR-20, "Generic Requirement for Optical Fiber and Optical Fiber Cables."
   7. TR-NWT-000179, "Quality System Generic Requirements for Software."
   8. TR-NWT-000233, "Wideband and Broadband Digital Cross-Connect Systems Generic Criteria."

9. GR-496, "SONET Add-Drop Multiplexer (SONET ADM); Generic Criteria for a Unidirectional, Path Protection Switched, Self Healing Ring Implementation."
10. GR-499, "Transport Systems Generic Requirements (TSGR): Common Requirements."
11. GR-1400, "SONET Dual-Fed Unidirectional Path-Switched Ring (UPSR) Equipment Generic Criteria."
12. GR-1230, "SONET Bi-Directional Line-Switched Ring Equipment Generic Criteria."
13. SR-NWT-002723, "Applicable TL1 Messages for SONET Network Elements."

B. ANSI/EIA/TIA Specifications:
1. T1.102, "North American Electrical Digital Hierarchy."
2. T1.105, "Synchronous Optical Networks (SONET) Phase 1 and Phase 2 Standards."
3. T1.106, "Digital Hierarchy Optical Interface, Single Mode."
4. T1.403, "Telecommunications Carrier to Customer Installation - DS-1 Metallic Interface."
5. ANSI/EIA-472, "Series Specifications for Fiber Optic Systems."
6. EIA/TIA-250, "Electrical Performance for Television Transmission Systems."
7. EIA/TIA-232, "Interface between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange."
8. EIA/TIA-422, "Electrical Characteristics of Balanced Voltage Digital Interface Circuits."
9. EIA-485, "Standard for Electrical Characteristics of Generators and Receivers for use in Balanced Digital Multi-point Systems."

C. Code of Federal Regulations, Title 47.

D. NFPA Standard 130, "Standard for Fixed Guideway Transit Systems".

1.04 SUBMITTALS

A. System Design.

B. Product Data Sheets, Shop Drawings and specifications.

C. Functional Site Block Diagram.

D. Arrangement Plan showing equipment layouts of all nodes.

E. Installation Plan.

F. Wiring Plan.

G. Power Wiring Plan.

H. Software and Firmware Plan.

I. Allocation and Provisioning Plan.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Contractor shall ensure that equipment has not been damaged during shipping or storage. Equipment shall be shipped separately from the equipment racks in which they are to be installed. Equipment shall remain in the original packaging until the time of installation. All equipment shall be stored in a protected area until installed.

1.06 DESCRIPTION OF WORK

A. This Section presents an outline of the communications work to be performed under this Contract. It does not supersede requirements detailed elsewhere. Contractor is responsible for complying with the Contract Documents in their entirety.

B. Contractor shall furnish all labor, material, equipment, supervision, transportation, and miscellaneous services, whether or not explicitly identified herein, to provide a completely tested and fully functional carrier transmission system.

C. Contractor shall sequence installation of all cable, CTS equipment and other system elements to minimize disruption of existing communications system.

D. The Work includes the installation of CTS equipment in the new Gateway Station, North Side Station, Allegheny Station, Pitt Tower, and the OCC to support the new NSC SONET Ring. The CTS includes, but is not limited to, the following equipment:
1. SONET Transmission/Multiplexer equipment.
2. Ethernet Switches
3. Channel Banks
4. DACS (OCC)
5. DSX Panel
6. Ancillary equipment such as racks, cabinets, mounting hardware, connector blocks, and cabling.

E. The Work also includes the installation of equipment in a new communications room to be built as part of the Gateway Station relocation. CTS equipment in the existing Gateway communications room will remain intact for use with the existing equipment that is to remain in service during and after the station relocation.

F. The Work also includes the installation of a new head-end SONET multiplexer at the OCC to support the creation of the new and separate NSC SONET Ring.

1.07 QUALITY ASSURANCE

A. Proposed Manufacturer(s) shall be submitted to the Engineer for approval. Contractor shall certify that the proposed Manufacturer complies completely with all the requirements of this Contract.

B. Contractor shall provide a list of existing installations and a list of product specifications for the Engineer's evaluation. The proposed Manufacturer shall have, as a minimum, five years experience in the successful manufacturing and installation of fiber optic and SONET communications systems and shall have manufactured a minimum of five systems of size and complexity comparable to the system specified herein. Each system shall have been on-line and operating satisfactorily for a minimum of 12 months.

C. The Manufacturer shall provide the names, addresses, and telephone numbers of operating personnel who can be contacted regarding the systems. Contractor shall make all of the necessary arrangements for any required demonstrations and tests.

1.08 CTS COMMUNICATIONS FUNCTIONS

A. The new SONET Ring shall provide communications for all Light Rail Transit (LRT) operating systems including voice, data, and control circuits. These operating systems are described below:
   1. Radio Communications System: Includes the channels between the OCC and radio base stations.
   2. Passenger Station PA (Public Address): Includes channels for making live audio announcements at each NSC station from the OCC and Pitt Tower.
   3. Passenger Station VMS/PA: Includes channels for downloading pre-recorded audio/visual messages to each passenger station platform from the OCC and Pitt Tower.
   4. Traction Power: Known as SACS (Substation Alarm and Control System), includes communications channels between the substations and the OCC.
   5. Tunnel Ventilation: Known as RICS (Remote Indication and Control System), includes the channels for alarm indications and ventilation controls between the underground portions of the LRT and the OCC.
   6. TWC (Train To Wayside Communications): Includes the channels for communication of train ID and route between wayside locations and the OCC.
   7. Signal System: Includes the channels for switch and signal controls and indications, between wayside locations and the OCC.

B. Network Management System: The upgraded CTS shall include a Network Management System, located at the OCC, for monitoring the performance of, the configuration of, and controlling the elements of the new SONET nodes and T1 Multiplexers on the CTS system.

   The Network Management System shall also detect and alarm a switchover to the secondary SONET path due to SONET equipment failure or fiber disruption. The NMS shall indicate this fiber rerouting to the radio system at the OCC to permit the radio system to compensate for different fiber optic transmission delay times to the simulcast transmitters at Allegheny Station.

1.09 SYSTEM REQUIREMENTS

A. The Carrier Transmission System shall be comprised of the following component systems:
   1. Fiber Optic Cable Plant: A 96 strand, single mode, fiber cable shall be installed as specified in Section 16701. The fiber cable shall be used to transport the optical signals used for the NSC Synchronous Optical Network (SONET) ring.
   2. SONET Ring: Contractor shall install SONET multiplexers at the Gateway, North Shore, and Allegheny stations as shown on the Contract Drawings.
   3. SONET Node (NSC station sites): Each station node on the SONET ring shall consist of a SONET multiplexer, Ethernet switches, digital signal cross connect (DSX) panels, and T1 multiplexers (digital channel banks), as shown on the System Schematic Plans, in Contract Drawings CM011 through CM013.
   4. SONET Node (Pitt Tower): Pitt Tower node shall consist of a SONET multiplexer, Ethernet switch, digital signal cross connect (DSX) panel, and a T1 multiplexer.
   5. SONET Node (OCC): OCC node shall consist of a head-end SONET multiplexer, Ethernet switches, T1 multiplexers, a DSX panel, and a DACS (Digital Access and Cross-Connect System). The DS-1 circuits from the DACS shall be connected to a DSX panel, and connected in turn to T1 multiplexers located in the OCC Computer Equipment Room.
   6. Network Management System (NMS): Contractor shall provide Ethernet interfaces at each node to permit the NMS located at the OCC to manage, provision, and view the current status of each element of the SONET multiplexer, the DACS, and the T1 multiplexers at each NSC station and Pitt Tower node.
   7. Equipment Racks and Cabinets: Refer to Section 16700, "Communications."

B. Contractor shall provide a new CTS that meets, at a minimum, the following requirements:
   1. Physical Topology
      a. Contractor shall provide fiber distribution panels, splice trays, fiber jumpers as needed to install the 96-count fiber cable at each NSC communications equipment room, as shown on the Contract Drawings and specified in Section 16701, "Fiber Optic Outside Plant."
      b. Contractor shall provide DSX patch panels as shown on the Contract Drawings. The panels shall allow maintenance personnel access to the DS-1 signals in order to facilitate testing and trouble-shooting.
      c. Contractor shall provide CTS nodes equipped sufficient T1 multiplexers and DS0 interface cards to service all channel requirements indicated on the Contract Drawings. Each CTS node shall also include 10% equipped spares for each type of DS0 card provided and a minimum of 30% spare channel capacity without the addition of new T1 multiplexers.
   2. Logical Topology.
      a. The SONET ring shall have a minimum bandwidth capacity of OC-12 (622 Mbps) and be upgradable to OC-48 (2.488 Gbps) by simply replacing the optic modules on the multiplexers.
      b. The SONET ring shall utilize an operational wavelength of 1310nm.
      c. The network shall be a SONET self-healing ring, employing a dual-fed

unidirectional path switched ring (UPSR) architecture as defined in Telcordia GR-1400. The UPSR architecture shall have a staggered configuration, as shown on Contract Drawings CM004 and CM007. The SONET ring shall be "self-healing" such that in the event there is a failure in the working ring, the system will automatically, within 60 milliseconds, switch transmission to the backup ring.

d. Each SONET multiplexer shall be capable of provisioning a minimum of 28 individual DS-1 (digital signal – level 1 at 1.544 Mbps) circuits.
e. Each SONET multiplexer shall be equipped with an integral 8-port Ethernet 10/100 mbps switch. The amount of bandwidth allocated to each Ethernet circuit shall be configurable in a range of 1 to 7 DS-1 circuits (1.544 to 10.808 Mbps).
f. The equipment at each node shall be capable of providing low speed interfaces down to the DS-0 level. This shall be achieved by using the combination of SONET multiplexer and T1 multiplexers.
g. A list of the type of DS-0 circuits, required at the NSC communications equipment rooms located on the SONET ring, is shown in Section 1.10, (Provisioning) of this Specification. The detailed distribution of each DS-1 circuit and channel assignments of each DS-0 circuit shall be created by Contractor from information on the Contract Drawings. Final Channel Allocation Tables including spare interface cards shall be submitted by Contractor to the Engineer for approval as part of the System Design.
h. DS-0 channels shall be grouped together to facilitate connection to the OCC Computer System. The DACS shall also be capable of recombining DS-0 circuits back into DS-1 (1/0/1 DACS) to simplify connection to other devices.

C. CTS shall conform to the following:
   1. ANSI T1.105, "Synchronous Optical Networks (SONET) Phase 1 and Phase 2 Standards."
   2. ANSI T1.102, "North American Electrical Digital Hierarchy."
   3. Telcordia GR-253, "Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria."
   4. Telcordia GR-496, "SONET Add-Drop Multiplexer (SONET ADM) Generic Criteria."
   5. Telcordia GR-1400, "SONET Dual-Fed Unidirectional Path-Switched Ring (UPSR) Equipment Generic Criteria."

1.10 PROVISIONING

A. Contractor shall develop Channel Allocation Tables for each of the three new NSC stations based upon the Contract Drawings and Communications Subsystem Specifications. Each set of Channel Allocation Tables shall include all active and equipped spare circuits for each type of communications circuit listed below.

B. The CTS system shall provide end-to-end communications between the NSC nodes and the OCC Central Equipment Room for the following communications circuits as a minimum:

1. VMS/PA, via Station Ethernet 10 mbps LAN and 4-Wire E&M
2. Public Address Live Audio from OCC to Station via 4-Wire E&M
3. WQED Audio from Pitt Tower to NSC Stations via 4-Wire E&M
4. Radio System Audio via 4-Wire E&M
5. Signal System Vital Processors via 4-Wire E&M
6. Substation RTUs via 4-Wire E&M
7. Fan Control PLCs via 4-Wire E&M
8. NMS to Station T1 Multiplexers via 10 mbps LAN
9. Future Ticket Vending Machine via Station Ethernet 10 mbps LAN

ARTICLE 2 PRODUCTS

2.01 SONET MULTIPLEXER

A. General

1. The NSC SONET Ring shall be configured with a head-end Add-Drop Multiplexer at the OCC and four remote Add-Drop Multiplexers at the NSC stations and Pitt Tower as indicated on Contract Drawing CM004. The following description applys to both types of SONET multiplexers with the exception of maximum expansion capabilities.

B. Add-Drop Multiplexer

1. Each SONET multiplexer shall be initially configured as an OC-12 Add-Drop Multiplexer (ADM) with the remote upgradable to OC-48 and the head-end upgradable to OC-192.
2. The ADM physical design shall feature ease of configuration with one or more shelves or racks containing removable modules. The ADM shall be capable of implementing various custom SONET configurations depending on the deployment of the various modules and software. Modules shall be easily combined and interchanged across shelf slots allowing for the custom configurations. Modules shall be readily replaced in the field.
3. The ADM shall support scaleable bandwidth migration, in order to provide increased capacity in the future, by replacing optic modules in the ADM.
4. The ADM shall support Time Slot Assignment (TSA), Time Slot Interchange (TSI), hairpining, drop and continue, and one- or two-way traffic routing.
5. The ADM shall support multi-vendor interoperability through the use of standardized interfaces.

C. Multiplexer Inputs

1. Each ADM shall be capable of terminating up to the full compliment of 28 DS-1 signals. Each multiplexer shall have flexible bandwidth management with the capability to accommodate a mixture of input signals to be multiplexed in combination, up to system capacity.
2. Each SONET OC-12 ADM furnished under this Contract shall be configured into a network of two-fiber UPSR (Unidirectional Path Switched Rings). Input to the multiplexer, as a minimum, shall be DS-1 signal format from the T1 multiplexers

(digital channel banks) as shown on the Contract Drawings. All components shall be expandable to provide full functionality over and above the requirements specified herein.

3. The OC-12 optical interfaces, in each ADM, shall permit operation at distances up to 25 miles in ring applications. This means that the distance between SONET nodes can reach up to 25 miles.
4. Each ADM shall implement a flexible TSA/TSI capability that maximizes the flexibility with which payload signals can be added or dropped.

D. Multiplexer High Speed Specifications

1. The optical line rate of the OC-12 ADM shall be 155.52 Mbps. The ADM shall be capable of being upgraded to OC-48 (2.488 Gbps) with the replacement of the optic modules.
2. The optical transmitters and receivers, on each ADM, shall be solid-state lasers. Optical receivers shall be Avalanche Photo Diodes (APD) or other Engineer approved photodiode.
3. The optical wavelength of transmitters and receivers shall be 1310 nm.
4. Optical gain of the system shall be 23 dB, nominal, to adequately support the optical losses in the network as determined by Contractor as per Specification Section 16701, "Fiber Optic Outside Plant". Contractor shall be responsible for system gain adjustment, including the selection of appropriately powered transmitters and receivers and the addition of optical attenuators, if required.
5. High speed automatic protection switching shall protect high speed optical operation against failure and shall provide full system redundancy through the redirection of traffic flow into the ring configuration in the event of the failure of the fiber optic cable, a transmitter, a receiver, or a multiplexer.
   a. Failure shall be defined as the complete loss of system operation or a receiver Bit Error Rate (BER) in excess of a user defined threshold (10^{-9} typical or better).
6. All common units, cards or components (power supplies, clock units, time slot interchange, microprocessors, etc.) that can cause failure of the high speed multiplexer or line operation by their failure shall be redundant and fully protected in a one-to-one (1:1) manner.

E. Multiplexer Low Speed Specifications

1. The line rate of the DS-1 interfaces shall be 1.544 Mbps as specified in ANSI T1.106.
2. Low speed equipped cards shall accept a minimum of 12 DS-1s each. Each multiplexer shall be equipped with the quantity of low speed cards required to meet the drop-and-insert requirements at each location as shown on the Channel Allocation Tables in the Contract Drawings and as detailed within the Functional Requirements section of this Specification. Each multiplexer shall be equipped with the necessary 30 percent equipped spare capacity and software capacity to accommodate low speed circuits to be added in the future on an in-service basis, up to the full complement of system capacity.
3. Automatic protection switching shall be provided in the following manner

(minimally):

a. DS-1 systems shall be protected at one to seven (1:7).

b. Protection switching shall be <60ms.

4. DS-1 signal outputs shall meet ANSI/EIA Standard T1.102 cross-connect specifications, and shall offer a switch selectable line code of AMI (Alternating Mark Inversion) or B8ZS (Bipolar Eight Zero Substitution).

F. Multiplexer Drop-and-Continue Capability

1. Each ADM shall be capable of performing add-drop of up to 14 DS-1s through the addition of appropriate printed circuit cards only.
2. A TSI shall be provided so that the ADM can add/drop any DS-1 (Virtual Tributary VT1.5) in the entire OC-12 payload. The TSI must be able to add/drop a single DS-1 without having to add/drop the entire VT group of 14 DS-1s. The ADM shall pass on, and not process, any traffic (DS-1s) that is not dropped at a node. This is sometimes referred to as "drop-and-continue".
3. Each ADM shall be equipped with a 8-port 10/100Base-T Ethernet switch. Each ADM shall be capable of provisioning access to a 10/100Base-T Ethernet circuit by combining a series of 1 to 7 VT1.5s. Ethernet capability shall be provided through the addition of dedicated hardware modules to any combination of nodes on the SONET ring. Ethernet capability at a node shall support both peer-to-peer, and client-server network environments.

G. System Timing and Synchronization

1. Each multiplexer shall be capable of at least two sources of timing:
   a. Internal Clock – The ADM internally generated clock from an integrated Stratum 3 clock with an accuracy of 4.6 ppm or better.
   b. External Clock - Internally synchronized to an external DS-1 signal.
2. System clocking and timing shall normally be derived from the incoming optical line signals. All remotely located multiplexers shall be timed from the timing reference, the DACS or SONET multiplexer, at the head-end node in the OCC. Each multiplexer shall have its own internal clock source take over timing in the event of a timing reference failure, and each shall be capable of acting as the timing reference for downstream units in the event of loss of primary clocking.
3. Each multiplexer shall feature synchronization status messaging.

H. Multiplexer Alarms

1. Each multiplexer shall be equipped with a front panel display for indicating the operational status of the multiplexer. The alarms displayed shall indicate overall system status and any specific failure. In lieu of a full function display on the unit, a Craft Interface Device (CID), such as a hand held RS-232 terminal, may be substituted in quantities as determined by the Engineer.
2. Individual modules shall have face plate LEDs to indicate alarm or failure condition.
3. Alarms minimally indicated by the multiplexer on the display (without the CID) shall be:
   a. Major Alarm - Service or non-service affecting, such as one or more circuits

(STS-1, DS-1) out of service.

b. Minor Alarm - Service or non-service affecting, such as loss of power.

4. Major and minor alarm relay contacts shall be provided to allow for activation of external local office alarms.
5. The SONET multiplexers shall provide a set of discrete contact closure outputs for indication of alarms. The head-end SONET multiplexer, located in the communications equipment at the OCC Facility, shall indicate major and minor alarms that may occur throughout the entire SONET ring. Contractor shall provide and install an RTU in the communications equipment room at each NSC site. The discrete contact closure outputs shall be connected to a discrete input module on the RTU. The RTU shall be part of the SCADA System, as described in Section 16742, "SCADA System," and shall serve as a means of communicating SONET alarms to the existing OCC Computer System.

I. Construction

1. Each ADM shall be suitable for mounting within a standard equipment rack as specified in Section 16700, "Communications."
2. Each ADM shall consist of one or more shelves containing removable modules.
3. Dust covers shall be placed over all unused slots in the shelf.
4. Modules of unlike function shall be mechanically keyed to prevent insertion into the wrong slot or connector.
5. All modules and assemblies shall be clearly marked with name, model number, serial number, and any other appropriate information required to facilitate equipment maintenance.
6. All external connections shall be made by means of connectors attached to a wiring harness or cable. The connectors shall be keyed to preclude improper hookups. All wires to and from the connectors shall be clearly identified through the use of appropriate markings or color-coding.
7. All necessary connectors, cables, cable harnesses, and accessories shall be provided and installed with the equipment.

J. Environmental

1. Multiplexers shall be suitable for installation in enclosed cabinets with thermostatically controlled forced air ventilation, or in open racks located in environmentally controlled communications equipment rooms. A controlled environment shall be provided to maintain the operating temperature of the multiplexers within Manufacturer's Specifications throughout its normal service life under the following conditions, unless otherwise noted on the Contract Drawings:
   a. Operating Temperature Range: 32 to 131 degrees F.
   b. Relative Humidity: 5 to 95 percent non-condensing.

K. Operations, Administration, Maintenance and Provisioning (OAM&P)

1. OAM&P for the SONET multiplexers shall be accomplished using several levels of access and control, as specified below:
   a. Local Access - Maintenance personnel shall have access to single

multiplexer, at a remote site, via front panel indicators or the CID, as described previously in this Section. The front panel or CID shall permit the maintenance person to read system alarms and status, and execute basic system control functions.

b. Remote Access – Each multiplexer shall be capable of remote OAM&P from the head-end node at the OCC. This shall be accomplished through the dedicated overhead data communications channels in the SONET signal. This interface shall allow full-featured system operation and access to any or all network elements including multiplexers and DACS.

2. The remote full-featured OAM&P shall be carried out via Transaction Language 1 (TL1). The TL1 interface shall be provided by the Network Management System located at the OCC.

L. Manufacturer:
1. Cisco, Model # ONS 15454 (Head-end node)
2. Cisco, Model # ONS 15310-MA (Remote nodes)

2.02 T1 INTELLIGENT MULTIPLEXER (CHANNEL BANK)

A. The T1 Intelligent Multiplexer is a digital, programmable channel bank providing access to DS-0 (64 kbps) level output circuits from the DS-1 input signals. Contractor shall furnish and install D4 compatible PCM T1 Multiplexers at the locations shown on the Contract Drawings. The T1 multiplexers shall be fully compatible with ANSI/EIA Standard T1.102 format signal at the DS-1 level.

B. The T1 multiplexer shall be an integrated access multiplexer/demultiplexer.
1. As multiplexers, they shall accept as input voice frequency and DS-0 level digital data signals (1.2 kbps to 56 kbps) and shall perform sampling, quantizing and coding of the signal into a multiplexed Pulse Code Modulation (PCM) DS-1 level signal into an adjacent DSX jackfield. DS-1 level signals shall operate at 1.544 Mb/s and shall be compliant with ANSI/EIA Standard T1.102.
2. As demultiplexers, they shall accept a DS-1 level signal and shall output DS-0 level voice frequency and digital data signals.
3. The multiplexer shall be capable of utilizing and combining any combination of multiple DS-0 channels up to the maximum of 24 DS-0 channels for high bandwidth applications (> 64 kbps). This capability is required for the high-speed data modules (RS-422, RS-449, RS-530, V.35, or Engineer approved equivalent) having speeds of N x 56/64 kbps up to 1.536 Mbps.

C. Each T1 multiplexer shall be microprocessor controlled, with redundant CPUs.

D. Each T1 multiplexer shall be capable of accepting multi-port and multi-function cards.
1. Voice Frequency Interface Card
   a. Four-wire E&M cards shall be multi-port (8-port nominal) configurable for loop-start or ground-start, normal or inverted E&M signaling. Four-wire cards shall be transformer isolated from the circuit, with capacitive coupling so that DC talk-battery can be applied to the instrument side of the circuit.

1) Each card shall be capable of setting port parameters on a port by port basis, including the mode, the PCM coding, and the trunk conditioning.
2) Each card shall include testing and diagnostic features to allow the NMS to monitor and control loopbacks, E and M leads, and ABCD signaling bits on a port-by-port basis. Each card shall include a single 50 pin female Amphenol connector.
3) On the transmit side, the incoming VF signal level shall be adjusted to the transmission level point (TLP), sampled at a frequency of 8 kHz, and converted to 8 bit PCM words to make up a 64 kbps signal. The incoming M-Lead status shall be detected, and M-Lead signaling bits shall be added into the outgoing bit stream.
4) On the receive side, the incoming 8 bit PCM words shall be decoded and filtered, and the recovered VF signal shall be adjusted to the appropriate TLP. Incoming signaling bits shall be decoded and interpreted to drive the E-Lead output relay.
5) Each E&M card shall include an extended transmit 24 dB at minimum, with high end level no less than +8 dBm, and low end level no greater than –14 dBm. This option shall support 4 wire modem applications.

b. Four-wire E&M cards shall meet, as a minimum, the following specifications:

1) Impedance	600 ohms.
2) Transmit Level	- Minimum range 24dB, Minimum high end level +8.0 dBm, Maximum low end level –14 dBm.
3) Receive Level	-17.0 to +8.5 dBm, adjustable.
4) Loss Stability	± 0.5 dB (end to end).
5) Idle Channel Noise	23 dBrnc0 max.
6) Signal Distortion	
a) 0 to -30 dBm0 Input	33 dB min.
b) -40 dBm0 Input	27 dB min.
c) -45 dBm0 Input	22 dB min
7) Return Loss	
a) 1,000 Hz	28 dB min
b) 300 to 3,000 Hz	23 dB min
8) Frequency Response	
a) 200 Hz	0 to 3 dB
b) 300 to 3,000 Hz	-0.3 to +.3 dB
c) 3,200 Hz	-0.3 to +1.5 dB max
d) 3,400 Hz	0 to +3 dB

2. Low-Speed Data Cards

a. The low-speed card provided shall be a multiport (6-port nominal), RS-232, RS-422, RS-485, or Engineer approved equivalent, sub-rate data module whereby each data port shall interface with one four-wire baseband bipolar data link. Each port shall be independently programmed to operate at synchronous or asynchronous data rates of 1.2, 2.4, 4.8, 9.6, 19.2 or 56 kbps using industry standard Digital Signal Level 0 subrate speed DS0-A or DS0-B

b. The low-speed data card shall provide up to 4 sub-rate ports within a single DS-0 channel. The following port configurations, per DS-0 channel, shall be supported:
    1) 4 ports at 9.6 kbps or less.
    2) 2 ports at 19.2 kbps.
    3) 1 port at 56 kbps.
c. Each low-speed data port shall be fully compatible with standard DDS (digital data service) loop-backs and shall include built-in bit error rate testing capabilities.
d. Each low-speed data port shall have an individual front or rear panel connector.

3. High-Speed Data Cards
    a. Each high-speed card provided shall be multiport (4-port nominal), RS-422, RS-530, V.35, or Engineer approved equivalent.
    b. Each port shall be independently programmable to operate at speeds of 56 or 64 kbps, or N x 56/64 kbps. When N = 24, the maximum data rate of 1.536 Mbps shall be provided.
    c. Each high-speed data port shall be fully compatible with standard DDS loop-backs and shall include built-in bit error rate testing capabilities.
    d. Each high-speed data port shall have an individual front or rear panel connector.
4. System Timing
    a. Each T1 multiplexer shall have a primary and secondary timing source; if the primary clock fails, the secondary source will automatically take over. An internal stabilized clock source shall also be included for automatic fallback if both sources fail. The internal clock shall be Stratum 4 or better with a stability of ±25 ppm. Each clock source shall have the capability to derive timing from three modes:
        1) Free-run Mode: The clock source operates independently, as a master source.
        2) Synchronized Mode: The clock source shall be slaved to a composite clock (DDS) signal provided from an external source. If the incoming clock signal is interrupted, the T1 multiplexer shall synchronize to the internal source.
        3) Generate Mode: The clock source shall be synchronized via a clock signal derived from the framing bits in the incoming DS-1 bit stream. If the incoming DS-1 bit stream synchronization is lost, the T1 multiplexer shall synchronize to the internal source.
5. Support Equipment
    a. In addition to the equipped spare capacity defined elsewhere, Contractor shall furnish 30 percent additional voice frequency interface and data port cards beyond those specifically required to be installed systemwide. Contractor shall furnish one additional circuit card for each type of T1 multiplexer common equipment card. All support equipment cards are to be delivered at a location designated by the Engineer.
6. Construction

a. The T1 multiplexers shall be suitable for standard 19 or 23 inch mounting in a standard EIA equipment rack and shall be of a size such that four T1 multiplexers can be mounted in a single 7feet high rack.

7. Environmental Specifications
   a. The T1 multiplexers shall meet, as a minimum, the following requirements:
      1) Temperature 14 to 113 degrees F.
      2) Humidity 5 to 95 percent, non-condensing.
   b. The T1 multiplexers shall be capable of operating in a hardened environment.
8. Power
   a. The T1 multiplexers shall meet, as a minimum, the following requirements:
      1) Voltage -48 VDC.
      2) Maximum Current 1.0 Amp (fully equipped).
9. DS-1 Interfaces
   a. Each T1 multiplexer shall support multiple DS-1 interface cards. The DS-1 interface card shall be available in single and dual DS-1 configurations.
   b. The DS-1 input signal shall be a standard North American Digital Hierarchy format signal, and shall be fully compatible with Bell System DS-1 standards as measured at the DSX-1 and shall meet ANSI/EIA Standard T1.102.
   c. Protection at the DS-1 input shall be one-to-one (1:1) configuration.
10. Each channel allocated under this contract shall receive a dedicated channel from source to destination, completely non-blocked via T1 multiplexers. Hybrid/key PBX systems in place of T1 multiplexers will not be allowed.
11. Multiplexer Alarms
    a. Each T1 multiplexer shall be capable of reporting alarm and status conditions locally and remotely, in addition to diagnostic and configuration capability. The T1 multiplexer shall include multiple levels of password protection for access to multiplexer functions, the lowest level being read-only of system parameters, the highest level being full access to configuration, diagnostics, and password management.
    b. The alarm messages shall indicate status of each port on every card in the system. In addition, each T1 multiplexer shall be equipped with alarm output relay contacts for indication of major failures (affecting service) and minor failures (not affecting service). All alarms shall be transported to the Control Center, and shall be used to interface with the NMS, as specified elsewhere.
12. Network Management
    a. The T1 multiplexers shall be capable of remote diagnostics and system management. The T1 multiplexers shall be capable of network management functions by means of SNMP (simple network management protocol) traps. The T1 multiplexers shall allow user interrogation of T1 multiplexer status and operation down to the DS-0 or sub-rate channel, and physically down to each port. The remote diagnostics and system management shall be compatible with the NMS, specified elsewhere.
    b. The SNMP data shall be transported to the NMS via a 4 kbps facility data link (FDL) embedded in a DS-1 extended super frame format from each T1 multiplexer. The FDL shall be extracted from each T1 multiplexer through the DACS, mapping the FDL into a DS-0 channel.

E. Manufacturer: Charles Industries, Model # 360-80(IAD) or approved equal

2.03 DIGITAL SIGNAL CROSS-CONNECT (DSX) PANEL

A. Contractor shall provide a digital signal cross-connect panel at each communications equipment room with DS-1 circuits as the point of demarcation for DS-1 signals.

B. The DSX shall be equipped for the required quantity of DS-1 signals (no less than 8), to be terminated on the panel.

C. The DSX shall be capable of EIA 23 inch or 19 inch rack mounting.

D. The DSX shall include the required number and length of DS-1 patch cables with appropriate connectors.

E. The DSX shall be equipped to terminate all permanent DS-1 circuits on the rear of the panel in RJ-48 jacks. The front of the panel shall be equipped with IN, OUT, and TEST bantam jacks to allow for temporary patching and in-service testing of DS-1 signals.

F. Manufacturer: ADC, Model # DD1-311001 or approved equal

2.04 WIRE AND CABLE

A. DS-1 Cable
1. Rated for DS-1 transmission.
2. RJ-48C connectors.
3. Minimum specifications:
    a. Insulation: plenum rated, low flame, no smoke.
    b. Jacket: plenum rated, low flame, no smoke.
    c. Resistance: 100 Ohm balanced.
    d. Temperature rating: 220 degrees F.
    e. Voltage rating: 6 V p-p $\pm$10%.

B. DS-1 Patch Cable
1. Rated for DS-1 transmission.
2. Appropriate connectors to mate with DSX panel.
3. Contractor shall supply at each communications equipment room one for each DS-1 circuit plus 100% spares.
4. Minimum specifications:
    a. Insulation: plenum rated, low flame, no smoke.
    b. Jacket: plenum rated, low flame, no smoke.
    c. Resistance: 100 Ohm balanced.
    d. Temperature rating: 220 degrees F.
    e. Voltage rating: 6 V p-p +/-10%.
    f. Length: 2 meters.

C. Cross Connect Wire
   1. Suitable for voice and high speed data communications up to 16 Mbps.
   2. UL Listed and conforming to Bellcore TA-TSY-000130.
   3. Minimum Specifications:
      a. Conductor gauge: 24 AWG.
      b. Maximum resistance: 29 ohms per 1000 ft.
      c. Insulation: Plenum rated, low flame spread, no smoke.
      d. Maximum capacitance: 0.15 mF per 1000 ft.

ARTICLE 3 EXECUTION

3.01 SONET OC-12 ADD-DROP MULTIPLEXERS

A. Contractor shall provide and install all equipment and material necessary to form a complete and operational OC-12 fiber optic network as specified within the Contract Documents and in accordance with the Manufacturer's Specifications.
   1. A Head-end OC-12 multiplexer shall be installed in the OCC equipment room.
   2. An OC-12 multiplexer shall be installed at the Gateway, North Shore, and Allegheny station nodes as shown on the Contract Drawings.
   3. An OC-12 multiplexer shall be installed in the CTS cabinet located in the Pitt Tower equipment room.
   4. Each OC-12 multiplexer shall be pre-assembled, pre-wired, and tested at the factory for the requirements of each node.
   5. All OC-12 multiplexers shall be configured at the factory in the UPSR ring configuration as shown on Contract Drawings CM004 and CM005 and specified herein. The OC-12 system shall be operated to simulate ultimate field operation, including random generation of fault conditions with subsequent network healing via path switching.
   6. All network simulation shall be documented for initial set-up, hardware and software configuration, test patterns, and test results.
   7. Contractor shall notify the Engineer a minimum of two weeks in advance of the testing of the system so that the Engineer or the Engineer's representative may be present for the tests, if the Engineer so elects, as specified in Section 16901, "Communication System Inspection and Test."
   8. All fiber optic and copper cable connections from the SONET multiplexer to the FDP and DSX panels shall be made according to the Contract Drawings.
   9. Equipment inside communications equipment rooms may be subject to interference from hand-held radio transmissions. To help prevent this, Contractor shall place a minimum of two signs inside the communications equipment rooms, such that a sign can be seen from all areas of the room. The signs shall state "HAND-HELD RADIOS, CELL PHONES, OR ANY WIRELESS TRANSMITTING DEVICE MUST NOT BE USED INSIDE THIS ROOM." The signs shall have lettering a minimum of 3/4 inch in height, be constructed of a highly visible durable plastic material, and rigidly mounted to walls or racks.

3.02 T1 INTELLIGENT MULTIPLEXER (CHANNEL BANK)

A. Contractor shall provide and install all equipment and material necessary to form a complete and operational CTS inclusive of the T1 intelligent multiplexers, as specified in the Contract Documents and in accordance with the Manufacturer's Specifications.

B. The required quantity of T1 multiplexers shall be installed in the OCC and each field site to meet the requirements specified in the Communication System specifications and on the Contract Drawings.

C. Each T1 multiplexer shall be pre-assembled, pre-wired, and tested at the factory for the requirements of each site.

D. All T1 multiplexers shall be configured at the factory as shown on the Contract Drawings and specified herein. The T1 multiplexer system shall be operated to simulate ultimate field operation, including random generation of fault conditions with subsequent recovery.

E. All network simulation shall be documented for initial set-up, hardware and software configuration, test patterns, and test results.

F. Contractor shall notify the Engineer a minimum of two weeks in advance of the testing of the system so that the Engineer or the Engineer's representative may be present for the tests, if the Engineer so elects, as specified in Section 16901, "Communication System Inspection and Test."

3.03 MAIN DISTRIBUTION FRAMES

A. The main distribution frames shall be rack-mounted frames within the communications equipment rooms at all NSC sites, in accordance with the approved communication equipment room layout plans.

B. All cross-connections shall be made within each distribution frame/field so that all connections to each T1 multiplexer card are complete to the line side of the associated protection block. Cross connections shall be made using 22 or 24 AWG solid copper insulated pairs, dressed in a neat and workman-like manner.

C. Contractor shall provide wiring harnesses, multipair cables, and connectors. Contractor shall install, number, and label all connections.

D. The Main Distribution Frame shall be securely mounted within the communications equipment room at a location proposed by Contractor, to be submitted to the Engineer for approval as part of the Site Arrangement Plan and the Site Wiring Plan.

3.04 TESTING

A. The system apparatus shall be included in the complete factory test procedures as required by Section 16901 "Communication System Inspection and Test" of these Specifications. Final in-service testing shall also comply with this specification.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16703.001 - Carrier Transmission System shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16703.001 - Carrier Transmission System will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16705

COMMUNICATIONS SYSTEM POWER SUPPLY

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the communications system power supply, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to design coordination and implementation of the following activities:
   1. Contractor shall furnish all labor, material, equipment, supervision, transportation, and miscellaneous services, whether or not explicitly identified herein, to provide a completely tested and fully operational communications power supply system.
   2. The Work includes the furnishing and installation of a -48 VDC Power Supply System in each NSC Communications Equipment Room (CER) to power the Carrier Transmission System (CTS) and other communications equipment as shown on Contract Drawing CM020 and as specified herein, to form an integral part of the communications system.
   3. The Work also includes the furnishing and installation of a UPS Power Supply System at Gateway, North Side & Allegheny CERs to power all AC powered equipment including, but not limited to VMS/PA, Digital Video System, Remote PBX, CER RTU, and Radio System equipment.
   4. The Work also includes furnishing and installing a replacement UPS system at Pitt Tower to supply power to the existing analog CCTV system and the new Digital Video System equipment as well as the removal of the existing 9KVA system.
   5. The Work also includes furnishing and installing a new UPS system at the OCC building to supply power to the new PBX head-end equipment being installed at the OCC. The UPS system will make use of utility power as the primary power source and backup power from the existing emergency generator.
   6. The Work also includes the furnishing and installation of an automatic transfer switch to select between a primary and backup 110/208 VAC power feed to the NSC station CER.
   7. The Work also includes the furnishing and installation of AC and DC power distribution equipment and all interconnections to all CER equipment.
   8. The Work also includes the furnishing and installation of all miscellaneous hardware including, but not limited to, rack, cable ladder and conduit to provide a functional, reliable and serviceable communications system.

C. The Contract Documents provide the performance parameters and design criteria to complete the communications system power supply. The Contractor shall be responsible to provide a complete design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16700, "Communications."

B. Section 16901, "Communication System Inspection and Test."

1.03 REFERENCE STANDARDS

A. UL Standard 94V-O.

B. Military Standards MIL-B-8565J and MIL-W-16878/1.

C. ICEA Standard S-68-516

D. NFPA 70, National Electric Code

E. NFPA 70E, "Standard for Electrical Safety Requirements for Employee Workplace"

F. NFPA Standard 130, "Standard for Fixed Guideway Transit Systems".

G. ANSI C62.41-1980

H. IEEE 587

1.04 SUBMITTALS

A. System Design.

B. Product Data, Shop Drawings and specifications.

C. Functional Site Block Diagram.

D. Power calculations for each Communications System Power Supply (CSPS) location including worksheets.

E. Arrangement Plan.

F. Installation Plan.

G. Wiring Plan.

H. Power Wiring Plan.

I. Software and Firmware Plan.

J. Allocation and Provisioning Plan.

K. Floor loading calculations.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Contractor shall ensure that equipment has not been damaged during shipping or storage. Equipment shall be shipped separately from the equipment racks in which they are to be installed. Equipment shall remain in the original packaging until the time of installation. All equipment shall be stored in a protected area until installed.

ARTICLE 2 PRODUCTS

2.01 SYSTEM REQUIREMENTS

A. Redundant power sources are provided to each NSC station CER, Pitt Tower equipment room, and the OCC UPS room by others.

B. The CSPS shall provide continuous regulated AC and DC power to the communications equipment located in the three new NSC communications rooms and continuous AC power to the communications equipment at Pitt Tower and the OCC PBX and to the related subsystems under normal and abnormal conditions, including loss of utility AC power for a duration of 4 hours or less.

C. The CSPS shall be capable of charging the DC Power Supply and UPS system batteries from a fully discharged state to a fully charged state in 4 hours or less.

D. The CSPS equipment shall be suitable for installation indoors with ambient temperatures from 15 to 110 degrees F and relative humidity from 5 to 95 percent.

E. Audible noise produced by the CSPS shall be 65 dBA or less at 3.3 feet.

F. Normal Operation:
1. DC Power Supply System: The battery charger supplies power continuously to the CTS equipment requiring -48 VDC via the circuit breaker disconnect panel. The battery charger also supplies the DC power for charging the DC Power System storage batteries. Utility power supplies AC power to the UPS, which converts the AC to DC through a rectifier/charger.
2. UPS System: The rectifier/charger supplies DC power continuously to the UPS inverter, which provides 120 VAC power to the communications equipment, indicated on the Contract Drawings, via a wall mounted distribution panel. The rectifier/charger also supplies the DC power for charging the UPS storage batteries.

G. Loss of Normal AC Input Power:
1. DC Power Supply System: The 48 VDC storage batteries supply DC power directly to equipment requiring -48 VDC.
2. UPS System: The storage batteries in the UPS System supply power to the UPS inverter so that there is no interruption of AC power to the equipment requiring AC power.

H. Return of Normal AC Input Power:
   1. DC Power Supply System: When normal AC power returns, the battery charger restarts and assumes the DC loads from the batteries and simultaneously recharges the batteries. This shall be an automatic function and shall not cause any disturbance to the loads.
   2. UPS System: When normal AC power returns, the rectifier/charger restarts and assumes the DC to AC inverter loads from the batteries and simultaneously recharges the batteries. This shall be an automatic function and shall not cause any disturbance to the loads.

I. Downgrade: If a battery is taken out of service for maintenance, the DC Power Supply System and the UPS System shall continue to function and meet all the performance criteria specified herein. Only the battery reserve time capability shall be interrupted until the battery is returned and placed back into service.

J. UPS Failure: The UPS unit shall be the primary source of 120 VAC power. In the event that the UPS unit fails to supply 120 VAC power, a transfer switch shall automatically switch to provide the secondary source of 120 VAC power derived from the local utility, as indicated on Contract Drawing CM020.

K. Power Calculations
   1. Contractor shall compute the size of the power distribution system, with 20% additional capacity for future growth, required to feed the equipment, and design the complete layout of feeders, transformers, fuses, breakers and buses, based on the locations and sizes of individual communication system loads. All designs shall be subject to approval of the Engineer.
   2. Contractor shall size all feeders to carry the rated load with a voltage drop of not more than 5 percent, except no feeder shall be smaller than No. 6 AWG. Size of feeders shall be able to carry a continuous load equal to 125 percent of the total continuous load that is required by the portion of the system to be fed.

2.02 48 VOLT DC POWER SUPPLY/BATTERY CHARGER

A. The charger shall be a solid-state switch mode type rectifier.

B. The charger shall be designed to charge VRLA lead acid cells.

C. The steady state output voltage shall have line regulation of 0.2 percent over the full range of input voltage, and load regulation shall be 0.4 percent from no load to full load over the specified input voltage, frequency and ambient temperature ranges.

D. Dynamic response of output voltage shall be regulated to within plus or minus 5 percent of initial steady state voltage for a step change from 20 percent to 100 percent of the full rated load. Recovery to steady state voltage regulation range shall not exceed 200 ms and all transient behavior shall disappear within 500 ms.

E. The charger shall be listed by UL.

F. The charger shall operate over a temperature range of 15 to 110 degrees F and shall be capable of operating from 5 to 95 percent relative humidity.

G. The charger shall consist of racked mounted modules, whereby each module can be removed and replaced with the power on (also known as "hot swap").

H. The charger shall be capable of using a nominal input voltage of 208 VAC single phase, and be capable of operating over an input voltage range of 180 to 264 VAC.

I. The charger shall be designed for input voltage nominal frequency of 60 Hz, with an operating range of 47-63 Hz.

J. Voice band noise shall be less than 22 dB and less than 32 dBrn C message weighting when used with batteries with an ampere-hour rating of at least four times the rated charger current.

K. The AC input into the charger shall have a circuit breaker equipped with a shunt trip. MOV (Metal Oxide Varistor)-type devices shall be used to provide surge protection in all chargers.

L. On application or re-application of the AC input voltage, the output current shall ramp gradually, eliminating surges and overshoots.

M. Positive and negative insulated terminals shall be located on the front of the charger to allow connection of a portable voltmeter.

N. The charger shall consist of two separate modules that under normal conditions share the load equally within 5 percent. Both of the modules shall be capable of supplying 100% of the load. Upon failure of one of the modules, the other module shall automatically assume 100% of the load.

O. The charger shall be equipped with the following controls. All controls shall be easily accessible and adjustable. All local indicators shall consist of meters and LEDs that shall be located on the front panel to facilitate readability. Status indicators shall be form "C" contacts suitable for connection to the SCADA (Supervisory Control and Data Acquisition) System RTU located in the communications equipment room.
   1. Local Controls: local controls shall meet the following specifications.
      a. The adjustable float voltage range shall be at least 50.9 to 54.0 VDC.
      b. The adjustable equalize voltage range shall be at least 54.2 to 57.6 VDC.
      c. Electronic current limiting control circuitry shall be provided and shall be adjustable over a range from 90 to 115 percent of the rated output current.
      d. The charger shall be equipped with high-voltage shutdown such that if the output voltage exceeds a preset adjustable value, the AC circuit breaker shall trip. Only the malfunctioning charger shall be shut down. The adjustable high-voltage shutdown voltage range shall be 56.0 to 59.0 VDC.
      e. The charger shall be equipped with a DC output breaker that is easily accessible for manual control.

2. Local Indicators: Charger shall be equipped with the following meters and LED (Light Emitting Diode) indicators.
   a. DC voltmeter and a DC ammeter that are easily readable on the front panel. Meters shall be accurate to within 2 percent at full scale. Scale of meters shall be appropriate for the voltage and current ratings of the charger.
   b. LED or equivalent type of indicators shall be provided on the front of the charger for the following:
      1) AC On: Illuminates when charger is operating.
      2) Float: Illuminates when charger is in float mode.
      3) Equalize: Illuminates when charger is in equalize mode.
      4) Tripped DC Breaker: Illuminates when DC breaker has tripped.
      5) High Voltage Alarm: Illuminates when the output voltage exceeds the preset adjustable high voltage point.
      6) Low Voltage Alarm: Illuminates when the charger output voltage has dropped below the preset adjustable voltage point.
      7) Low Current Alarm: Illuminates when the charger output current falls below 0.5% of rated DC output.
      8) Rectifier Fail Alarm: Illuminates when a failure has occurred that may disable the charger.
3. Remote Indicators: Charger shall provide form "C" contacts for the following alarm conditions. These contacts will be inputs to the SCADA System.
   a. Low Battery.
   b. Charger Failure.
   c. AC Power Failure.

2.03 BATTERY SYSTEM (48VDC SYSTEM)

A. The battery system shall include the cells, racks, battery trays, matting, connectors, wiring, and hardware that will provide the 48 VDC battery to be used with the battery charger and inverter described in this Section.

B. The battery type shall be a high reliability, valve regulated lead acid, maintenance-free battery. The battery shall not require any venting and shall exceed MIL spec MIL-B-8565J for hydrogen gas emissions. Contractor shall provide catalog cut sheets that identify the gassing and venting requirements of the proposed batteries.

C. The battery shall be rated in constant discharge amperes per cell for an 8-hour discharge time increment to 1.75 volts per cell at 77 degrees F.

D. Internal resistance of battery shall be less than 0.010 ohms.

E. Battery float voltage shall be 2.27 volts per cell ±1 percent.

F. Battery equalize voltage range shall be within 2.35 to 2.40 volts per cell.

G. Battery nominal open circuit voltage shall be 2.05 volts per cell.

H. Battery shall not produce measurable gas when charged to voltages up to 2.35 volts per cell.

I. Operating temperature shall be at least 15 to 140 degrees F for discharging batteries and at least 15 to 110 degrees F for charging batteries.

J. Battery case material shall be ABS or polypropylene. Case material shall have oxygen index greater than 28 percent and shall meet requirements of UL 94V-O.

K. Battery electrolyte shall be immobilized and non-spillable.

L. Battery vents shall be pressure regulated and non-removable.

M. Battery plates shall be long life lead calcium.

N. Battery terminal posts shall be 5/16 inch – 18 threads per inch studs. Terminal lugs, back-to-back, and end-to-end connecting cables, anti-corrosion grease, and any required wrenches or other tools shall be provided.

O. Contractor shall provide battery rack, tray, or cabinet as appropriate in strict accordance with the battery manufacturer's requirements.

P. Batteries shall deliver at least 80 percent of their rated capacity for ten years from the date of shipment.

2.04 DC POWER DISTRIBUTION CENTER

A. The power distribution center shall include ground bars, breaker panels, and disconnect panels for the CSPS.

B. The power distribution center shall be designed for 48 VDC and be rated for a maximum distribution of at least 100 amps.

C. The power distribution center shall have positive and negative bus bars rated for at least 100 amps for terminating batteries and load return leads.

D. The power distribution center shall be equipped with low voltage load disconnect. The low voltage load disconnect shall be field adjustable. A fused disconnect contactor shall be employed.

E. The power distribution center shall be capable of providing a minimum of 10, 2 pole breakers. Each breaker position shall be capable of handling up to a maximum 50 amp breaker, with maximum distribution of at least 100 amps. All empty panel positions should be filled with blank panels.

F. The power distribution center shall have front panel LEDs, an audible alarm, and form "C" contacts for each of the following alarm conditions. The form "C" contacts shall provide an input to the SCADA System for remote monitoring.

1. Breaker Tripped.
2. Low Voltage.
3. High Voltage.
4. Rectifier Fail – major.
5. Rectifier Fail – minor.

G. The power distribution center shall provide LED or equivalent indications of the following conditions:
   1. Calibration voltage adjustment.
   2. Pickup adjustment.
   3. Dropout voltage adjustment.
   4. Connected.

2.05 CONTROLLER

A. The Power System Controller shall monitor and control the operation of the DC power system rectifiers. This unit shall be capable of monitoring multiple rectifiers and providing local and remote alarm indications in the event a failure occurs.

B. The Power System Controller shall include, as a minimum, the following features:
   1. Front Panel Indicators and Test Jacks
   2. Front Panel Adjustments for Float/Boost Levels
   3. 4-Digit LCD Display for Measuring Voltage and Current
   4. Shunt and Shuntless Current Monitoring
   5. Alarm Outputs: Isolated "C" Contacts, rated at .5 amps at 125VDC
   6. Operates from Rectifier Output 48 VDC.

2.06 120VAC UPS SYSTEM

A. General: The UPS System shall provide a 120VAC regulated voltage and frequency source for the Communications System equipment with battery backup. The UPS system shall be designed around the component specifications and operational requirement described below. The UPS shall be a true double conversion, on-line design.

B. Rectifier/Charger Module: Incoming AC power shall be converted to a regulated DC output supplying DC power to the inverter and batteries.

C. Inverter: The inverter shall convert DC power from the rectifier/charger output or batteries into a regulated AC power output.

D. Battery System: The batteries shall be maintenance-free, sealed LC valve regulated lead acid batteries, high rate discharge cells with the following requirements:
   1. Fire-retardant, plastic containers designer for communications service.
   2. Sized to provide 150% of calculated load current for 4 hours after AC source power failure.
   3. Batteries shall have an expected life of 200 complete full load discharge cycles.

E. UPS Automatic Bypass Switch: Transfer control logic shall automatically operate the static transfer switch, transferring the UPS output load to a bypass source, after sensing one of the following conditions:
   1. Inverter overload capacity exceeded
   2. UPS AC output overvoltage or undervoltage
   3. UPS fault condition

F. Maintenance Bypass Switch: Manually transfers the UPS output load to a bypass source to permit the servicing of the UPS unit in a de-energized state. The Maintenance Bypass Switch shall include the following features:
   1. Make-Before-Break
   2. Installed in separate cabinet from UPS

G. Isolation Transformer: Contractor shall provide an isolation transformer as part of each UPS system. The isolation transformer shall be used to provide isolated, low noise, conditioned power (spike suppression, EMI filtering) in the event the inverter fails and 120 VAC power must be derived from the utility. The isolation transformer shall meet the following specifications:
   1. Input Voltage: 208 VAC, 60 Hz
   2. Nominal Output Voltage: 120 VAC, 1 phase, 60 Hz

   The isolation transformer shall be in the circuit for both the automatic and maintenance by-pass switches.

H. User Interface: The UPS shall be equipped with a user-friendly interface panel to permit changing operating modes, set system parameters, check alarms and inverter logs.

I. Trouble Alarm Contact: The UPS shall be equipped with a relay contact module, which shall generate a contact closure for various alarm conditions, such as, loss of inverter output, low battery, high temperature, etc.

J. Input Ratings:
   1. Voltage Range: 208-240VAC
   2. Frequency: 45 to 65 Hz
   3. Power Factor: 0.98
   4. Current Distortion: 10% THD max at full load
   5. Inrush Current: 150% of full load input current max of 3 cycles
   6. Surge Protection: Sustain input surges without damage per ANSI C62.41-1980 (IEEE 587), Category A and B.

K. Output Ratings:
   1. Nominal Voltage: 120VAC
   2. Voltage Regulation: +/-3%
   3. Transient Response: +/-3%
   4. Transient Recovery Time: 1% of steady state output voltage within 50 msecs

5. Voltage THD: 3% max into 100% linear load, 5% into non-linear load
6. Nominal Frequency: 60 Hz Auto Selectable
7. Frequency Regulation: Sync with line +/-3Hz
8. Current Overload Capability: 150% for 10 seconds
9. Bypass: Auto Bypass shall provide an alternate path to utility powering the event of UPS failure or overload.
10. Efficiency: Minimum of 97% in High Efficiency Mode, Nominal 88% in Normal Mode with full resistive load and fully charged batteries.

L. Mechanical Requirements:
1. UPS unit comprised of rectifier/charger, inverter, bypass switches, and batteries shall be housed in freestanding enclosures.
2. Matching External Battery Cabinets shall be the same size as the UPS enclosure.

M. Manufacturers: Eaton/Powerware or approved equal

2.07 POWER WIRE

A. Power Wire shall be UL Listed and conform to MIL-W-16878/1.

B. Conductors shall be stranded tinned copper.

C. Insulation shall be ethylene propylene rubber (EPR) per ICEA Standard S-68-516, plenum rated, low flame spread, no smoke.

D. Overall jacket shall be Hypalon plenum rated, low flame spread, no smoke.

E. Temperature rating shall be 194 degrees F.

F. Voltage rating shall be 600 V minimum.

ARTICLE 3 EXECUTION

3.01 SYSTEM DESIGN

A. The CSPS shall be provided in the NSC communications equipment rooms, Pitt Tower equipment room and the OCC UPS room as indicated in Contract Drawing CM020. Contractor shall design the CSPS for each communications equipment location.

B. Contractor shall install the UPS system at Pitt Tower in two phases as indicated on CM031. In the interim phase the new UPS system will be installed in two segments splitting the battery cabinets. Upon the successful startup and operation of the new UPS system the existing system will be removed and shipped to PAAC at South Hills Junction. After removing the existing UPS cabinets, the second segment of battery cabinets will be moved next to the first segment making a continuous row of cabinets as indicated on CM031.

The Work at this location will also include the installation of new breakers in the existing breaker panel and power cabling/conduits to the new Digital Video System equipment cabinets and monitors in the Pitt Tower control room.

C. Contractor shall install a new UPS system in the basement room 107 at the OCC to power the new PBX head-end equipment installed in room 206 on the floor above. The installation will require the installation of power cabling/conduit between floors and the installation of new breakers in the existing breaker panel in room 206. Installation of power wiring/conduit to the primary power source and the backup generator will also be required as part of this Work. See "Also" drawings for the existing OCC power system.

D. Contractor shall size the power supply system to provide the power requirements of all equipment at each location, calculated to include the following:
   1. Peak current demand of all connected equipment.
   2. Peak current demand of batteries recharging.
   3. Battery ampere-hour capacity required for all equipment to continue functioning for four hours in the event of a commercial power failure.
   4. Recharge time of batteries with stated duty cycle of load.
   5. Wire size of all power distribution circuits and for main supply circuit(s) from electrical distribution panel to CSPS.
   6. All of the above data shall be included in the Power Calculations submittal.

E. Contractor shall submit a description of the CSPS for each location to the Engineer for approvals as part of the System Design and Functional Block Diagram Submittals. A block diagram showing all connections necessary for the various components to function as an integrated power supply system shall be included. Description shall include:
   1. Configuration.
   2. Approximate power draw.
   3. Approximate standby time.
   4. Approximate battery cabinet dimensions and weight.

F. Contractor shall calculate floor loading to demonstrate that the floor of each location is capable of supporting the weight of batteries and CSPS equipment.

3.02 EQUIPMENT MOUNTING

A. All equipment making up the CSPS, with the exception of batteries, shall be mounted in the manufacturer's standard cabinets.

B. Batteries shall be contained on a rack, tray, or cabinet in strict adherence to the battery manufacturer's requirements. If possible the container shall be mounted on a standard equipment rack.

3.03 INSTALLATION

A. The equipment shall be installed in accordance with local codes and the manufacturer's recommendations.

B. Contractor shall provide and install power cable in conduit for the distribution of power to equipment locations from the incoming pull boxes to the equipment housing/room.

C. An approved method shall be used to mount a typed or machine printed nametag for each power supply, battery charger, rectifier and other power-related devices, on the front plate of the equipment. The nametag shall be easily replaceable, but not come off during normal service.

D. All power supplies, battery chargers, rectifiers and other power-related devices shall be tested in accordance with the manufacturer's recommendations.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16705.001 - Communications System Power Supply shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16705.001 - Communications System Power Supply will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16706

DISCONNECT SWITCHES

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for disconnect switches, in accordance with the Contract Documents.

B. The work in this section includes, but is not limited to, the following activities:
   1. DC Manual Disconnect Switches
   2. DC Motorized Disconnect Switches
   3. Related accessories for the Overhead Contact System (OCS).

C. This Section specifies general requirements for the manufacture, furnishing, installing and testing of OCS Disconnect Switches.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 01910, "Operations, Maintenance and Repair Data"

C. Section 16602, "General Requirements Overhead Contact System."

1.03 REFERENCE STANDARDS

A. ANSI
   1. C37.34 Test Code for High-Voltage Air Switches.
   2. Z55.1 Gray Finishes for Industrial Apparatus and Equipment.
   3. American Society for Testing and Materials (ASTM)
   4. B187 Copper Bus Bar, Rod and Shapes.

B. NEMA
   1. 250 Enclosures for Electrical Equipment (1000 Volts Maximum).
   2. ICS 1 Industrial Control and Systems General Requirements.
   3. ICS 2 Industrial Control and Systems Controllers, and Overload Relays Rated Not More Than 2000 VAC or 750 VDC.
   4. SG 5 Power Switchgear Assemblies.

C. NFPA

D. NEC

1.04 SUBMITTALS

A. The following submittals shall receive the Engineer's approval prior to fabrication:
   1. Complete manufacturer's descriptions, catalog data, and information including model number.
   2. Manufacturer's general and detail arrangement Shop Drawings, and installation instructions.
   3. Operation and maintenance manual with list of recommended spare parts.
   4. Electrical schematic and wiring diagrams.

B. Submit qualification and production test reports (See Section 1.05) within 1 week after completion of each component testing procedure.

1.05 TESTS

A. General: Disconnect switches shall be tested at the factory prior to shipment, as specified herein.

B. Qualification Tests: Qualification tests shall be performed to prove compliance with the Contract Documents. Tests shall be conducted generally in accordance with those described in ANSI C37.34, including the following:
   1. Dielectric tests.
   2. Short-time current test.
   3. Temperature-rise test.

C. Production Tests: Production tests shall be performed on switches to check the quality and uniformity of workmanship and materials used. Test shall include the following:
   1. Operation of all components.
   2. Power frequency dielectric withstand.
   3. Electric resistance of current path.

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. This Section consists of manufacture, supply and installation of DC manual and motorized disconnect switches and related accessories for the Overhead Contact System (OCS), as shown on the Contract Documents.

B. Contractor shall prepare detailed Shop Drawings for each of the required assemblies, based on the general concepts specified on the Contract Drawings. Contractor's Shop Drawings shall be subjected to approval by the Engineer.

C. The dc disconnect switches shall be dead bolt outdoor type, single-pole, single-throw, no-load break and non-fusible air switches, with manual or motorized operation, according to location. The switches shall be exposed type, suitable for pole or wall mounting. Design shall comply with the applicable requirements given in ANSI C37.34 and Z55.1, ASTM B187, NEMA 250, SG 5, ICS 1, and ICS 2. Typical experienced OCS hardware manufacturers are MAC Products and Powerswitch MNC, or other approved equal suppliers.

D. Switches shall be capable of operation with a 1/4 in thick covering of glazed ice on the switch mechanism and operating rods.

E. The disconnect switches shall be equipped with auxiliary contacts. A minimum of two sets of contacts shall be provided that operate when the disconnect switch is in the fully open position, and a minimum of two sets contacts shall be provided that operate when the disconnect switch is in the fully closed position. The auxiliary contacts shall be form C contacts, with normally open, normally closed and common terminals available for use.

2.02 RATINGS

A. Switches shall be rated for 1000V DC operation with 3.0 kV, rms, minimum insulation level. Continuous current ratings shall be 2500A without exceeding 120 degrees F rise above a maximum ambient temperature of 100 degrees F. Switches shall have a momentary current withstand rating of not less than 100 kA, rms.

B. Auxiliary contacts and associated wiring and terminal blocks shall be rated for 250 VDC operation and continuous current rating of 15A, at minimum.

2.03 CONSTRUCTION

A. Switch Contacts

1. Moving and stationary contact surfaces shall be silver plated copper. All other current-carrying parts shall be of high-conductivity copper or copper alloy. Contacts shall be self-aligning, wear-compensating, and with initial wiping action.

B. Cable Termination: The line and load side disconnect switch terminals shall be furnished with silver plated copper buses complying with ASTM B187, to accommodate the number and size of copper cables as indicated on the Contract Drawings. The switch terminals shall have provision for NEMA drilled (2-hole or 4-hole) cable terminal lugs. The cable terminals shall be included within the switch enclosure. Disconnect switches with cable terminals located outside of enclosure will not be accepted.

C. Switch Enclosures: Switch Enclosures shall be of a ventilated, watertight design suitable for outdoor mounting. The enclosure shall have a gasketed, hinged door with padlockable stainless steel handle, catch, full length stainless steel hinge and hooded ventilation openings with stainless steel screens. Provide outdoor type padlock with each cabinet, all keyed alike. An external dead front operating handle and linkage shall be provided. The switch position shall be indicated by the handle alignment with "OPEN" and "CLOSED" plates large enough to be visible from the ground. The enclosure shall be of sufficient size to accommodate the switch, internal linkages and operating gear, cabling and terminations without grounding. All maintainable components shall be readily accessible through the door opening, and sufficient space shall be provided for the manipulation of required tools. The enclosure construction of non-metallic boxes shall be a minimum of 1/8 inch thick polyester with a glass to resin ratio of 30 to 70. Enclosure color shall be ANSI-61 grey.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. Switches shall be field installed on the OCS structures as shown on the Contract Drawings and specified herein. Field mounted switches shall be installed in accordance with the manufacturer's instructions. Bolts and support items shall be provided as required.

B. Contractor shall ensure adequacy of poles for supporting the mounted disconnect switches and accessories.

C. Prior to energizing of the OCS, Contractor shall verify correct operation of all disconnect switches installed under this Contract, and shall demonstrate to the satisfaction of the Engineer the intended operation.

D. All wiring shall be provided as required. Conductor sizes, composition and insulation shall be as indicated on the Contract Drawings. All necessary additional hardware such as bushings, connectors, grounding conductors, and all basic electrical materials needed for the installation of the equipment and accessories shall be supplied and installed by the Contractor.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16712

CONTACT WIRE HEATER SYSTEM

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for contact wire heater system, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the general requirements for a constant wattage heating cable specifically designed for the purpose of deicing overhead contact wire for Light Rail systems, in accordance with the Contract Documents.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 01910, "Operations, Maintenance and Repair Data"

C. Section 16602, "General Requirements Overhead Contact System."

1.03 REFERENCE STANDARDS

A. ASTM D3032-98

B. ASTM D2565-99

C. IEEE 515

1.04 SUBMITTALS

A. The following submittals shall receive the Engineer's approval prior to fabrication:
   1. Complete manufacturer's descriptions, catalog data, and information including model number.
   2. Manufacturer's general and detail arrangement Shop Drawings, and installation instructions.
   3. Operation and maintenance manual with list of recommended spare parts.
   4. Electrical schematic and wiring diagrams.

B. Submit qualification and production test reports within 1 week after completion of each component testing procedure.

1.05 TESTS

A. General: Constant Wattage Heating Cable shall be tested at the factory prior to shipment, as specified herein.

B. Qualification Tests:

IEEE 515:

4.1.1 - Dielectric Test

4.1.2 - Insulation Resistance Test

4.1.3 - Water Resistance Test

4.1.4 - Integral Components Resistance to Wear

4.1.5 - Elevated Temperature Exposure Dielectric Test

4.1.6.1 -Thermal Performance Benchmark (Primary Test)

4.1.7 - Deformation Test

4.1.8 - Impact Test

4.1.9 - Cold Bend Test

4.1.10 - Flammability Test

4.1.11 - Verification of Rated Output

ASTM D3032-98

Section 6.6 – Insulation Resistance

Section 8.5 – Voltage Withstand

ASTM D2565-99

Practice G151 & G155 – Light Exposure

MIL-STD -202G – Department of Defense

Method 101E, Test Condition A – Corrosion

C. Production Tests:

ASTM D3032 – Voltage Withstand

ASTM D3032 – Insulation Resistance

IEEE 515 – Voltage Withstand

ARTICLE 2 PRODUCTS

2.01 GENERAL

A. This Section consists of design, manufacture, supply and installation of an ice melting system complete with heating cable, mounting hardware, controls, installation and assembly instructions. The heater shall be installed on all grooved contact wire North of the Allegheny Station using spring clips at 1 ft. intervals specified herein.

B. The heating cable and termination components shall be per RTR Tech. Inc. Specification #501017 or approved equal.

C. The heating cable shall consist of an insulated constant wattage heating conductor surrounded by a silicon based heat transfer material.

D. Power output shall be controlled by a micro processor based On/Off controller provided by the heater cable manufacturer. A nominal 8 w/ft output shall be constant along the entire heater length.

ARTICLE 3 EXECUTION

3.01 INSTALLATION

A. The heating cable shall be installed according to the manufacturer's recommendations.

B. A 2500Vdc Megger test of the cable assembly shall be performed by the installer prior to installation onto the contact wire.

C. Pre-installation preparation of the grooved trolley wire shall be performed per the manufacturer's installation instructions..

D. All heater lengths shall be connected and referenced to the same (+) potential DC power source, and ALL heater positive (+) terminations shall be landed in the control box.

E. ALL negative (-) common DC connections shall be protected in conduit on support poles and at any foot traffic levels and shall be connected to the reference using the authority approved methodology.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16721

TELEPHONE SYSTEM

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, designing, furnishing, and installing a new Telephone System, as well as, providing all labor, materials, tools, equipment, and incidentals necessary for the telephone system integration, operation and replacement of the existing AVAYA PBX. The Telephone System Factory and Field Testing shall be as defined in Section 16901.

B. The work of this Section includes, but is not limited to, the design coordination and implementation of the following activities at the locations as shown on the Contract Drawings and reference drawings for the Operations Control Center (OCC), Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012:
1. Installation and integration of the redundant Head-End PBX at the OCC
2. Installation of PAAC business telephones.
3. Installation of patron emergency telephones on station platforms and mezzanines
4. PBX support of elevator patron emergency phones provided in the elevators by others.
5. Installation of Blue-Light Emergency telephones in tunnels, on aerial structures and emergency exit stairways.
6. Installation of emergency telephones at fire panel locations.
7. Installation of all required cabling between the communications room and each device for each location which is to be run in conduit as specified on the NSC station finish contract drawings and the tunnel CR drawings.
8. Coordination with PAAC for the cutover, commissioning and Factory and Field testing of all equipment installed as part of this Specification.
9. Integration of the new Telephone System PBX and Remote PBX Modules on an Ethernet Ring via the new NSC SONET communications system.

1.02 RELATED SECTIONS

A. Section 01300, "Submittals"

B. Section 01777, "Construction Certification Program"

C. Section 16700, "Communications"

D. Section 16702, "Copper Outside Plant"

E. Section 16703, "Carrier Transmission System"

F. Section 16705, "Communications System Power Supply"

G. Section 16901, "Communication System Inspection and Test"

1.03 REFERENCE STANDARDS

A. ADA. American Disabilities Act

B. ANSI/ICEA Standard S-80-576. Communications Wire and Cable for Wiring of Premises

C. EIA Standard RS-359.

D. NFPA Standard 130, "Standard for Fixed Guideway Transit Systems".

E. UL Standards 467, "Grounding and Bonding Equipment, 910 "Steiner Tunnel Flame Test and 444, "Type CMP"

F. NFPA Standard 130, "Standard for Fixed Guideway Transit Systems"

1.04 SUBMITTALS

A. System Design, A summary description of the overall system and its operation.

B. Product Data, Shop Drawings and specifications to include the following in addition to the requirements stated in Section 16700, "Communications."
   1. List of existing installations for each manufacturer.
   2. Product descriptions and specifications
   3. Catalog Cuts
   4. Power schematics per site
   5. Numbering Plan

C. Overall System Block Diagram

D. Functional Site Block Diagram.

E. Rack Arrangement Plan per Site.

F. Installation Plan including Schedule per Site.

G. Wiring Plan per Site.

H. Power Wiring Plan per Site

I. Allocation and Provisioning Plan per Site.

J. Parts List
The Contractor shall submit a Parts List for all equipment furnished under the Contract.

1. The list shall include replaceable components, circuit boards, assemblies, consumable items, meters and instruments, electrical fillings, nameplates, tags and all comparable items.
2. The listing shall include component name, drawing reference, description, rating, accuracy class, tolerance, part number, supplier or source and any other essential data.
3. The parts list shall be provided in spreadsheet or table form that shows the quantity of each item installed at each location.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Contractor shall ensure that equipment has not been damaged during shipping or storage. Equipment shall remain in the original packaging until the time of installation. All equipment shall be stored in a protected area until installed.

1.06 DESCRIPTION OF WORK

A. This Section presents an outline of the communications work to be performed under this Contract. It does not supersede requirements detailed elsewhere. Contractor is responsible for complying with the Contract Documents in their entirety.

B. The Contractor shall furnish all labor, material, equipment, supervision, transportation, and miscellaneous services, whether or not explicitly identified herein, to provide completely tested and fully operational telephone system including integration with the new NSC telephones, the existing PBX telephones, and the SONET based telephone architecture.

C. The Work of this Section includes the furnishing and installation of rugged, outdoor, tamper-resistant, single-button telephones, telephone service, and all required mounting and wiring to all Patron Telephones shown on the communications equipment location drawings for each station under this Contract. The Patron Emergency Telephones shall be located at station platforms, mezzanine areas and elevators at each NSC station. Telephones shall be surface or recess-mounted, as required by the specific mounting requirements as shown in the Contract Reference Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012.

D. The Work of this Section also includes the furnishing and installation of rugged, outdoor, tamper-resistant, telephone service, and all required mounting and wiring to all fire panel Emergency Telephones shown on the communications equipment location drawings for each station as shown on

Reference Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012.

E. The Work of this Section includes the furnishing and installation of rugged, outdoor, tamper-resistant ring-down Blue Light Emergency Telephones and all required mounting and wiring at the locations shown on the CR Contract Drawings. The Blue Light Emergency Telephones shall be located in tunnels and on elevated structures. Telephones shall be installed in a phone box equipped with a Blue Light Dome and heater as shown on Contract Drawing CM040. Tunnel and Elevated Structure mounting details are shown on Contract Drawings CM038, CM039 & CM041.

F. The Work of this Section also includes the furnishing and installation of Plain Old Telephone Service (POTS) equipment to each Communications Equipment Room. Each Communications Equipment Room shall be provided with one wall mount telephone equipped with a standard 12-button keypad. Contractor shall coordinate the interface of this service with Authority and the Engineer and provide a complete operational dial service.

G. The Work of this Section also includes the furnishing and installation of POTS equipment with an external loud ringing bell and required wiring at each SACS (Substation Alarm and Control System) substation and tie breaker station and RICS (Remote Indication and Control System) equipment room, under this Contract, in conjunction with the copper outside plant work specified elsewhere. Each SACS location and RICS equipment room shall be provided with one wall mount telephone equipped with a standard 12- button keypad. Contractor shall coordinate the installation and testing of these telephones with Authority to assure proper operation with the new PBX telephone system.

H. The Contractor shall provide POTS equipment to each Relay/Signal Room. Each Relay/Signal Room shall be provided with one wall mount telephone equipped with a standard 12-button keypad. Contractor shall coordinate the installation and testing of these telephones with Authority to assure proper operation with the new PBX telephone system.

I. The Contractor shall coordinate with Authority through the Engineer to assign telephone extension numbers, and all other configuration data required by the PBX for all telephones covered under this Contract.

J. Grounding shall be provided by Contractor for each unit installed in accordance with Section 16700, "Communications."

1.07 EXISTING CONDITIONS

A. The existing AVAYA PBX system to be replaced is a Definity ProLogix G3csi system running Version 8.3 software. This system is approaching its end of life using Distributed Communications System (DCS+) software to integrate with nine other existing Version 8.3 Port Authority systems. The system currently has the maximum number of T1 cards allowed in a ProLogix

Since R8.3 is no longer supported by AVAYA and the system goal is to start to move to Voice over IP (VoIP) a system upgrade is required.

The ProLogix system, located at the OCC, supports Patron Telephones, Emergency Telephone and Equipment Room Telephone service via the fiber optic Carrier Transmission System. The Contractor shall verify that the new PBX is equipped with adequate capacity to support the addition of the NSC telephones specified under this contract, the existing CTS phones, the existing OCC office phones, and the spare capacity identified herein. .

B. The Prologix system currently supports:
   1. 486 station line port licenses and 54 trunk port licenses
   2. ISDN-PRI and DCS+ Feature Set
   3. 1-T1 Card for ISDN-PRI access to outside telephone network (off-network)
   4. 1-T1 Card for ISDN-PRI for DCS+ access to the Manchester G3siV8.3 switch and the Octel 200 voicemail system.
   5. 10-T1 cards to support 204 remote analog telephone stations currently via D4 channel banks over SONET to remote FXS ports.
   6. 1 Analog CO trunk supporting 8 analog CO trunk lines.
   7. 1 Call Classifier card (tone detector/generator).
   8. 1 Internal Announcement card.
   9. 2-24 port Avaya Digital DCP Station Line Cards supporting 25 active DCP Digital Telephones.
   10. 7 – 24 port Analog Station Line Cards supporting 134 active Analog Station ports.

C. The new Telephone System must support all of the above interfaces and provide interoperability with all of the existing station phones, including the Octel 200 voice mail system, as well as the requirements for expansion of the existing system as defined herein and on the contract drawings.

1.08 PBX SYSTEM FUNCTIONAL REQUIREMENTS

A. Administrative Software Change: The capability shall be provided for the user to enter the software program and make changes and modifications to the database (e.g. class of service, feature assignment, line and trunk access). Access shall be both local and remote.

B. PBX Switch Delays Connection: All calls shall be connected in a virtually non-blocking method.

C. Signal Tone Consistency: PBX switch signaling tones shall be in accordance with CCITT recommendations. Telephone busy tones (60 IPM) shall indicate that a telephone is busy. Fast busy tone (120 IPM) shall indicate that the PBX switching equipment or trunk circuits are busy. Audible ring-back tone shall be returned to the calling party to indicate that the called number is ringing.

D. Tone and Pulse Compatibility: The PBX shall be compatible with Dual Tone Multi- Frequency (DTMF) telephone instruments using standard equipment or electronic telephone sets.

E. Classes of Service: The PBX shall offer a choice of class of service categories for each user. A minimum of ten (10) different classes of service shall be available. The service class shall define the calling privileges of the associated station.

F. Console-less Operation: The PBX shall be equipped to permit operation without an attendant console.

G. Direct Inward Dialing (DID): The PBX switching shall be equipped to permit the routing of incoming calls from an incoming trunk directly to the called party without attendant intervention.

H. Direct Outward Dialing (DOD): The PBX shall allow users, based on class of service, to obtain access to the network without attendant assistance.

I. Intercom/PA: The PBX shall support Intercom/PA capability to be implemented in the future.

J. Hunting (Circular and Sequential): The PBX shall be equipped to permit hunting. The instructions for proceeding from the called number to a desired series of other numbers shall be programmable, as either a sequential or unique series of numbers, in a unidirectional or circular pattern.

K. Line Lockout with Warning: When a telephone is off-hook for a predetermined length of time without originating a call, the PBX shall release the connection and a "howler" signal shall be provided to alert the user. When the telephone is placed back on-hook, dial tone shall be restored and the howler automatically removed. The "Howler" signal shall be provided to the off-hook telephone for a minimum of 1 minute.

L. Night answer Service: The PBX shall be equipped to permit manual or automatic transfer or answering of incoming calls normally directed to user's telephone or to an answering service, or to a specified extension.

M. Multiple Trunk Access Codes: Trunk access code assignment shall accommodate two or three digit access.

N. Flexible Numbering: The PBX implementation shall support the existing system dial plan including connecting:

1. Any line number to any line circuit.
2. Any line number for direct inward calls.
3. Any access code for outward dialed calls to any trunk.
4. Three or four digit user numbers.

O. Trunk Answer from any Telephone: The PBX shall be equipped to permit a night answering arrangement, activated by a user, whereby incoming calls energize a common signal (bells, horns, or gongs) and any user can answer the call by entering a one or two digit code.

P. Live System Programming: PBX programming shall be accomplished from any Maintenance Terminal or personal computer/ laptop without disrupting operation of the system.

Q. Customer Set Relocation: Convenient procedures shall allow customer set relocation without the need for service calls.

R. PIN Number: The ability to restrict placing outside calls (off-network) or to limit placing outside calls by entering predefined codes shall be a feature of the PBX. Use of the PIN Number shall not be restricted to specific lines.

S. Overflow: The PBX shall permit forwarding unanswered calls to a designated operator station to overflow to another destination after a definable time period.

T. Caller ID: Caller ID shall appear on all digital telephone instruments. IDs of Wayside and Intra-system calls shall be displayed in a fashion that identifies the originating point as a station, signal house (letter designation) and TPSS (number).

U. Station Detail Recording: The system shall be capable of providing call detail records.

V. System Traffic Recording: Call statistics must be maintained and reports must be available to on demand identifying activity for any period up to a year as well as automated monthly reports. Traffic statistics such as incoming/outgoing calls, individual stations, and key resources should be available.

W. TDD Support: The system shall provide TDD (telecommunications devices for the deaf) support, including prompts in TDD tones.

X. Dynamic Reconfiguration: The system shall allow the reconfiguration of the system via the Administrative or Maintenance Terminals.

Y. Remote Diagnostic/Maintenance: Ability for the system to be accessed from a remote location in order to determine fault conditions and to test, modify or change the software program.

Z. 911 Service: The system shall allow local notification to take place for emergency calls made from either the Operations Control Center (including local Control Center Rail Offices) or from any of the station facilities regardless of whether the call goes out over an analog or DS-1 trunk. The system shall operate so that when the number 911 is dialed from either facility it will provide the 911 system features to all access lines at the location. The 911 system features shall include:
   1. Automatic Location Identification.
   2. Automatic Number Identification.
   3. Selective Routing.

AA. Existing Digital Phones: The system must support the existing Avaya 6400 series digital telephones.

BB. Redundancy: The system provided shall provide an availability of 99.999%. Therefore software and hardware shall be included to accommodate failure of the processing server to a backup processor running in an active hot-standby mode. The processors shall monitor each other with the standby processor taking control of the failed primary processor. In addition the system provided shall be capable of being physically separated up to 1000 meters with no more than a 5% increase in processor loading.

CC. System Management: It is required that all diagnostics, maintenance, administration, and monitoring operations be supported by a centrally maintained database. All system management and control functions must be accessible through local and remote PC LAN/WAN connections, using a web browser via the internet. The management system shall support:
   1. Network Management
   2. Fault Management
   3. Configuration Management
   4. Performance Management
   5. Directory Management
   6. Quality of Service Manager

DD. System Administration: The system shall support administrative functions using user friendly tools. The management system shall be operated by GYI tools, formatted screens, pulldown menus, and templates. As a minimum the following capability shall be provided for system and group functions:

System
   1. Station move, adds, and changes
   2. Trunk group definition and individual trunk circuit programming
   3. Telephone parameters

4. Call restriction assignments
5. Class of service
6. Routing tables
7. Group definitions and assignments
8. Feature access codes
9. Dial plan
10. Paging/code call assignments

Groups
1. Hunt
2. Call coverage answer
3. Pickup
4. Intercom
5. Trunk

EE. System Reports: As a minimum the following system activity and performance reports shall be provided:
1. Call Coverage identifying distribution of traffic
2. 24 Hour Packet Error History – history of packet level statistics
3. Network Usage - including detailed data for all intercom and trunk calls
4. Call Processor - identifying the degree of call processing load.
5. Tracelog - to include IP end point registrations, Ethernet interfaces and VoIP traffic
6. Traffic – reports for trunk circuits, trunk groups, and stations
7. Trunk Line – reports for number of call attempts, traffic intensity (Erlangs), and identification of any blocked trunk lines.
8. Busy Hour Traffic Analysis – measurements for trunks, stations, and internal switched network.
9. Erlang Ratings – Calculations for individual trunk lines, each trunk group
10. Call Detail – Call record data including items such as Date, Time, Call Duration, Account Code, Dialed Number, Calling Number, Authorization Code, ISDN Access Code, ISDN Bear Capability, Call Bandwidth, Time in Queue, Incoming/Outgoing Trunk ID.

FF. System Security: The system shall provide private secure connections that can be configured between the Head-End PBX, Remote PBX Modules and remote peer units that employ real-time media encryption. The Communications Manager shall capture and report the following security events:
1. Successful and failed admin logins
2. Successful and failed endpoint authentication
3. Denial of Service attacks
4. SAT administration changes, including data describing the exact

change.
5. Logout.

GG. Network Security: In addition to security features for access to the system, the system shall include security features to protect the existing system supporting mailboxes.

HH. System Administration/Maintenance: System functions shall be provided to update changes, monitor and detect failures and errors via the System Administration/Maintenance Terminal. The maintenance diagnostics shall include monitoring of port and service circuit packs, power units, switch over to backup systems, and provide alarm information that alerts maintenance personnel of system errors by a variety of means for failure analyses and alarm reporting. As a minimum the following shall be provided:

1. Threshold Alarms
2. Major/ minor alarms
3. Remote diagnostics for performance and diagnostic assessments.
4. Packet Sniffing
5. VoIP Debugging
6. QoS Detection

II. System Expansion: The system provided must accommodate 20% expansion capability at the Head-End PBX and at each Remote PBX Module.

1.09 REQUIRED USER FEATURES FOR EXISTING OFFICE TELEPHONES

The new telephone system shall support the user features identified below for the existing digital office telephones located at the South Hills Village facility.

A. Features: All features shall be available to any user in the OCC or at any phone in the South Hills Village Facility

B. Automatic Call Back Busy: On encountering a busy signal, a user with the appropriate class of service shall be able to request that the PBX alert him when both lines are idle. The requesting user's telephone shall be able to operate normally while waiting for the callback signal. The user shall be able to cancel the command at will or upon receipt of the callback signal. The call back shall be denoted by a distinctive ring.

C. Automatic Redial: The PBX shall be equipped to permit any user to re-try the connection to any busy destination automatically.

D. Variable Call Forwarding: The PBX shall be equipped to permit a user to program a number, using his telephone, to which all calls will be forwarded. The class of service of the forwarding telephone shall not change the class of service of the telephone to which calls are forwarded. Forwarding to network destinations shall be permitted, based on the originating user's class of service. The PBX shall provide an audible or visual indication to the user, with a telephone instrument equipped to receive such indication that his telephone is still in a call-forwarding mode. The user shall be able to deactivate call forwarding.

E. Call Hold: The PBX shall be equipped to permit users to place any call on hold and to return to that call at will via a dialing code or, if a telephone instrument is so equipped, the use of a dedicated feature button.

F. Call Pickup: A user shall be able to answer any call directed to another user within a programmable call pick up group by dialing a special code. If more than one (1) telephone in a group is ringing, calls shall be picked up sequentially in the order in which they started ringing.

G. Call Transfer: The PBX shall be equipped to permit either internal or external calls directed to a user to be transferred to another user, by depressing the telephone switch-hook and entering the number to which the call is to be transferred. The party making the transfer can disconnect prior to the call being answered.

H. Consultant Hold: The PBX shall be equipped to permit users to place a call on hold and be able to dial a third party. The user shall be able to release or hold the call, establish a second consultation call, return to the original call or connect the original call and the consulted party together.

I. Common Speed Dial: The PBX shall be equipped to permit preprogrammed abbreviated dialing (1, 2 or 3 digits) of frequently dialed numbers within or outside the PBX switches. This common speed dial list shall be accessible to any user at the OCC. A minimum list of 25 numbers of at least 10 digits each is required.

J. Individual Speed Dial: The PBX shall be equipped to permit abbreviated dialing (1, 2, or 3 digits) on a user-controlled basis. With the exception of emergency telephones, each individual speed dial list shall contain a minimum of 10 numbers of at least 10 digits. The OCC console phones shall require a minimum of 25 numbers of at least 10 digits.

K. Camp-On: The PBX shall be equipped to permit camp-on for calls reaching a busy user. Users with the appropriate class of service will receive a distinctive tone signal when they are on their telephone indicating that a second call is waiting. The user can place the first call on hold to answer the second call and have the capability of returning to the original call.

L. Busy Override: The PBX shall permit a user, based on class of service, to override a busy signal and enter a previously established conversation. The PBX shall provide a warning tone that indicates the third party's entry to the conversation.

M. Call Priority: The PBX shall be implemented to recognize calls from Emergency Phones and place them at the head of the cue for response by the Passenger Assistance Agents. The Agents shall be notified of the pending priority call.

1.10 INHERENT CAPABILITY

A. Future Capacity: As a minimum, the PBX/Remote PBX Modules provided shall have the capacity to accommodate the future implementation of the following functions:
   1. Four Additional LAN connections
   2. VoIP transport.
   3. Standard data interfaces.
   4. Computer Telephone Integration, including support for both TAPI and TSAP

1.11 NUMBERING PLAN

A. The Contractor shall work with the Authority to coordinate the numbering plan with the existing plan for the telephones and ensure that it readily allows identification of calls originating at the remote sites.

1.12 TRAINING

A. Contractor shall provide System Administrator training for <u>four</u> of the Port Authority's employees. As a minimum the training shall provide:
   1. Training shall be conducted in a class room environment at the vendor's facility with hands-on instruction by the manufacturer's certified instructor.
   2. One working administrative console for each Port Authority trainee shall be provided.
   3. The training shall cover all administrative and maintenance reports provided for the system.
   4. Training shall cover system traces available for all installed equipment.
   5. Training shall cover moves, adds, and changes for all installed equipment
   6. Training shall cover all user, installer, and system programming available on all installed equipment.
   7. The Contractor shall provide one copy of each manual used in the training for each trainee, plus one set of manuals for the OCC.
   8. The Contractor shall provide the Port Authority with additional

copies of the any administrative manuals for the duration of the warranty period and any subsequent maintenance contract periods at no additional charge.

9. The Contractor shall cover any and all training costs associated with travel, meals, and lodging for Port Authority employees if training is done outside of the local area. Local being defined as any area within thirty miles of the Manchester Office location.

B. Administration Manual Updates

1. The Contractor shall provide, at no cost to the Port Authority, any revisions to administration or maintenance manuals required due to system upgrades and/or changes in software for the duration of the warranty period and any subsequent period covered by maintenance contracts.

ARTICLE 2 PRODUCTS

2.01 SYSTEM REQUIREMENTS

A. The telephone system consists of the PBX located at the OCC and Remote PBX Modules interconnected via an Ethernet ring as shown on Contract Drawing CM037, telephones, telephone cables and ancillary equipment as specified herein, to form an integral part of the Communications System.

B. The new PBX shall be an AVAYA system or one that is equivalent with the features/requirements defined herein and capable of providing interoperability with the existing telephones at the OCC and the existing stations that are currently connected to the existing PBX via the Authority's existing SONET system. As a minimum the system shall:

1. Be modular to enable expansion to full capacity without replacement of any previously installed hardware.
2. As a minimum spare memory capacity must be provided to allow for 20% expansion over and above the initial PBX capability of supporting 650 telephone extensions.
3. The internal system shall be non-blocking.
4. The existing AVAYA systems are QSIG compatible; therefore the Contractor shall provide a QSIG compatible system for reasonable feature transparency.

C. The Remote Module shall be provisioned to support 10/100 Base T Ethernet as depicted on Contract Drawing CM037. For bidding purposes the tables below are a summary of the equipment to be connected at each of the sites to be added to the current network. Actual quantities to be installed may depend on the Contractor's design and may vary from the items defined below.

Table 1-1 Station Telephone Requirements

Gateway Station	32 Analog Telephones 1 Autodial Modem 1 Local Phone Line
North Side Station	44 Analog Telephones 1 Autodial Modem 1 Local Phone Line
Allegheny Station	33 Analog Telephones 1 Autodial Modem 1 Local Phone Line

D. The telephone system shall support service to all Equipment Room Telephones installed at the following room locations within or near each NSC station:
   1. Communications Equipment Rooms (CER).
   2. Equipment rooms associated with the tunnel ventilation system.
   3. Relay/Signal Equipment Rooms.
   4. Traction Power Substations, Circuit Breaker Rooms and Tie-Breaker Rooms.
   5. Signal Rooms
   6. Police Room
   7. Maintenance Support Rooms.

E. All Equipment Room Telephones shall be on individual circuits connected to the Remote PBX Module and shall be standard manual-dialing telephones. Each circuit shall be routed to the new PBX at the OCC via the NSC Carrier Transmission System (CTS), as specified elsewhere under this contract.

F. All Patron Telephones shall be automatic ring-down telephones on individual circuits connected to the Remote PBX Module. Each circuit shall be routed to the OCC PBX and automatically rerouted to the Pitt Tower Transit Police Console.

G. All Blue Light Emergency Telephones shall be automatic ring-down telephones on individual circuits and shall be connected to the Remote PBX Module. Each circuit shall be routed to the PBX at the OCC and automatically rerouted to an OCC operations console.

H. The Fire Control Panel Telephone at each NSC station shall be automatic ring-down telephone connect to the Remote PBX Module. Each circuit shall be routed to the PBX at the OCC and automatically rerouted to an OCC operations console.

I. Existing digital phones are AVAYA 6400 series with a range of programmable features keys that must be supported by the system proposed or replaced in total with equivalent features.

2.02 REMOTE PBX MODULE

A. General: A Remote PBX Module shall be provided at each of the three stations to support the analog telephone services required for the patron emergency telephones, Blue Light Emergency Phones, and PAAC Business Telephones. The Modules shall be linked to the OCC PBX via 10/100 Base T Ethernet Ring as depicted on Contract Drawing CM037

B. The unit shall support the connection of PC's, IP phones, and trunks as well as support ISDN-PRI, T1, and PRI trunks, a Fast Ethernet WAN port, and analog phone lines.

C. Expansion: The Module provided shall be expandable or have the ability to be networked to support a growth in the system by a minimum of 20% beyond the requirements defined herein for the Remote PBX Module.

D. Alarms: The Remote PBX Module shall have features for error detection, alarms and trouble shooting. Failure of communications with the OCC shall result in the autodial of a modem to either the vendor's service center or to the OCC indicating the failure to communicate. The Vender's Service Center shall be able to run diagnostics and correct problems remotely from his facility. Detailed diagnostic information and trouble shooting shall be software based solutions accessible by laptops in the field or remotely from a Maintenance PC. Arrangements for providing this phone line to be provided by PAAC.

E. Local Exchange: In addition to supporting the OCC Link, station telephones and the tunnel emergency phones, the remote PBX Module shall provide an off-network line to the local phone company should the link to the OCC be broken for emergency calls. Arrangements for this service with the phone company to be provided by PAAC.

F. Loop Lengths: The Remote PBX Module shall support loop line lengths of 20,000 feet over # 22 AWG wire.

G. Numbering of the analog lines and the DS-1 links shall be coordinated with the CO to insure cut-through dial tone in the case of multiple failures.

2.03 UPS SYSTEM

A. The PBX and associated equipment at the OCC shall be powered by a single phase 120 VAC communications UPS power supply as specified in Section 16705 "Communications System Power Supply". The unit shall be sized to power the new OCC PBX plus 20% growth and provide a minimum of 4 hours backup power.

2.04 PROVISIONING

A. The OCC PBX shall be implemented to support the existing requirements identified in paragraph 1.07 B. as well as the requirements for the three NSC stations identified below.

B. The location and specific quantity of Patron Emergency Telephones, Equipment Room PAAC Telephones, and Fire Control Panel Telephones for each station are shown on the referenced drawings as indicated below:
   1. Gateway Station Finishes Construction Contract No. NSC-010
   2. North Side Station Finishes Construction Contract No. NSC-011
   3. Allegheny Station Finishes Construction Contract No. NSC-012

C. The location and number of Blue Light Emergency Telephones for the tunnels and elevated structures as shown on the Contract CR drawings.

2.05 SPARE PARTS

A. As a minimum one replaceable card type for each card type in the PBX shall be provided as a spare part. In addition 2 spare cards shall be provided as a spare for the replaceable cards in the Remote PBX, as well as, a spare power supply for the Remote PBXs.

2.06 PATRON EMERGENCY TELEPHONE

A. The Patron Emergency Telephone shall have at a minimum the following features:
   1. Vandal resistant, Americans with Disabilities Act (ADA) compliant, and designed for outdoor use. The Patron Emergency Telephone shall use a recessed or surface mount enclosure.
   2. One button, auto-initiate function. The button shall be identified "EMERGENCY" with associated Braille markings. The button shall activate the manual ring-down function. Contractor shall work with the Engineer and Authority to configure the telephone for manual ring-down operation and program the PBX at the OCC Facility to connect the call to Pitt Tower.
   3. LED (Light Emitting Diode) indicator that lights when the call is answered.
   4. Voice-activated, speakerphones with fast switching between transmit and receive that allow clear, normal, un-chopped two-way conversation. The unit shall automatically disconnect (go back on hook) when the individual at Pitt Tower hangs up.
   5. Powered via the phone line and be compatible with the Remote PBX Module ports. Each unit shall be compatible with touch-tone dialing and control.
   6. Minimum of one auxiliary output, optically isolated, contact closure for activating a light or CCTV (Closed Circuit Television) camera when the button is pushed.

B. Each unit shall meet, at a minimum, the following electrical specifications:
   1. Signaling: DTMF (Dual Tone Multi Frequency).
   2. Max Loop Resistance: 1500 Ohms.
   3. Frequency Response: 300 Hz to 3 kHz.
   4. Power: derived from phone line.

C. Each unit shall meet, at a minimum, the following mechanical and environmental specifications:
   1. Max Dimensions: Wall Opening
      8 W x 10 H x 4 D inches.
      Front Panel
      10 W x 12 H inches.
   2. Connectors: RJ-11, Auxiliary outputs, power if applicable.
   3. Panel: 12 gauge steel, yellow panel, secured with tamper-resistant one-way screws.
   4. Operating Temp: Patron Emergency Telephone as installed must operate reliably at -22 to +140 degrees F ambient. Patron Emergency Telephone instrument must be rated -4 to +140 degrees F at minimum.

D. Manufacturer: Surface Mount: GAI-Tronics Model # 293AL or approved equal.
   Flush Mount: GAI-Tronics Model # 297 or approved equal.

2.07 PAAC TELEPHONE

A. Telephones in communications, SACS locations, RICS equipment rooms, and Signal/Relay Rooms shall be standard single line wall telephones manufactured with proven, industry standard components. These telephones shall have, at a minimum, the following features:
   1. Standard 12-button keypad, compatible with touch-tone dialing and control.
   2. Each unit shall be connected to a single telephone line, and be compatible with PBX lines. Each unit shall be compatible with touch-tone dialing and control. The unit shall be connected to a 2-wire FXS circuit at the associated communications equipment shelter. The circuit shall be transported via the CTS to the OCC Facility for ultimate connection to the PBX, provided by others.
   3. Hearing aid compatible, with ringer volume adjustment.
   4. Dual tone ringing, 80 dab at 39 inches.
   5. Mechanical, multi-contact hookswitch, with metal baseplate.
   6. Black high-impact plastic handset and housing with 25 foot handset cord.
   7. Each unit shall meet, at a minimum, the following electrical specifications:

a. Signaling: DTMF
b. Max Loop Resistance: 1500 Ohms.
c. REN: 1.0 ± 10 percent.
d. Frequency Response: 300 Hz to 3 kHz.
e. Power: derived from phone line.

8. Each unit shall have a 5-year warranty.

B. Manufacturer: Cortelco Model # 3554-20M or approved equal.

2.08 BLUE LIGHT EMERGENCY TELEPHONE

A. Rugged, weatherproof telephone, suitable for use in areas subjected to extended temperature ranges, high-intensity vandalism, and abuse. Housing shall be stainless steel; hook-switch and cradle shall be chrome. Handset cord shall armored and three (3) feet in length. Telephone shall be equipped with ringer.

B. Programmed for Manual Ring-down operation to an OCC operator.

C. Line powered, i.e. power derived from phone line. No external power source required.

D. Compatible with 2-wire FXS circuit provided by the Remote PBX Module.

E. Loop current range 20 to 120 mA.

F. Talk battery range 24 to 56 VDC.

G. Frequency Response 300 Hz to 3000 Hz.

H. Emergency Telephone instrument must be rated at -4 to +122 degrees F minimum.

I. Emergency Telephone such as CEECO, Model SSW-321-X or approved equal.

2.09 BLUE LIGHT

A. Blue Light Dome Assembly

B. Blue Light Power Requirements: 120VAC, 25 watts, incandescent

2.10 FIRE CONTROL PANEL EMERGENCY TELEPHONE

A. Rugged, weatherproof telephone, suitable for use in areas subjected to extended temperature ranges, high-intensity vandalism, and abuse. Housing shall be stainless steel; hook-switch and cradle shall be chrome. Handset cord shall be armored and three (3) feet in length. Telephone shall be equipped with ringer.

B. Programmed for Manual Ring-down operation.

C. Line powered, i.e. power derived from phone line. No external power source required.

D. Compatible with 2-wire FXS circuit provided by the Remote PBX Module.

E. Loop current range 20 to 120 mA.

F. Talk battery range 24 to 56 VDC.

G. Frequency Response 300 Hz to 3000 Hz.

H. The unit shall be surface mounted in the Fire Control Panel

I. Color: Red

J. Emergency Telephone instrument must be rated at -4 to +122 degrees F minimum.

K. Manufacturer: CEECO, Model SSW-321-X or approved equal.

2.11 HEATERS

A. Flexible, silicone rubber heater.

B. Operate on 120 VAC power.

C. 25 Watt.

D. Heater such as Omegalux model SRFG/5-P or approved equal.

2.12 TEMPERATURE CONTROLLER

A. Temperature range 60 to 70 degrees F.

B. Temperature controller such as Omegalux model CCD101N-70 or approved equal.

2.13 TRANSFORMER

A. Step-down transformer for Blue Light Emergency Telephones

B. Step-down Voltage: 277/120VAC

C. Installation: Mounted inside junction box.

2.14 TWO-PAIR STATION PROTECTOR

A. Designed to meet Telcordia TR-TSY-000070, GR-1361-CORE, GR-974-CORE, and RUS PE-80 requirements.

B. Equipped with heavy-duty gas-tube modules with a DC breakdown voltage of 265-600 volts (400 volts nominal).

C. DC holdover of less than 150 ms.

D. An insulation resistance of greater than 100 MΩ.

E. Station Protector such as Marconi Model 394 or approved equal.

2.15 CROSS-CONNECT BLOCKS

A. Contractor shall provide cross connect blocks that are compatible with the equipment room's main distribution frame.

B. Cross-connect side of cross connect blocks shall accept 20-26 AWG insulated conductors and 18-19 AWG skinned conductors.

C. Equipped with fanning strip on cross reconnect side to organize jumpers.

D. UL listed.

E. Cross-Connect Block such as Krone 25-Pair FT Block or approved equal.

2.16 ELECTRICAL WIRE

A. Annealed, ninety-eight percent (98%) conductivity, soft drawn copper.

B. 600-volt insulation.

C. NEC type THHN / THWN such as manufactured by the Okonite Co.; Carol Cable Co. Inc.; General Cable Corp.; Pirelli Cable Corp. or approved equal.

2.17 EMERGENCY EXIT SIGN

A. An Emergency Exit Sign shall be installed next to each Blue Light Emergency Telephone indicating the stationing location of the telephone and the distance to the nearest emergency exits to the right and left of the telephone. The signs shall be attached to the walls of the tunnel with mounting screws, adhesives are not acceptable.

B. Minimum size 8 in wide by 6 in high.

C. Sign Material: Reflective Surface to be provided and submitted for approval.

D. Black letters on white background. Vinyl letters permanently bonded to the sign material. Minimum height of letters shall be 0.5 inch.

E. Wording: “Emergency Telephone – Station XXX.XX”, where XXX.XX indicates the unique station identification for the sign to be supplied by the Engineer.

F. Distance to Nearest Exist: Left and Right Arrow with distance to exist in feet.

G. Suitable for long term, outdoor display.

2.18 GROUND MATERIALS

A. Ground Wire: Minimum No. 6 AWG stranded copper ground wire shall be furnished and ties to the common ground cable.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Contractor shall provide all equipment, hardware, accessories, terminal blocks, protector blocks, cabinets, conduits, raceways, cable trays, and wire required for installation of the PBX, Remote PBX Module and all telephone instruments defined in this Section.

B. In each station and OCC communications equipment room, the Contractor shall make all necessary connections and cross-connections as required to ensure interoperability among all new and existing equipment.

C. Installation of all telephones shall be in accordance with approved Contractor Drawings and consistent with industry standard telephone practices and subject to approval by the Engineer.

D. Installation of all telephones shall be consistent from site to site to provide uniformity in telephone installations.

E. Unless otherwise specified, all attachment hardware including, but not limited to, hangers, brackets, clamps, bolts, nuts, or washers shall be hot-dip galvanized. The zinc coating shall be of commercially pure zinc and shall be continuous and through with at least 2 ounces of zinc per 1 square foot of galvanized surface. Plating shall not scale, blister, or be removed by any process of handling during installation. All material shall be cut, formed, or drilled prior to plating.

F. Penetration of drilled anchors shall not exceed three (3) inches in the bored tunnel.

G. Final conduit locations shall be determined by the Contractor for approval by the Engineer for all tunnels and aerial structure mounted emergency telephone units installed as part of the Work.

H. All painting shall be performed prior to installation. Any painted areas damaged during shipment or installation shall be repainted with matching colors.

I. Contractor shall coordinate with the Engineer and identify the naming convention used by Authority for phones and correlate this with the names used in this Section.

J. All wires, cables, and each conductor of multi-conductor cables (except lighting and receptacle wiring) shall be uniquely identified at each end with wire and cable markers.

K. The Contractor shall ground the PBX, which shall be tied via a separate isolated ground wire to the designated ground bus. In addition the Contractor shall provide ground wire and proper grounding for all telephone protectors.

L. The Contractor shall procure and provide four phones of each type phone specified under this contract and any associated light fixtures.

M. The Contractor shall take all precautions necessary to protect existing Authority equipment. This shall include but not be limited to temporarily powering down equipment and disconnection of circuits. Existing Authority equipment damaged as a result of Contractor not taking precautions shall be repaired or replaced as necessary to restore the equipment to its previous state at no additional expense to Authority.

3.02 TELEPHONE INSTRUMENT INSTALLATION

A. Each line-powered telephone instrument shall have, at minimum, a dedicated two-pair cable as specified herein from the telephone location to the assigned frame block in the communication equipment room.

B. At all locations, all telephone instruments, connecting blocks, and terminals shall be labeled with extension numbers. Contractor shall coordinate with Authority and the Engineer to assign PBX telephone extension numbers. All locations shall be field verified by Contractor, referenced to the Contract Drawings, and approved by the Engineer.

3.03 PATRON EMERGENCY TELEPHONE INSTALLATION

A. Patron telephones shall be installed at each NSC station in accordance with the locations shown on Reference Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012. Patron Telephones to be installed as shown on finish contract plans for each station. See "Also Plans". Patron Telephones shall be installed using stainless steel, tamper resistant screws.

3.04 EQUIPMENT ROOM TELEPHONE INSTALLATION

A. A wall-mounted PAAC business telephone shall be installed in each location as identified on Reference Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012. The telephone shall be mounted on a junction box with modular wall phone jack. The center of the junction box shall be 54 inches above the finished floor.

3.05 FIRE CONTROL PANEL EMERGENCY TELEPHONE

A. Fire Control Panel Emergency Telephones shall be installed at each NSC station where shown on Reference Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012. The emergency telephones shall be mounted inside Fire Control Panel.

3.06 INSTALLATION OF PHONES IN GATEWAY/NORTH SHORE TUNNEL

A. General

1. The phones in the Gateway/North Shore Tunnel between Gateway Station and Location 6024+50 shall be serviced from the Gateway Station Communications Equipment Room. The phones in the Gateway/North Shore Tunnel between Location 6026+50 and North Side Station shall be serviced from the North Side Station Communications Equipment Room. All power and telephone cabling defined in this subsection shall originate from their respective communications equipment rooms and terminate at each phone.
2. The Contractor shall install phones at the locations indicated on the Contract CR Drawings.
3. The Contractor shall refer to Sheet CM041 of the Contract Drawings for Mounting Details to Bored Tunnel Walls.
4. Each phone shall be mounted in a telephone enclosure, which includes a blue light assembly, heater, and ID Stationing Tag as indicated on the Emergency Telephone Assembly Drawing CM040.

5. The Contractor shall install separate inbound and outbound cables per the Contract Drawings to service the e-phones. Each phone shall be terminated on a separate telephone cable twisted pair.

B. Installation
   1. The Contractor shall install 18-pair telephone cable in conduit as indicated on the Contract Drawings per Section 16702 "Copper Outside Plant".
   2. All multi-pair cable splice connections shall be made on the terminal block located inside the Emergency Telephone Enclosure.
   3. The Contractor shall provide 277 VAC power cabling to blue light and heaters as shown on the contract drawings. Contractor shall size power wiring and provide conduit and junction boxes as required.

C. Testing
   1. The Contractor shall conduct testing of each e-phone as specified in Section 16901, "Communication System Inspection and Test."

3.07 INSTALLATION OF E-PHONES IN NORTH SIDE TUNNEL

A. General
   1. The phones Between North Side Station and Location 6050+00 shall be serviced from the North Side Station Communications Equipment Room. All power and telephone cabling defined in this subsection shall originate from the North Side Station communications equipment room and terminate at each phone.
   2. Contractor shall install e-phones at the locations indicated on the Contract CR Drawings.
   3. Contractor shall refer to Sheets CM039 CM041 of the Contract Drawings for Mounting Details to Bored and Boxed Tunnel Walls.
   4. Each phone shall include a blue light assembly and heaters as indicated on the Emergency Telephone Assembly Drawing.
   5. Contractor shall install separate inbound and outbound cables per the Contract Drawings to service the e-phones. Each phone shall be terminated on a separate telephone cable twisted pair.

B. Installation
   1. The Contractor shall install 18-pair telephone cable in conduit as indicated on the Contract CR Drawings per Section 16702 "Copper Outside Plant".
   2. All multi-pair cable splice connections shall be made on the terminal block located inside the Emergency Telephone Enclosure.
   3. The Contractor shall provide 110 VAC power cabling to blue lights and heaters. The Contractor shall size power wiring and provide conduit and junction boxes as required.

C. Testing

1. The Contractor shall conduct testing of each phone as specified in Section 16901, "Communication System Inspection and Test."

3.08 INSTALLATION OF PHONES ON THE ALLEGHENY AERIAL STRUCTURE

A. General

1. The phones between Location 6052+00 and the end of the Allegheny Aerial Structure shall be serviced from the Allegheny Station Communications Equipment Room. All power and telephone cabling defined in this subsection shall originate from the Allegheny Station communications equipment room and terminate at each phone.
2. The Contractor shall install e-phones at the locations indicated on the Contract Drawings.
3. The Contractor shall refer to Sheet CM038 of the Contract Drawings for Mounting Details on an aerial structure.
4. Each phone box assembly shall include a blue light assembly, heaters, surge protector, and ID Stationing Tag as indicated on the Emergency Telephone Assembly Drawing.
5. The Contractor shall install separate inbound and outbound cables per the Contract Drawings to service the e-phones. Each phone shall be terminated on a separate telephone cable twisted pair.

B. Installation

1. The Contractor shall install 18-pair telephone cable in cable troughs as indicated on the Contract Drawings.
2. All multi-pair cable splice connections made in the cable trough shall be protected by a splice closure.
3. The Contractor shall provide 110 VAC power cabling to blue lights and heaters. The Contractor shall size power wiring and provide conduit and junction boxes as required.
4. The Contractor shall connect surge protectors to local ground point on aerial structure.

C. Testing

1. The Contractor shall conduct testing of each e-phone as specified in Section 16901, "Communication System Inspection and Test"

3.09 INSTALLATION OF PBX

A. The Head-End PBX and all associated equipment including the Administrative/Maintenance Terminal and printer shall be installed in the OCC Communications Equipment Room (Room 206) along with the associated MDF, incoming lines, subscriber line terminations, protector blocks and other related system equipment. Required cabling internal to the facility shall be provided by the Contractor, as well as necessary cabling between facilities, protector blocks, and any other necessary equipment required for safe and proper operation of the system.

B. The UPS System required for providing 120 VAC backup power to the PBX will be installed in the OCC building basement in Room 107. Detail requirements for the UPS System are specified in Section 16705, "Communications System Power Supply".

C. Any new backboards required shall be a minimum of 1 inch thick, fire retardant telephone backboards painted white. If necessary, backboards provided at the station equipment rooms. The size and location of all backboards shall be subject to the approval of the Engineer.

D. The Contractor shall provide wiring, installation, and testing for the PBX and its UPS and all circuits designated for the new PBX at the OCC Facility.

E. The Contractor shall perform all required testing to verify and ensure all equipment and circuits provided under this Contract operate properly with operation approved by the Engineer.

F. The Contractor shall conduct testing of the PBX/Remote PBX Module/Station Phones as specified in Section 16901, "Communication System Inspection and Test.

G. The Contractor shall coordinate with the Port Authority and the Engineer, for cutover and all interfacing and testing with the Existing PBXs.

3.10 REMOTE PBX

A. The Remote PBX Module shall be installed in the Communications Room of each station along with any associated MDF, incoming/outgoing lines, terminations, protector blocks, and other related field system equipment.

B. The Remote PBX Module shall be connected to the UPS System being installed at each Communications Equipment Room under Section 16705, "Communications System Power Supply". The UPS System shall be sized to supply power to all communications equipment in the CER including the Remote PBX Modules. The UPS battery system shall be sized to provide backup power for 4 hours in the event primary AC power is lost.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16721.001 - Telephone System shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16721.001 - Telephone System will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16722

RADIO SYSTEM EXPANSION

PART 1 GENERAL

1.01 SUMMARY

A. This project work shall consist of providing a complete Radio System for the North Shore Connector segment of the Light Rail Transit (LRT) system integrated into the existing Radio System. The work site consists of approximately three miles of dual tunnel, three multi-level transit rail passenger stations, and augmentation of the OCC equipment.

B. The NSC Radio System shall provide radio communications for the 470 MHz LRT users integrated with the existing systems, for the NSC segment, both above ground and below ground. The NSC Radio System shall provide radio communications for the Transit Police, as well as several UHF-Band Support Agencies, users integrated with the existing systems, for the NSC segment, in the passenger stations and below ground. LRT and Support Agency radio services are provided by existing systems with above and below ground infrastructures. The NSC Radio System will add one above ground base station site at Allegheny Station that will provide radio signal on the NSC above ground right of way and feed radio signal to the tunnel Bi-Directional Amplifiers through an RF-on-fiber transmission system. The NSC radio service area shall include the three NSC LRT stations; Allegheny, North Side and Gateway along with the interconnecting tunnels and above ground right of way.

C. The Work of this Section consists of designing, furnishing, installing, testing, and commissioning improvements to the Authority's existing radio system for the Authority's Light Rail Transit (LRT) System, as described in the Contract Documents and as specified herein. The complete system responsibility shall include the following: Site surveys, system provisioning, installation and construction, integration, optimization, acceptance testing and commissioning, spares, documentation, training, and warranty.

D. The NSC Radio Communications System segment supplied under this Section shall be integrated into existing LRT Radio Communication System as implemented by the Authority. This integration includes, but is not limited to, interfacing with the Operations Control Center (OCC) display and user consoles to provide control and operation of the LRT Radio System in the same manner as the existing radio sites.

E. The NSC Radio System shall consist of, but is not limited to, the following major items, all of which shall be supplied by Contractor as part of the implementation of this Work:

1. Voter Modules
2. Bulk Delay Module
3. Base Stations
4. Antenna System
5. RF on Fiber Optic System

6. Bi Directional Amplifiers (BDA)
7. Antenna Systems including Radiating Coaxial Cables
8. All Interface Electronic Equipment

1.02 RELATED SECTIONS

A. Section 01300 Submittals

B. Section 01840 Interfaces

C. Section 16901, Communication System Inspection and Test

D. Section 16950 Operations Control Center (OCC) System Upgrade

1.03 REFERENCED STANDARDS

A. Code of Federal Regulations, Title 47.Part 15, Part 90

B. National Electrical Code (NEC) Current Revision

C. NFPA-130 Standard for Fixed Guideway Transit and Passenger Rail Systems (2007)

D. Electronic Industry Association/Telecommunications Industry Association (EIA/TIA) Standards 152, 603

E. National Electrical Manufacturers Association (NEMA) Standard 250

F. American National Standards Institute (ANSI)/Insulated Cable Engineers Association (ICEA) Standard S-80-576

G. Electronics Industry Association (EIA) Standard RS-359

H. MIL-STD-810, "Environmental Test Methods and Engineering Guidelines"

I. UL Standard 444 Communications Cables

1.04 SUBMITTALS

A. Submit product data sheet/manual for each product and major component specified

B. Submit Shop Drawings for each component and for the Radio System

C. Submit hardware and software design plans, for approval by the Engineer

D. Submit wiring diagrams, for approval by the Engineer

E. Submit Product Certifications signed by the product manufacturers certifying compliance with the specifications

F. Submit Equipment Arrangement Plan, for approval by the Engineer

G. Submit Installation Plan, for approval by the Engineer

H. Submit qualifications of installation and optimization personnel

I. Submit Allocation and Provisioning Plan, for approval by the Engineer

J. Submit Software and Firmware Plan, for approval by the Engineer

K. Submit Inspection and Test Plan and Procedures, for approval by the Engineer

L. Test Reports, for approval by the Engineer

M. Submit maintenance data, materials, products, and spare parts list

N. Submit Operating and Maintenance Manuals

O. Submit As-Built Drawings and As-Configured data and documentation, for approval by the Engineer

1.05 NSC RADIO SYSTEM EXISTING CONDITIONS

A. The existing LRT Radio System provides communication throughout the entire Authority LRT System. The FCC licensed channels used in the NSC Radio System above and below ground are indicated in Table 1.

TABLE - 1

Radio Channels	**Transmit**	**Receive**	**Above Ground**	**Below Ground**
LRT Operations	470.6625 MHz	473.6625 MHz	X	X
LRT Support	470.7375 MHz	473.7375 MHz	X	X
LRT Data	470.6125 MHz	473.6125 MHz	X	X
LRT Yard	470.6875 MHz	473.6875 MHz		
LRT Right of Way (ROW)	471.8125 MHz	474.8125 MHz	X	X
Transit Police	452.7750 MHz	457.7750 MHz		X
City of Pittsburgh Police	453.1000 MHz	458.1000 MHz		X
City of Pittsburgh Police	453.2500 MHz	458.2500 MHz		X
City of Pittsburgh EMS	462.9500 MHz	467.9500 MHz		X

City of Pittsburgh Fire Dept.	453.7000 MHz	458.7000 MHZ		X

1.06 NSC RADIO SYSTEM RELIABILITY PERFORMANCE

A. The NSC Radio Communications System shall provide two-way radio voice and data communications for the system frequencies as indicated in the above table. The NSC Radio Systems shall provide above and below ground communications for Allegheny Station, North Side Station, Gateway Station, the NSC tunnel system, and within 500' of above ground right of way. The NSC Radio System shall provide radio communications, over all of the right-of-way and station areas including the platform, mezzanines, walkways, ticket areas and associated NSC radio system elements. The NSC Radio System includes an above ground Base Station site feeding the NSC below ground system. The NSC Radio System shall communicate with mobile and portable radios.

B. The Contractor shall provide minimum -97dBm RF signal from the OCC to a portable radio in a moving LRV. Successful talk-in or talk out for voice or data shall be possible 98 percent of the time in the NSC service area.

C. The Contractor shall not desensitize the receivers more than 1dB with all base stations transmitting, Talk Around excepted. The Contractor shall either re-optimize the site RF filters or add additional filters to mitigate the condition if the RF site is degraded more than specified. Transmitter Carriers shall be attenuated at the radio receivers.

D. The Contractor shall not degrade the noise floor more than 1dB of the radio receivers with all radios transmitting, Talk Around excepted. The Contractor shall either re-optimize the site RF filters or add additional filters to mitigate the condition if the RF site is degraded more than specified. Transmitter Noise shall be attenuated in the receiver pass band.

PART 2 NSC PRODUCTS

2.01 LRT VOTER COMPARATORS MODULE

A. The Authority operates four Voter Comparators at OCC, one for each LRT channel (Operations, Support, Data, and ROW), Raytheon/JPS Model SNV-12. One additional Voter Module is required in each Voter Comparator to add the NSC site. The Control Processor Module software of Model SNV-12 shall be upgraded if required for compatibility with the new Voter Module. The Voter Modules shall be furnished, installed, configured and programmed as required to include the North Shore Connector into the existing Voter Comparators. All other necessary Voter Comparator components shall be incidental.

B. Manufacturer: Raytheon/JPS
   Model #: SVM-2 Site Voter Module.

2.02 BULK DELAY MODULE

A. The Authority operates a Simulcast Equalization System at OCC for the LRT channels (Operations, Support, Data, and ROW) which equalizes and delays the audio signal to the existing LRT radio transmitter sites. The existing Simulcast Equalization System equipment shelf is Convex Model 2342. One four channel Bulk Delay Module is required in the existing chassis to add the four LRT channels for the new NSC Base Station site. The Bulk Delay Module shall be furnished installed, configured, programmed, and simulcast optimized for both the Prime and Redundant audio paths on the NSC CTS as required to add the North Shore Connector into the existing Simulcast Equalization System. All other necessary Simulcast Equalization System components shall be incidental. The NSC CTS provides a Prime and Redundant audio path for audio distribution to the radio site. The Network Management System indicates when the Redundant NSC CTS path is in use through a contact closure. The bulk delay and equalization are different for the two paths. The Bulk Delay Module can store Prime and Redundant bulk delay and equalization parameters. The Simulcast Equalization System shall be programmed to use the Prime parameters when the Prime NSC CTS path is in use. It shall use the redundant parameters when the Redundant NSC CTS path is in use. The switch between the Prime and Redundant parameters shall be automatic based on the path indication contact closure from the Network Management System.

B. Manufacturer: Convex
   Model #: 2042 Bulk Delay Module 4 channel.

2.03 PENTA PCX VOICE MATRIX LINE CARD

A. The Penta PCX Voice Matrix Line Card is specified in Section 16950.

2.04 AGELESS GPS MASTER OSCILLATOR

A. The Authority operates a simulcast radio system for the LRT channels (Operations, Support, Data, and ROW) which requires synchronized radios at each transmitter site. The Ageless GPS Master Oscillator shall be manufactured by Spectracom to provide the necessary synchronization for simulcast at the NSC base station site. The Ageless GPS Master Oscillator shall be furnished, installed, configured and programmed as required to include the North Shore Connector into the existing simulcast radio system. All other necessary Master Oscillator components shall be incidental.

B. Manufacturer: Spectracom
   Model #: 8195B
   Option 02: Internal Battery Backup
   Option 14: CTCSS Outputs 1 and 2

2.05 CTCSS FILTER BOARD

A. The Authority operates a simulcast radio system for the LRT channels (Operations, Support, Data, and ROW) which requires synchronized CTCSS and PTT. One CTCSS Filter Board is required for each simulcast channel at the new NSC transmitter site. The CTCSS Filter Board shall be manufactured by Spectracom or approved equal. The CTCSS Filter Board shall be furnished, installed, configured and programmed as required to include the North Shore Connector into the existing simulcast radio system. All other necessary CTCSS Filter Board components shall be incidental.

B. Manufacturer: Spectracom
   Model #: 1118-1

2.06 GPS ANTENNA

A. The Authority operates a simulcast radio system for the LRT channels (Operations, Support, Data, and ROW) which requires a suitable GPS Antenna for the Ageless GPS Master Oscillator. The GPS Antenna shall be manufactured by Spectracom or approved equal. The GPS Antenna shall be furnished, installed, configured and programmed as required to include the North Shore Connector into the existing simulcast radio system. The coaxial cable between the GPS Antenna and the Ageless GPS Master Oscillator shall comply with all Spectracom requirements including the maximum allowed cable loss. All other necessary GPS Antenna components shall be incidental.

B. Manufacturer: Spectracom
   Model #: 8225

2.07 GPS ANTENNA SURGE PROTECTOR

A. The Authority operates a simulcast radio system for the LRT channels (Operations, Support, Data, and ROW) which requires a suitable GPS Antenna Surge Protector. The GPS Antenna Surge Protector shall be manufactured by Spectracom or approved equal. The GPS Antenna

Surge Protector shall be furnished, installed, configured, and programmed as required to include the North Shore Connector into the existing simulcast radio system. All other necessary GPS Antenna Surge Protector components shall be incidental.

B. Manufacturer: Spectracom
   - Model #: 8226 Surge Protector
   - Model #: 8226-0002-0600 Grounding Kit

2.08 LRT BASE STATIONS

A. The LRT Base Station radios shall be M/A-COM or approved equal. The radios shall be FCC Type Accepted OWDTR-0039E or approved equal. The radios shall be furnished, installed, configured, programmed, and simulcast optimized as required to include the North Shore Connector into the existing simulcast radio system. Note that one LRT Base Station is programmed for simplex operation and is used for Talk Around. All other necessary radio components shall be incidental.

B. Manufacturer: M/A-COM
   - Model #: SXVMCX - 470-494MHz Conventional Advanced Digital Capable Radio, 100 Watts
   - Model #: SXPS9R - Power Supply, 120VAC/ 60Hz, 1 per Station
   - Model #: SXSF1W - Voting Tone- 1950Hz Includes 4- Wire Audio
   - Model #: SXDP1B - Test Data printed Factory Test Results

2.09 TRANSIT POLICE AND SUPPORT SERVICES BASE STATIONS

A. The non-simulcast Transit Police and Support Services Base Station radios shall be M/A-COM or approved equal. The radios shall be FCC Type Accepted OWDTR-0039E or approved equal. The radios shall be furnished, installed, configured, programmed, and optimized as required to include the North Shore Connector into the existing radio systems. All other necessary radio components shall be incidental.

B. Manufacturer: M/A-COM
   - Model #: SXUMCX - 450-470 MHz Conventional Advanced Digital Capable Radio, 100W
   - Model #: SXPS9R - Power Supply, 120VAC/ 60Hz, 1 per Station
   - Model #: SXSF1W - Voting Tone- 1950Hz Includes 4- Wire Audio
   - Model #: SXDP1B - Test Data printed Factory Test Results

2.10 RADIO COMMUNICATIONS CABINETS

A. The Radio Communications Cabinets shall be suitable for communications as required by the Base Station manufacturer. The Radio Communications Cabinets shall be M/A-COM or approved equal. The Radio Communications Cabinets shall be furnished, installed, and configured as required. All other necessary Radio Communications Cabinets components shall be incidental.

B. Manufacturer: M/A-COM

Model #:	SXCA1U - 83" CABINET, as required by site drawings
Model #:	SXFNIA - 2 SPD FAN, 120 VAC as required by manufacturer
Model #:	SXMN3Y - mounting hardware kit (1 per Cabinet)
Model #:	SXMN9C - Cover, Screen, T/R Shelf, as required by manufacturer
Model #:	SXMN9H - Cabinet Top CVR, 1 per Cabinet

2.11 BI-DIRECTIONAL SENSOR

A. The Bi-Directional Sensor shall be dbSpectra or approved equal. The Bi-Directional Sensors shall be furnished, installed, and configured with each Base Station as required to monitor forward and reflected power. All other necessary Bi-Directional Sensor components shall be incidental.

B. Manufacturer: dbSpectra

Model #:	DB8882A-100
Frequency Range:	406-1000MHz
Phono Plug, Output:	0-5 VDC
Directivity, F/B Isolation:	20 dB
Insertion Loss:	0.1 dB or better
VSWR:	1.2:1 or better
Connectors:	N-Female and N-Male

2.12 RF POWER METER

A. The RF Power Meter shall be dbSpectra or approved equal. The RF Power Meter shall be furnished, installed, and configured with each Base Station as required to monitor alarm forward and reflected power. All other necessary RF Power Meter components shall be incidental. The RF Power Meter alarms shall be sent to the OCC via the Communications RTU for Talk-Around and LRT RF channel coordination at the Penta Console.

B. Manufacturer: dbSpectra

Model #:	DB8820A
Frequency Range:	30-1000 MHz
Max. Rated Power:	100 Watts
Power (AC converter supplied):	12 VDC @ approx. 100mA
Power Alarm Range:	0-350 Watts
SWR Alarm Range:	1.1 to 3.0
Analog Inputs:	Two, 0-5 volt range, 8 bits resolution (0-100, 0-350, and 0-1000)
Digital Inputs:	On, pull-to ground (100μA)
Relay Outputs:	2 amps N.O. or N.C.
Display:	6 digits (3+3) Red LED
Key Delay (adjustable):	0.5 to 2 seconds

2.13 RECEIVER MULTICOUPLER

A. The Receiver Multicoupler shall distribute the common received RF signal to the Base Station receivers at the NSC Base Station Radio site. The Receiver Multicoupler shall be Kathrein or approved equal. The Receiver Multicoupler shall be furnished, installed, configured, and programmed as required. All other necessary radio components including power supply and termination loads for unused ports shall be incidental. All unused RF ports shall be terminated with a load.

B. Manufacturer: Kathrein

Model #:	727 622
Number of Input Ports:	1
Number of Output Ports:	16
Frequency Range:	350-550MHz
Gain (System):	1 dB +1.5/-1.5dB
Noise Figure:	< 4.3 dB+0.5/-1.0dB
Amplifier IP3 (output):	>12dBm (typical)
Isolation (Rx to Rx):	25dB (Min)
VSWR (Input/Output):	<1.4
Impedance:	50Ω
DC (Input Power):	+11 to +48 VDC 9Watts Maximum
Weight:	13 lbs
Connectors:	N-Female
Temperature Range:	-20° C to +55° C
Standard Mounting Hardware:	19" Rack Mountable

2.14 HYBRID TX COMBINER

A. The Hybrid TX Combiner shall combine the LRT Base Station Transmitter RF outputs on to a common output port at the NSC Base Station Radio site. The Hybrid TX Combiner shall be Kathrein or approved equal. The Hybrid TX Combiner shall be furnished, installed, and configured as required. The Hybrid TX Combiner where integrated with other RF combining equipment shall be integrated, optimized, and tested by the manufacturer. All other necessary Hybrid TX Combiner components shall be incidental.

B. Manufacturer: Kathrein

Model #:	784-10063
Number of Input Ports:	5
Number of Output Ports:	1
Frequency Range:	350-472MHz
Insertion Loss:	<8.3dB
RF Power per Input:	100 Watts Maximum
Minimum Frequency Separation:	`0 MHz
Isolation:	70 dB Minimum
Impedance:	50Ω
VSWR:	<1.2

Dual Isolators:	included
Loads:	included
Connectors:	N-Female
Standard Mounting Hardware:	19" Rack Mountable

2.15 SINGLE CHANNEL RF FILTER

A. The Single Channel RF Filter shall pass only the desired RF frequency while attenuating all others at the NSC Base Station Radio site. The Single Channel RF Filter shall be Kathrein or approved equal. The Single Channel RF Filter shall be furnished, installed, configured, and optimized as required. The Single Channel RF Filter where integrated with other RF combining equipment shall be integrated, optimized, and tested by the manufacturer. All other necessary Single Channel RF Filter components including phase cables and connectors shall be incidental.

B. Manufacturer: Kathrein

Model #:	K6521251 D
Number of Input Ports:	1
Number of Output Ports:	1
Frequency Range:	380-470MHz
Insertion Loss:	<2.0 dB
VSWR at Pass Band:	<1.5
Impedance:	50Ω
Input RF Power per Channel:	200 Watts Maximum
Temperature Range:	-30° C to +60° C
Connectors:	N-Female
Tuning Curve:	D
Transmitter Noise Attenuation:	>30 dB
Carrier at Receiver Attenuation:	>56 dB

2.16 BAND PASS RF FILTER

A. The Band Pass RF Filter shall pass only the desired RF band while attenuating all other at the NSC Base Station Radio site. The Band Pass RF Filter shall be Kathrein or approved equal. The Band Pass RF Filter shall be furnished, installed, configured, and optimized as required. The Band Pass RF Filter where integrated with other RF combining equipment shall be integrated, optimized, and tested by the manufacturer. All other necessary Band Pass RF Filter components including phase cables and connectors shall be incidental.

B. Manufacturer: Kathrein

Model #:	790 966 A
Number of Input Ports:	1
Number of Output Ports:	1
Frequency Range:	380-475MHz
Insertion Loss:	<1.0 dB
VSWR at Pass Band:	<1.3

Impedance:	50Ω
Input RF Power:	75 Watts Maximum
Temperature Range:	-30° C to +60° C
Connectors:	N-Female
Tuning Curve:	A
Transmitter Noise Attenuation:	>35 dB
Carrier at Receiver Attenuation:	>35 dB

2.17 DUAL ISOLATOR

A. The Dual Isolator shall isolate the Base Station transmitter output port at the NSC Base Station Radio site. The Dual Circulator shall be Kathrein or approved equal. The Dual Circulator shall be furnished, installed, and configured as required. The Dual Circulator where integrated with other RF combining equipment shall be integrated, optimized, and tested by the manufacturer. All other necessary Dual Circulator components including loads, phase cables and connectors shall be incidental.

B. Manufacturer: Kathrein

Model #:	790 215
Frequency Range (MHz):	400-470MHz
Insertion Loss:	<0.5 dB
Isolation:	50 dB Minimum
VSWR:	<1.22
Impedance:	50Ω
Temperature Range:	-10° C to +55° C
Input RF Power:	100 Watts Maximum
Connectors:	N-Female

2.18 DECOUPLED POWER SPLITTER

A. The Decoupled Power Splitter shall equally divide or equally combine four RF Ports to a single RF Port at the NSC Base Station Radio site. The Decoupled Power Splitter shall be Kathrein or approved equal. The Decoupled Power Splitter shall be furnished, installed, and configured as required. The Decoupled Power Splitter where integrated with other RF combining equipment shall be integrated, optimized, and tested by the manufacturer. All other necessary Decoupled Power Splitter components including loads, phase cables and connectors shall be incidental.

B. Manufacturer: Kathrein

Model #:	725 871
Frequency Range (MHz):	400-475MHz
Power Ratio:	1:4
Insertion Loss:	<6.5 dB
Isolation:	30 dB Minimum
VSWR:	<1.2
Impedance:	50Ω

RF Power per Input:	100 Watts Maximum
Connectors:	N-Female

2.19 HYBRID DIRECTIONAL COUPLER (-10DB)

A. The Hybrid Directional Coupler shall unequally divide or unequally combine two isolated RF Ports to two isolated RF Ports at the NSC Base Station Radio site. The Hybrid Directional Coupler shall be Kathrein or approved equal. The Hybrid Directional Coupler shall be furnished, installed, and configured as required. The Hybrid Directional Coupler where integrated with other RF combining equipment shall be integrated, optimized, and tested by the manufacturer. All other necessary Hybrid Directional Coupler components including loads, phase cables and connectors shall be incidental.

B. Manufacturer: Kathrein

Model #:	720 297
Frequency Range (MHz):	400-475MHz
Attenuation (Port 1 to 3 or 4 to 2):	0.5 +0.2 dB
Attenuation (Port 1 to 2 or 4 to 3):	10.0 +0.5 dB
Directivity on Isolation Port:	>27 dB
VSWR:	<1.1
Impedance:	50Ω
RF Power:	500 Watts Maximum
Connectors:	N-Female

2.20 RF ATTENUATOR (-20DB)

A. The RF Attenuator shall reduce all input levels by 20 dB at its output port where used at the NSC Base Station Radio site. The RF Attenuator shall be Kathrein or approved equal. The RF Attenuator shall be furnished, installed, and configured as required. The RF Attenuator where integrated with other RF combining equipment shall be integrated, optimized, and tested by the manufacturer. All other necessary RF Attenuator components including loads, phase cables and connectors shall be incidental.

B. Manufacturer: Kathrein

Model #:	784 10238
Frequency Range:	0-4000MHz
Attenuation:	20.0 ±0.5 dB
VSWR:	<1.12
Impedance:	50Ω
RF Power:	2 Watts Maximum
Connectors:	N-Female

2.21 ROOF ANTENNA:

A. The Roof Antenna shall be the primary means to transmit and receive the LRT channels (Operations, Support, Data, and ROW) for the NSC right of way above ground. The Roof

Antenna shall be Kathrein or approved equal. The Roof Antenna shall be furnished, installed, and configured as required. All other necessary Roof Antenna components including attachment mechanism and connectors shall be incidental.

B. Manufacturer: Kathrein/Scala

Model #:	K733621
Type:	Panel Antenna
Frequency Range:	406-512 MHz
Gain:	9dBi
Impedance:	50 Ohm
VSWR:	< 1.4:1
Polarization:	Vertical
Front-to-back-ratio:	>17dB
Maximum input Power:	500 Watts
H-plane beamwidth:	63 degrees (half-power)
E-plane beamwidth:	63 degrees (half-power)
Connector:	N female
Weight:	13.2 lb

2.22 IN BUILDING ANTENNA:

A. The In Building Antenna shall be the primary means to transmit and receive all channels for the NSC Base Station Radio site inside the station. The In Building Antenna shall be a Sigma Wireless Technologies Ltd or approved equal. The In Building Antenna shall be furnished, installed, and configured as required. All other necessary In Building Antenna components including attachment mechanism and connectors shall be incidental.

B. Manufacturer: Sigma Wireless Technologies Ltd.

Model #:	SWANSS450W4
Frequency Range:	450-470 MHz
Gain:	4dBi
Impedance:	50 Ohms
VSWR:	< 1.5:1 typical
Polarization:	Linear
-3dB H-plane Beamwidth:	130 degrees
-3dB E-plane Beamwidth:	110 degrees
Front-to-Back Ratio:	8dB
Power Rating:	25 Watts
Connectors:	N type socket
Cables:	250mm Cable
Weight:	1.7 lbs
Radiating Elements:	Aluminum Alloy

2.23 CEILING ANTENNA

A. The Ceiling Antenna shall be the primary means to transmit and receive all channels for the NSC North Side site at the station. The Ceiling Antenna shall be MAXRAD or approved equal. The Ceiling Antenna shall be furnished, installed, and configured as required. All other necessary Ceiling Antenna components including attachment mechanism and connectors shall be incidental.

B. Manufacturer: MAXRAD

Model #:	MLPC450
Frequency Range:	450-470 MHz
Gain:	Unity
Maximum Power Input:	150 Watts
Polarization:	Vertical, Linear
Nominal Impedance:	50 Ohms
VSWR:	< 2.0:1
Radiator Material:	Solid Brass Radiator
Mounting Method:	Off-white ceiling-mounted P.A. speaker baffle
Connector:	N- female

2.24 LIGHTNING PROTECTOR

A. The Authority operates a simulcast radio system for the LRT channels (Operations, Support, Data, and ROW) transmitting above ground which require a Lightning Protector to limit damage conducted in the event of a lightning strike. The Lightning Protector shall be manufactured by PolyPhaser or approved equal. The Lightning Protector shall be furnished and installed as required including all ground connections. All other necessary Lightning Protector components shall be incidental.

B. Manufacturer: PolyPhaser

Model #: IS-VU50HN Lightning Protector

2.25 CABLE HANGER

A. The Authority will require the installation of leaky coax cable for the NSC both in stations and in tunnels. The Cable Hanger shall be manufactured by Eupen or approved equal. The Cable Hanger shall be furnished and installed with stainless steel anchor as required. The cable shall be secured to the hanger by the specified cable tie. All other necessary Cable Hanger components shall be incidental.

B. Manufacturer: Eupen

Model #:	HKHG (Universal Hook Hanger)
Overall dimensions:	6.9 inches x 3.4 inches
Cable Diameter Range:	0.59 inches to 1.97 inches
Maximum Load:	220 lb force
Flame Retardant:	UL 94V0& Halogen Free

Color:	Black (RAL 9005)
Weight:	0.3 lbs
Mechanical:	Suitable for Ceiling or Wall Mount

2.26 CABLE TIE

A. The Authority will require the installation of leaky coax cable, specified hangers for the NSC both in stations and in tunnels secured by Cable Ties. The Cable Tie shall be manufactured by Thomas & Betts or approved equal. The Cable Tie shall be furnished and installed per the manufacturer's instructions as required. All other necessary Cable Tie components shall be incidental.

B. Manufacturer: Thomas & Betts

Model #:	TY275MX
Length:	18 inches
Width:	0.270 inches
Max. Wire Bundle Diameter:	5 inches
Locking Device:	Stainless Steel Tang
Material:	Nylon 6.6 Weather Resistant
Color:	Black
Tensile Strength:	120 lbs
Temperature Range:	-40° C to +85° C
Flammability Rating:	UL 94 V-2
Application Tools:	ERG297, WT197A

2.27 COAXIAL JUMPER CABLE 1/4"

A. The Authority will require the installation of Coaxial Jumper Cable for the NSC to feed the above ground antenna at the Base Station site. The Coaxial Jumper Cable shall be manufactured by Andrew or approved equal. No Coaxial Jumper Cable shall exceed 3 foot in length to limit signal loss unless approved. The Coaxial Jumper Cable shall be furnished and installed with the cable manufacturer's connectors as required. All other necessary Coaxial Jumper Cable components shall be incidental.

B. Manufacturer: Andrew

Model #:	FSJ1RN-50B Superflex
Normal Size:	1/4"
Operating Frequency Band:	50-1800MHz
Cable Impedance:	50 Ohm
VSWR:	1.2
Peak Power:	6.4kWatt
Velocity of Propagation:	84%
Flexibility:	Super Flexible
Jacket Material:	Non-halogenated, fire retardant polyolefin
Dielectric Material:	Foam PE
Inner Conductor:	Copperclad aluminum wire

Outer Conductor Material:	Corrugated Copper
Installation Temperature:	-25 ° C to +60 ° C
Operating Temperature:	-30 ° C to +80 ° C
Storage Temperature:	-30 ° C to +80 ° C
Fire Retardancy Test Method:	IEC 60332-1, UL VW1/CATVX
Attenuation/100ft:	3.9 dB. @ 450MHz

2.28 COAXIAL FEED CABLE 7/8"

A. The Authority will require the installation of Coaxial Feed Cable for the NSC to feed the above ground antenna at the Base Station site. The Coaxial Feed Cable shall be manufactured by Andrew or approved equal. The Coaxial Feed Cable shall be furnished and installed with the cable manufacturer's connectors as required with the specified Cable Hanger. All other necessary Coaxial Feed Cable components shall be incidental.

B. Manufacturer: Andrew

Model #:	VXL5RN-50 7/8 Heliax
Normal Size:	7/8"
Operating Frequency Band:	1-5000MHz
Cable Impedance:	50 Ohm
VSWR:	1.2
Peak Power:	90 kWatt
Velocity of Propagation:	88%
Flexibility:	Very Flexible
Jacket Material:	Non-halogenated, fire retardant polyolefin
Dielectric Material:	Foam PE
Inner Conductor:	Corrugated Copper Tube
Outer Conductor Material:	Corrugated Copper
Installation Temperature:	-25 ° C to +60 ° C
Operating Temperature:	-30 ° C to +80 ° C
Storage Temperature:	-30 ° C to +80 ° C
Fire Retardancy Test Method:	IEC 60332-1, UL VW1/CATVX
Attenuation/100ft:	0.88 dB @ 450MHz

2.29 COAXIAL RADIATING CABLE 7/8"

A. The Authority will require the installation of Coaxial Radiating Cable 7/8" for the NSC both in stations and in tunnels. The Coaxial Radiating Cable shall be manufactured by Andrew Corporation or approved equal. The Coaxial Radiating Cable shall be suitable for use in the UHF Band, the 700MHz Band, and the 800MHz Band. The Coaxial Radiating Cable shall be oriented for maximum radiation as indicated by the bump on the cable jacket. The Coaxial Radiating Cable shall be furnished and installed with the cable manufacturer's connectors as required with the specified Cable Hanger. All other necessary Coaxial Radiating Cable components shall be incidental.

B. Manufacturer: Andrew Corporation

Model #:	RCT5-LTC-2A-RNT1
Normal Size:	7/8"
Operating Frequency Band:	50-1000MHz
Cable Impedance:	50 Ohm
VSWR:	1.3
Polarization:	Vertical
Peak Power:	91 KWatt
Velocity of Propagation:	89%
Jacket Material:	Non-halogenated, fire retardant polyolefin, Low Smoke and Fume, with single mica tape wrap
Dielectric Material:	Foam PE
Inner Conductor:	Copper Tube
Outer Conductor Material:	Copper Foil
Installation Temperature:	-30° C to +60° C
Operating Temperature:	-30° C to +80° C
Storage Temperature:	-30° C to +80° C
Fire Retardancy Test Method:	IEC 60332-1, UL VW1/CATVX, IEC 60332-3C-24, IEEE 383, UL 1685
Smoke Index Test Method:	IEC 61034
Toxicity Index Test Method:	IEC 60754-1, IEC 60754-2
Attenuation/100ft:	0.89 dB @ 450MHz
Coupling Loss (50%):	67 dB @6 feet
Attenuation Test Method:	IEC 61196-4
Coupling Test Method:	IEC 61196-4

2.30 COAXIAL RADIATING CABLE 1 5/8"

A. The Authority will require the installation of Coaxial Radiating Cable 1-5/8" for the NSC both in stations and in tunnels. The Coaxial Radiating Cable shall be manufactured by Andrew Corporation or approved equal. The Coaxial Radiating Cable shall be suitable for use in the UHF Band, the 700MHz Band, and the 800MHz Band. The Coaxial Radiating Cable shall be oriented for maximum radiation as indicated by the bump on the cable jacket. The Coaxial Radiating Cable shall be furnished and installed with the cable manufacturer's connectors as required with the specified Cable Hanger. All other necessary Coaxial Radiating Cable components shall be incidental.

B. Manufacturer: Andrew Corporation

Model #:	RCT7-LTC-4A-RNT1
Normal Size:	1-5/8
Operating Frequency Band:	50-1000MHz
Cable Impedance:	50 Ohm
VSWR:	1.3
Polarization:	Vertical
Peak Power:	310kWatt
Velocity of Propagation:	89%

Jacket Material:	Non-halogenated, fire retardant polyolefin, Low Smoke and Fume, with single mica tape wrap
Dielectric Material:	Foam PE
Inner Conductor:	Corrugated Copper Tube
Outer Conductor Material:	Copper Foil
Installation Temperature:	-30° C to +60° C
Operating Temperature:	-30° C to +80° C
Storage Temperature:	-30° C to +80° C
Fire Retardancy Test Method:	IEC 60332-1, UL VW1/CATVX, IEC 60332-3C-24, IEEE 383, UL 1685, UL 1581/CATV
Smoke Index Test Method:	IEC 61034
Toxicity Index Test Method:	IEC 60754-1, IEC 60754-2
Attenuation/100ft:	0.49 dB @ 450MHz
Coupling Loss (50%):	68 dB @6 feet
Attenuation Test Method:	IEC 61196-4
Coupling Test Method:	IEC 61196-4

2.31 FIBER OPTIC TRANSCEIVER

A. The Authority will require the installation Fiber Optic Transceivers for the NSC Radio System to distribute RF signal below ground of fiber optic cable. The Fiber Optic Transceivers shall be furnished and installed as required. All other necessary components shall be incidental.

B. Manufacturer: Axell Wireless Limited

Model #:	20-005601
Frequency Range (RF path):	70-3000MHz
Frequency Range (Data path):	20-35 MHz
Available Link Gain (RF path):	18 dB
Link Gain (DATA path):	0 dB
Gain Flatness:	± 1.5 dB p-p
Gain vs. Temperature -20° to 70°:	3.5 dB
Gain adjustment range (RF path):	30 dB
In/Out RL (RF path):	10 dB min.
Output IP3@ max gain:	37dBm
In/Output IP3@ 0dB gain:	33dBm
RF Impedance:	50 Ohm
Noise Figure @ 0dB (400MHz):	36dBm
Optical Transmit Power:	2.7±0.3dBm
Optical Return Loss:	>50 dB
Received power Alarm Threshold:	-10dBm (optic)
Optical Wavelength:	1310/1550nm
DC Supply Voltage:	10-12Vdc
DC Supply Current:	420mA
Unit Temperature:	+25 deg C
Operating Temperature:	-20° C to +70° C

Storage Temperature:	-30 ° C to +85 ° C
RF connector type:	SMA
Fiber Optic connector type:	FC/APC
DC Voltage:	30V Maximum
RF Input Power:	+ 10dBm Maximum
Receiver Optical Input power:	+10dBm Maximum

2.32 BI-DIRECTIONAL AMPLIFIER SYSTEM

A. The Authority will require the installation of Bi-Directional Amplifiers for the NSC North Side Station and Gateway Station to provide Radio System Coverage below ground. The Bi-Directional Amplifiers shall be furnished and installed as required. All other necessary Bi-Directional Amplifiers components shall be incidental.

B. Manufacturer: Axell Wireless Limited

Model #:	UHF Band
Downlink Frequency Range:	452.7750 - 453.7000 MHz 462.9500 MHz 470.6125 - 471.8125 MHz
Uplink Frequency Range:	457.7750 - 458.7000 MHz 467.9500 MHz 470.6125 - 471.8125 MHz Talk Around 473.6125 - 474.8125 MHz
RF Switch:	Simplex Operation on 470MHz Band
Passband Ripple:	±0.5dB
Downlink Power Amplifier:	40 Watts Linear @452-454MHz 10 Watts Linear @462.9500MHz 40 Watts Linear @470-472MHz
Downlink PA IP3:	≥63dBm ≥50dBm ≥63dBm
Duplexer Output Power:	+30dBm per channel
Uplink LNA IP3:	≥35dBm
Maximum Input Power:	+10dBm
Gain:	50dB Downlink 40dB Uplink
Gain Adjust:	0-15dB in 1dB steps (electronic)
Propagation Delay:	<5usec
VSWR:	1.5:1
Impedance:	50 Ohms
Uplink Noise Figure:	<6dB (at 40dB gain)
Uplink AGC:	30dB Dynamic Range Attack Time <5msec
AGC Output Threshold:	+10dBm ±1dBm
Sampling Ports:	-20dBm Resistive
Downlink RF Power Monitor:	0-5VDC, 5VDC Maximum

Power Supply:	110VAC
Power Consumption:	<200 Watts
Alarms Form C Relay:	High Temperature Pre- Amplifier Downlink Failure Power Amplifier Downlink Failure Pre Amplifier Uplink Failure Power amplifier Uplink Failure
Operating Temperature:	-24° C to +63° C
Storage Temperature:	-30° C to +70° C
Cooling:	Convection
Environmental Sealing:	NEMA 4X
Humidity:	95%
Mechanical:	Aluminum
Dimensions:	24"X 36"X 10"
Weight:	< 80lb
RF Connectors:	N-type Female
AC Connection:	UL rated# 12 THHN with #12 ground

PART 3 EXECUTION

3.01 INSTALLERS' QUALIFICATIONS

A. Each communications equipment component shall be installed and optimized by qualified personnel. Personnel shall provide objective evidence of their qualifications such as training and experience on particular components. Manufacturer training is required for, but not limited to base station, bi-directional amplifier, comparator, RF connector, and interface electronics installation. A minimum of five years of experience is required for, but not limited to, antenna, antenna feed system components, and telecommunications interface installation. At least one Radio System installer or tester must possess an FCC General Radio Telephone License or NABER certification while working at any Authority site.

3.02 PRE INSTALLATION SURVEY:

A. The Contractor shall perform a comprehensive survey of the subway tunnels, cross passages, vent shafts and emergency stairways prior to the ordering of the leaky feeder cable. Data for cable lengths may be compiled for the pre-engineered cable lengths. The cable routing, exact placement of drilled holes and other cable attachment points shall be determined. Personnel circulation on tunnel emergency walkways, cross passages, vent shafts, pumping stations and emergency stairways shall not be obstructed by cable installations. The leaky feeder cable shall be run in continuous lengths between BDA sites without intermediate connectors.

B. The Contractor shall survey the subway stations to include the platforms, mezzanines, emergency stairways and rooms such as the TC&C, TPSS, substation, and access hallways. This survey will enable the Contractor to determine the final detailed requirements for the radiating cable and antenna systems, RF distribution cable and miscellaneous couplers, splitters and cable taps. Refer to Section 16700, "Communications." Any identified inadequacies and required modifications shall be identified prior to the commencement of work and shall be subject to the approval of the Engineer.

3.03 INSTALLATION:

A. The Contractor shall perform all site preparation. The Contractor shall install the new NSC Radio System equipment while not disturbing operation of the existing Radio System. The Contractor shall submit a cut-over plan, subject to the approval of the Engineer which shall be used to systematically, merge the NSC with the existing Radio.

B. PAAC Support: In addition to the coordinated planning for the tunnel access, the Contractor shall cooperate with the Authority for the use of PAAC crews, rail work trains or other PAAC high-rail vehicles, which shall be used for the conveyance of Contractor personnel for the cable hanger installation and cable placement in the tunnel and station areas.

C. The leaky feeder cable may be provided in bulk reels or may be ordered in pre-engineered lengths for each cable span as determined during the site survey and other field investigations. The Contractor shall maintain accurate accounting of cable reels such that the appropriate reel is loaded for the corresponding work section. The cost of cable waste due to mishandling or installation of designated reels at incorrect work sections shall be borne by the Contractor.

D. Install all cable hangers at a nominal spacing of four feet to support the leaky feeder cable. Install leaky cable on a span basis with a continuous reel of cable. Install RF connectors on the tunnel wall within 12 inches of exits from tunnel area. The tunnel leaky feeder RF connectors shall be weatherproof in accordance with the manufacturer's recommended means and materials. The cable hanger anchor and placement shall be submitted as data sheets and shop drawings, subject to the approval of the Engineer.

E. Stations: The antenna and leaky coaxial cable shall be placed to achieve RF coverage as well as be aesthetically acceptable. Proposed arrangement for antenna and distribution cable shall be approved by the Engineer.

3.04 SPECIAL REQUIREMENTS

A. The Contractor shall test all the radiating coaxial cable, feeder cable, jumpers, antenna systems, and optical paths that are installed for the NSC radio system. The Contractor shall verify the performance (signal attenuation) of each section of RF and Optical cable after placement and connector installation. All NSC radiating coaxial cable and antenna systems that are required shall be approved by the Engineer.

B. The Contractor shall perform the final design, furnishing, the installation, and the testing of the Radio System. Certain tasks such as equipment cut-over or tunnel equipment installation may require work during non-revenue hours. The Contractor shall coordinate with the Engineer as necessary. Other efforts may be done during revenue hours and shall be coordinated by the Contractor with the Engineer as necessary.

3.05 SEQUENCING OF OPERATIONS

A. Contractor shall coordinate the sequencing of the design, installation, furnishing, and testing efforts to complete the Contract efficiently and safely. Contractor shall include planned sequencing in the Installation Plan submittal and in the schedule submittal.

3.06 SOUTH HILLS VILLAGE (OPERATIONS CONTROL CENTER)

A. The Contractor shall furnish and install Penta Line Cards as required in Section 16950. The Contractor shall interface the NSC Radio System with the existing console at the OCC. The interface is at the audio and control level requiring that certain equipment is augmented with additional modules and the Penta console is reprogrammed to add the functionality of a new radio site. Section 16950 describes the required work at the OCC. The operations personnel will control the NSC Allegheny Station base stations through the Penta consoles at the OCC. Audio signals with control are sent from the OCC to Allegheny Station for transmission on the selected base stations. Received audio signals demodulated by the base stations with status are sent from Allegheny Station to the OCC for voting and presentation to the operations personnel at OCC.

B. The Contractor shall furnish and install an additional Voter Comparator Module for each of the four existing Voter Comparators. The new module shall be programmed for NSC Allegheny Station received audio. The existing Voter Comparator shall be firmware upgraded if required for compatibility with the new card. The new module in the existing Voter Comparator shall receive inputs from NSC Radio System as well as the existing sites and communicate the best received signal for each channel to the OCC and remote display console users. The NSC integrated radio system shall permit OCC and remote display console users to selectively control transmitted signals. The interface electronics shall permit the integrated operation and control of the PAAC LRT Radio System with the OCC and remote user display and consoles.

C. The Contractor shall furnish and install an additional Bulk Delay Module to the existing simulcast equipment. The new module shall be programmed for the NSC Allegheny Station downlink audio signal delays. A delay is calculated for each direction of the CTS loop. The alternate delay shall be configured in the simulcast equipment and used when the CTS loop reverses direction. The network management system will provide a contact closure to indicate the path direction on the loop. The simulcast equipment shall be configured to automatically select the correct delay based on loop direction as indicated by the contact closure, an inherent equipment capability. The entire PAAC LRT simulcast system will require optimization to accommodate the NSC addition. The delay and alternate delay for each transmission node shall be determined by the Contractor in order to optimize the simulcast performance in accordance with the equipment manufacturer's recommendations.

D. The Penta console shall control the Talk Around base station at Allegheny Station exactly as the other sites. The Talk Around functionality shall be duplicated in the Penta console for the new radio site. All required control and status inputs from Allegheny Station shall be integrated into the console.

3.07 ALLEGHENY STATION SITE

A. The Contractor shall furnish and install the cabinets, base stations, and other site equipment at Allegheny Station. The base stations and other equipment shall be installed in accordance with the manufacturer's instructions, NEC, NFPA-130, and other applicable codes and regulations. The base stations and equipment shall be programmed and configured similar to the base stations and similar equipment at the existing PAAC radio sites. The base stations shall interface at the audio and control level with the NSC CTS. Power receptacles will be provided under a separate section of the NSC. The equipment shall be arranged according to the plans subject to the approval of the Engineer.

B. The NSC Contractor shall furnish and install Cable Hangers, RF jumper Cables, Radiating Cable, RF Connectors, RF Feeder Cable, Lightning Arrestors, and other system components that support the Radio System. The RF components shall provide signal for radio communications in the station areas, the NSC above ground right of way, and the Fiber Optic electronics.

C. The Contractor shall furnish and install Redundant RF Fiber Optic Transmitters and Receivers at Allegheny Station. The Redundant RF Fiber Optic Transmitters shall always operate together, both always transmit. The Redundant RF Fiber Optic Receivers shall be configured as Prime and Backup. The Prime Receiver shall disable the Backup Receiver while the Prime Receiver is operational. The Prime Receiver shall enable the Backup Receiver while the Prime Receiver is failed or powered off. The Fiber Optic electronics shall carry the RF signal between Allegheny Station and North Side Station or Gateway Station. The Fiber Optic electronics shall be optimized to preserve dynamic range, minimize system noise, and maintain signal sensitivity. Fiber jumper cables required to interface the Fiber Optic electronics with the NSC CTS shall be provided and installed.

D. The Contractor shall optimize the performance of the site. The contractor shall verify the audio, RF, and optical signal levels throughout the transmission paths prior to on air testing.

3.08 NORTH SIDE STATION SITE

A. The Contractor shall furnish and install the Bi Directional Amplifier (BDA) at North Side Station to provide radio coverage at the station and in the tunnels for all the channels. The BDA and other equipment shall be installed in accordance with the manufacturer's instructions, NEC, NFPA-130, and other applicable codes and regulations. The BDA shall be mounted in the Communications Room as indicated in the plans. Power receptacles will be provided under a separate section of the NSC.

B. The Contractor shall furnish and install Cable Hangers, RF jumper Cables, Radiating Cable, RF Connectors, RF Feeder Cable, Lightning Arrestors, and other system components that support the Radio System. The RF components shall provide signal for radio communications in the station areas, the below ground right of way, and the Fiber Optic electronics.

C. The Contractor shall furnish and install Redundant RF Fiber Optic Transmitters and Receivers at North Side Station. The Redundant RF Fiber Optic Transmitters shall always operate together, both always transmit. The Redundant RF Fiber Optic Receivers shall be configured as Prime and Backup. The Prime Receiver shall disable the Backup Receiver while the Prime Receiver is operational. The Prime Receiver shall enable the Backup Receiver while the Prime Receiver is failed or powered off. The Fiber Optic electronics shall carry the RF signal between North Side Station and Allegheny Station. The Fiber Optic electronics shall be optimized to preserve dynamic range, minimize system noise, and maintain signal sensitivity. Fiber jumper cables required to interface the Fiber Optic electronics with the NSC CTS shall be provided and installed.

D. The Contractor shall optimize the performance of the site. The contractor shall verify the RF and optical signal levels throughout the transmission paths prior to on air testing.

3.09 GATEWAY STATION SITE

A. The Contractor shall furnish and install the Bi Directional Amplifier (BDA) at Gateway Station to provide radio coverage at the station and in the tunnels for all the channels. The BDA and other equipment shall be installed in accordance with the manufacturer's instructions, NEC, NFPA-130, and other applicable codes and regulations. The BDA shall be mounted in the Communications Room as indicated in the plans. Power receptacles will be provided under a separate section of the NSC.

B. The Contractor shall furnish and install Cable Hangers, RF jumper Cables, Radiating Cable, RF Connectors, RF Feeder Cable, Lightning Arrestors, and other system components that support the Radio System. The RF components shall provide signal for radio communications in the station areas, the below ground right of way, and the Fiber Optic electronics.

C. The Contractor shall furnish and install Redundant RF Fiber Optic Transmitters and Receivers at Gateway Station. The Redundant RF Fiber Optic Transmitters shall always operate together, both always transmit. The Redundant RF Fiber Optic Receivers shall be configured as Prime and Backup. The Prime Receiver shall disable the Backup Receiver while the Prime Receiver is operational. The Prime Receiver shall enable the Backup Receiver while the Prime Receiver is failed or powered off. The Fiber Optic electronics shall carry the RF signal between Gateway Station and Allegheny Station. The Fiber Optic electronics shall be optimized to preserve dynamic range, minimize system noise, and maintain signal sensitivity. Fiber jumper cables required to interface the Fiber Optic electronics with the NSC CTS shall be provided and installed.

D. The Contractor shall optimize the performance of the site. The contractor shall verify the RF and optical signal levels throughout the transmission paths prior to on air testing.

3.10 NSC RADIO COVERAGE TESTING

A. Testing shall be accomplished by site. Allegheny Station shall be tested for both station radio reliability and right of way radio reliability. Below ground coverage shall be tested on a leaky feeder span basis with coverage testing to extend from the BDA under test completely along the span to the adjacent BDA, in each direction in each tunnel, with the adjacent BDA turned off.

B. Tunnel subsystem tests shall be conducted on each BDA with all spans of leaky feeder cable to a simulated portable on board a moving train. The Contractor's test plan and BDA span test procedures shall be coordinated with the Authority. These span level tests shall be conducted with acceptable results prior to the conduct of system level tests.

C. Disregarding equipment malfunctions, two-way UHF communications between the OCC and an LRV shall be possible at any location on the ROW, all tunnels areas, station related service areas, or in yard limits. Data communications shall be possible at all NSC locations at rates of at least 4800 bits per second via analog input to any radio base station/voting receiver combination. At all NSC Radio System locations, the minimum measured talk-out signal strength shall be – 97dBm. At 90 percent of the NSC locations, the minimum measured talk-out signal strength shall be –87dBm. Successful talk-in or talk out for voice or data shall be possible 98 percent of the time. The NSC Contractor shall attempt no less than a combination of 100 voice and data communication events at different locations to determine this success rate for LRV.

D. Disregarding equipment malfunctions, two-way UHF communications between the OCC and hand-held portables shall be possible at any location within the NSC radio system stations, platforms, mezzanines and related communications areas, on the ROW or in yard limits. Coverage shall also be possible on any public station or stop platform, mezzanine, escalator, hallway or staircase. At all locations the minimum measured talk-out signal strength shall be – 97dBm. At 90 percent of the locations so designated, the minimum measured talk-out signal strength shall be –87dBm. At all locations the minimum measured talk-out signal strength shall be –97dBm. Successful talk-in or talk out for voice or data shall be possible 98 percent of the time. Contractor shall attempt no less than 100 voice communication events at different locations to determine this success rate for hand-held portables.

E. The quantitative talk-out field tests shall be conducted, at the NSC stations, in the tunnels, and on the ROW using an omni-directional 0dB gain antenna mounted on the top of an LRV and attached to either an RF field strength meter or a spectrum analyzer, subject to the approval of the Engineer. Either measurement device shall have an NTSB traceable calibration certificate that the Engineer may request to see. The measurements shall be conducted using a continuous wave transmitted signal without audio. The measurement bandwidth shall be that of a single audio channel and the configuration of the measurement device shall be subject to the approval of the Engineer. The quantitative talk-out field tests, for a portable unit, shall utilize the same measurement device but may use a device-mounted omni-directional 0dB gain antenna, with the appropriate attenuator to reflect the inefficiency of a portable and the attenuation of the signal penetrating the LRV vehicle to a portable unit with the radio and antenna at the hip level, in the LRV, furthest away from the radiating coaxial antenna system.

3.11 INADEQUATE RF COVERAGE MITIGATION VERIFICATION

A. Contractor shall demonstrate, subject to the approval of the Engineer, that the above coverage requirements have been met by establishing voice and data communication for the NSC radio system. Further, Contractor shall establish voice communications links within and to any public station or stop platform, mezzanine, escalator, hallway and staircase. Engineer will designate which specific sites to be demonstrated. Any failure to establish a communications link within the above coverage requirements shall be reason to declare the installation incomplete, subject to the approval of the Engineer.

B. If the Engineer declares the installation incomplete because of inadequate coverage, Contractor shall perform all modifications to existing equipment and/or licenses and shall add new NSC Radio System equipment as necessary to meet the coverage requirements.

PART 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16722.001 – Operations and Control Center Upgrade including final design, equipment, installation, optimization, programming, configuration, testing, documentation, and acceptance of the new modules for the radio system will be measured as a lump sum. This line item does not include work that is part of Section 16950.

B. Item 16722.002 – Allegheny Station work including final design, equipment, installation, optimization, programming, configuration, testing, documentation, and acceptance of the site for the radio system will be measured as a lump sum except Radiating Cable which is addressed in Item 16722.005 and Item 16722.006..

C. Item 16722.003 – North Side Station work including final design, equipment, installation, optimization, programming, configuration, testing, documentation, and acceptance of the site for the radio system will be measured as a lump sum except Radiating Cable which is addressed in Item 16722.005 and Item 16722.006.

D. Item 16722.004 – Gateway Station work including final design, equipment, installation, optimization, programming, configuration, testing, documentation, and acceptance of the site for the radio system will be measured as a lump sum except Radiating Cable which is addressed in Item 16722.005 and Item 16722.006.

E. Item 16722.005 – Radiating Cable 7/8" work including final design, equipment, installation, optimization, testing, documentation, and acceptance of the cable section will be measured per linear foot.

F. Item 16722.006 – Radiating Cable 1-5/8" work including final design, equipment, installation, optimization, testing, documentation, and acceptance of the cable section will be measured per linear foot.

4.02 PAYMENT

A. Item 16722.001 – Operations and Control Center Upgrade including final design, equipment, installation, optimization, programming, configuration, testing, documentation, and acceptance of the new modules for the radio system will be paid as a lump sum. This line item does not include work that is part of Section 16950.

B. Item 16722.002 – Allegheny Station work including final design, equipment, installation, optimization, programming, configuration, testing, documentation, and acceptance of the site for the radio system will be paid as a lump sum except Radiating Cable which is addressed in Item 16722.005 and Item 16722.006.

C. Item 16722.003 – North Side Station work including final design, equipment, installation, optimization, programming, configuration, testing, documentation, and acceptance of the site for the radio system will be paid as a lump sum except Radiating Cable which is addressed in Item 16722.005 and Item 16722.006.

D. Item 16722.004 – Gateway Station work including final design, equipment, installation, optimization, programming, configuration, testing, documentation, and acceptance of the site for the radio system will be paid as a lump sum except Radiating Cable which is addressed in Item 16722.005 and Item 16722.006.

E. Item 16722.005 – Radiating Cable 7/8" work including final design, equipment, installation, optimization, testing, documentation, and acceptance of the cable section will be paid per linear foot.

F. Item 16722.006 – Radiating Cable 1-5/8" work including final design, equipment, installation, optimization, testing, documentation, and acceptance of the cable section will be paid per linear foot.

SECTION 16741

VARIABLE MESSAGE SIGN/PA SYSTEM

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the variable message sign/pa system, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to the design coordination and implementation of the following activities:
1. Contractor shall furnish all labor, material, equipment, supervision, transportation, and miscellaneous services, whether or not explicitly identified herein, to provide a completely tested and fully operational VMS/PA system at each station.
2. The work of this Section also includes furnishing and installing the VMS/PA system station and platform equipment at Gateway Station, North Side Station and Allegheny Station. This equipment includes, but is not limited to, loud speakers, ambient noise microphones, fire panel microphones, and VMS signs as shown on Contract Drawing CM023 and at the locations shown on the reference drawings from Authority Contracts NSC-010, NSC-011 and NSC-012 and as specified herein, to form an integral part of the Communications System.
3. The work of this Section also includes furnishing and installing VMS/PA system equipment including, but not limited to, VMS/PA controllers, pre-amplifiers, power amplifiers, automatic level controllers, racks, cable and other miscellaneous mounting hardware located in the Communications Equipment Rooms (CER) at Gateway, North Side and Allegheny Stations.
4. The work of this Section also includes any modifications required to the OCC equipment and the NSC carrier transmission system required to support the additional VMS signs and speaker zones installed as part of the Work.
5. The work of this Section also includes furnishing and installing all cables between the station communications devices and the CER using conduit installed under the Authority Station Contracts as shown on the reference drawings for the Gateway Station Finishes Contract NSC-010, North Side Station Finishes Contract NSC-011 and Allegheny Station Finishes Contract NSC-012.
6. The work of this Section also includes coordination with Authority personnel for the testing and commissioning of the VMS/PA equipment as described in this Section.

C. The Contract Documents provide the performance parameters and design criteria to complete the Variable Message Sign/PA System. The Contractor shall be responsible to provide a complete design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16700, "Communications."

B. Section 16705, "Communications System Power Supply"

C. Section 16901, "Communication System Inspection and Test."

D. Section 16950, "OCC Upgrade."

1.03 REFERENCE STANDARDS

A. EIA Standard 310.

B. UL Standard 1480.

C. ADA.

D. NFPA 72, "National Fire Alarm Code, Chapter 4"

E. NFPA Standard 130, "Standard for Fixed Guideway Transit Systems."

F. ANSI/ICEA Standard S-80-576.

G. EIA Standard RS-359.

1.04 SUBMITTALS

A. System Design.

B. Product Data, Shop Drawings and specifications.

C. Functional Site Block Diagram.

D. Arrangement Plan.

E. Installation Plan.

F. Wiring Plan.

G. Power Wiring Plan.

H. Software and Firmware Plan.

I. Allocation and Provisioning Plan.

J. Integration Plan for Variable Message Signs/PA System, which shall be a detailed description of how the new station equipment will be integrated with existing OCC equipment.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Contractor shall ensure that equipment has not been damaged during shipping or storage. Equipment shall be shipped separately from the equipment racks in which they are to be installed. Equipment shall remain in the original packaging until the time of installation. All equipment shall be stored in a protected area until installed.

1.06 OPERATIONAL DESCRIPTION

A. The VMS/PA system shall consist of double-faced, ADA compliant, LED signs installed at each of the NSC stations. ADA compliance requires that audio announcement at a station occur while the corresponding text message appears on the LED signs for that zone at the station.

B. The VMS/PA system shall include VMS signs, station control units, and audio amplification equipment at each station; and a GEisys computer control system located in the OCC building. The GEisys system provides public address and variable message sign information to patrons in the stations.

C. The VMS/PA equipment installed at the NSC stations must interface with the existing VMS/PA computer control system located at the OCC and the existing VMS/PA workstation at Pitt Tower. The control center equipment consists of a PC server and two PC workstations, with control software and graphical user interface (GUI) that performs the following functions:
   1. Create/Edit text messages to be displayed on signs.
   2. Create digitized audio messages to be played on the PA.
   3. Create/Edit a schedule for the messages.
   4. Select and control which stations will play the various messages.
   5. Provide live announcements at the stations.

D. The schedule, text messages, and digitized audio messages are downloaded to the station controller, which can play messages immediately or according to the schedule. The messages are downloaded to the station control unit via an Ethernet interface using the NSC CTS.

E. Provide background music from radio station WQED when no other higher priority announcements are required at a station.

ARTICLE 2 PRODUCTS

2.01 SYSTEM REQUIREMENTS

A. General Requirements
   1. Contractor shall install VMS/PA equipment at the new North Shore Connector

Stations (Gateway, North Side, and Allegheny).

2. Contractor shall integrate new VMS/PA equipment with the existing VMS/PA System located at the OCC to operate as a single integrated system.
3. The VMS/PA System consists of variable message signs, station control units, audio equipment, and ancillary equipment as shown on Contract Drawings CM023 and the referenced Contract Drawings from Authority Contract NSC-010, NSC-011 and NSC-012 and as specified herein, to form an integral part of the Communications System.
4. All new VMS/PA system components shall be totally compatible with the existing GEisys computer system..
5. Contractor shall modify/upgrade the OCC GEisys computer system software, database and displays, as described in Section 16950, "OCC Upgrade" to accommodate the new VMS/PA equipment installed at the new stations.

B. Functional Requirements

1. The VMS/PA System shall include a Station Control Unit (SCU), audio equipment, speakers, and VMS signs at each NSC station.
2. The existing VMS/PA System head-end server in the OCC shall download the audio/visual message files and schedules to the station controller units. One Ethernet connection per station shall be used for this purpose. The head-end server shall be capable of transporting all control and system data under full load conditions with no loss of operation or timing.
3. The station controllers shall accept and implement commands to play, stop, repeat, delete, and view audio/visual messages and schedules, from the head-end server in the OCC.
4. Stations shall be divided into two or more separate PA zones: the platform zone(s) and a mezzanine/entrance level zone.
5. Each station shall have one pre-amplifier with two independent audio output channels, one for each zone. Each zone shall have a separate power amplifier. A minimum of two power amplifiers shall be provided at each station.
6. Contractor shall configure the pre-amplifier so that all audio inputs, regardless of priority level, shall be assigned to all outputs, such that each PA zone plays the same announcement.
7. The amplification equipment shall have multiple inputs whereby each input can be assigned a unique priority via the local front panel controls. Higher priority inputs shall have precedence over lower priority inputs. The inputs shall have priority assigned in the following order, where 1 = highest to 6 = lowest, as shown in Table 16741-1. Lower priority inputs that are pre-empted by higher priority inputs are not recorded or placed onto a queue.

Table 16741-1 -Announcement Priority Levels	
Priority Level	**Source of Announcement**
1,2	Local microphone inputs from Fire Control Panel (minimum of 1)
3	Live announcements from Pitt Tower
4	Live announcements made via the OCC Computer System
5	Pre-recorded audio announcements made via the VMS/PA System
6	Background music

8. Each station shall be provided with a double-faced, amber color, LED (Light Emitting Diode) VMS sign, one for each track. These VMS signs shall be ADA (Americans with Disabilities Act) compliant.
9. Each VMS sign shall be associated with the appropriate zone coverage provided for by the audio system. Each sign shall have a unique address to allow for individual data communications with a single sign.
10. Station-level components of the VMS/PA System shall consist of four elements: audio switching, audio processing, microphone and speakers, and the controller.
11. The station VMS/PA System shall deliver the sound levels, specified herein, at ear level, and provide coverage to more than 95 percent of the total station platform area. Contractor is responsible for providing the coverage described herein, and shall propose to the Engineer any modifications required to do so. Contractor shall submit a report detailing speaker placement and coverage area as part of the Arrangement Plan described herein. The audio output level shall use ALC (Automatic Level Control) by using an ambient noise sensor associated with the station platform area. This sensor, in conjunction with its control module, shall automatically and electronically adjust the audio level of announcements an average of 6 dBa above ambient noise levels. In no case shall volume at the ear level exceed 115 dBa. Contractor shall provide these sound levels for all NSC stations.
12. The pre-amplifier shall be configured to provide a consistent audio output level for all source inputs. Contractor shall compensate for variable line levels from source inputs by adjusting input trim controls and/or programming preset volume levels associated with each input to the pre-amplifier.

2.02 STATION CONTROL UNIT

A. The Station Control Unit (SCU) at each station shall be a COTS, industrial rated, microprocessor controlled, modular system, rack mounted in each station communications room.

B. The following summarizes the general operating parameters and functions which the combined components will perform as an operating unit:

1. The remote equipment will provide a passenger station with the facilities for remote control of pre-recorded station platform announcements to the patrons from the VMS/PA system. Customer Sevice will be able to select stations,

scheduled time/date, day, and frequency by which to play the announcements.

2. The Movement Director will have connectivity to any station in the system via the CTS, SONET network. The SCU at each station shall be capable of communicating with the OCC head-end server via an Ethernet interface.
3. The SCU shall contain two RS-232 serial ports. One port will be used to communicate with the PA controller, the other to communicate with the VMS units. One RS-232 port shall be converted to RS-485 for communication with the VMS units supplied as part of the Work. Each sign at the station shall have a unique address. The SCU shall communicate to each sign at a minimum data rate of 9600 bps.
4. The head-end equipment located in the OCC Facility shall provide the ability to address and page individual station, groups of stations or, the entire light rail system. A continuous display of station status on the control consoles in the OCC indicates when a station is free for selection, successfully addressed, malfunctioning, or being overridden by audio/visual messages from Pitt Tower.
5. Each SCU shall have its own logical address and respond with a unique station verification code sent back via the CTS after it has received a transmission. The head-end server shall acknowledge the corresponding station by indicating a status icon on the operator interface, indicating to the operator that this station is on-line and communicating properly.
6. The SCU shall have mass storage by means of solid-state flash RAM mass storage system with a minimum capacity of 8 GB (unformatted). Hard disk drives will not be used in the SCU. The SCU shall also have a CD-ROM drive and USB interface for maintenance purposes, such as installing software, running diagnostics.
7. The SCU shall contain a sound card capable of playing the pre-recorded 16 bit audio announcements.
8. The SCU server to be supplied as part of the Work shall be equipped as follows:
   a. Intel Pentium 42 GHZ Processor (minimum)
   b. G4E606-P-G Revision Controlled Motherboard
   c. 300 W Power Supply
   d. Integrated Realtek RTL8101L Fast Ethernet controller
   e. Integrated VGA Graphics Accelerator
   f. 1 GB RAM memory
   g. Integrated AC97 audio
   h. Windows XP or newer Operating System
   i. IDE Minimum 8 GB flash drive
   j. Two USB2.0/1.1 ports
   k. ATEN IC485S RS-232 to RS-485/RS-422 serial protocol converter

C. Manufacturer: Advantech or approved equal

2.03 STATION AUDIO EQUIPMENT

A. Fire Control Panel Microphone Preamplifier:

1. The preamplifier shall accept the FCP microphone signal and boosts it to line level. The preamplifier shall meet the following specifications:
   a. Inputs: One, microphone-level
   b. Gain: Adjustable, 50 dB nominal
   c. Input Impedance: 150 to 600 ohms balanced
   d. Output Impedance: 150 ohms balanced
   e. Frequency response: $\pm$ 1 dB 50 Hz to 30 kHz
   f. THD+N: Less than 0.05%
   g. Noise: Less than –66 dBu with 150 ohm input termination
2. Manufacturer: Radio Design Labs, Model STM-1 or approved equal

B. Fire Control Panel Microphone
1. The Fire Control Panel shall be equipped with a microphone for making announcements over the PA system during an emergency. The microphone shall meet the following specifications:
   a. Type: Moving coil dynamic microphone
   b. Impedance: 600 ohm balanced
   c. Sensitivity: -55dB
   d. Frequency Response: 50 Hz to 12 kHz
   e. Talk Switch: Slide on/off switch
   f. Cable: 10 meter XLR-F shielded cable with ¼" phone plug
   g. Accessory: Microphone holder.
2. Manufacter: TOA, Model DM-1200 or approved equal

C. Ambient Noise Sensor
1. Automatic level control (ALC) shall be accomplished using sensor microphones for each zone on the platforms and mezzanines in combination with the PA Controller in the communications equipment room. The Sensor shall be mounted inside the station on a louvered stainless steel one-gang electrical box cover plate. The audio level throughout the station platform area will be adjusted automatically to maintain an average of 6 dBA above ambient noise levels, with a $\pm$ 2 dBA tolerance from this differential.
2. The sensing microphones supplied under this contract shall meet the following specifications:
   a. Transducer Type: Electret condenser
   b. Frequency Range: 80 Hz to 10 kHz, typical
   c. Polar Pattern: Hemispherical
   d. Impedance: 75 ohms, balanced
   e. Sensitivity: 1.4 V/Pa (line-level)
   f. Operating Temperature Range: 14° to 140° F
   g. Materials: Stainless steel, louvered plate, high-impact plastic capsule holder, plastic capsule membrane
3. Manufacturer: Crown, Model PZM11-LLWR or approved equal

D. PA Controller

1. The PA controller has eight inputs, each suitable for use with microphone- or line-level signals. Each input shall be capable of assignment to any of eight audio-sensing and automatic priority levels. Activity on inputs with higher priority will automatically and completely mute all inputs with lower priority assignment. The PA Controller shall have ten independent audio output channels. All inputs shall be played at all zones (all-call). PA controller faults are reported to the SCU via serial communication.
2. The PA controller shall meet the following specifications:
   a. Gain: 17 dB minimum
   b. Frequency Response: ± 2 dB from 20 to 20,000 Hz
   c. Output level: +20 dBu (+18 dBV) balanced
   d. Distortion plus Noise: Less than 0.1 % THD from 20 to 20,000 Hz
   e. Input Impedance: 20 kilohms balanced
   f. Signal to Noise Ratio: -70 dBr A-weighted 20 to 20,000 Hz.
3. Manufacturer: Crown, Model USM-810 or approved equal

E. Automatic Level Control (ALC)
1. Ambient-noise sensing automatic level control is a feature of the PA controller.
2. Specifications:
   a. Controller Input Impedance: 20 kilohms, balance
   b. Automatic Gain Range: 20 dB in 0.5 dB steps
   c. Controller Signal to Noise Ratio: -70 dBr A-weighted 20 to 20, 000 Hz
   d. Controller Distortion plus Noise: Less than 0.1% THD from 20 to 20,000 HZ

F. Power Amplifier
1. A separate power amplifier channel will be used for each station loudspeaker zone.
2. The power amplifier shall be a equipped with integral digital signal-processing (DSP) capabilities. Power amplifier faults will be detected and reported by the DSP modules to the PA controller via current-loop communication. The PA controller reports faults to the SCU via serial communications. The SCU reports faults to the OCC workstations via the CTS. The workstations shall display a fault message and shall produce an audible trouble signal upon amplifier failure. Tone-generating equipment will not be used.
3. The power amplifier shall have the following specifications:
   a. Output Power: 300 watts (rms) per channel at (70.7 V)
   b. Distortion: Less than 0.5 % THD between 20 and 20, 000 Hz at 1 W output
   c. Frequency Response: Within ± 0.25 dB between 20 and 20, 000 Hz at 1 W output
   d. Input Impedance: 20 kilohms balanced
   e. Output Loads: 4 ohms, 8 ohms, 16.7 ohms (at 70.7 V)
   f. Load Voltage: 70.7 V
   g. Signal-to-Noise Ratio: 105 dB below rated output, A-weighted
   h. Power Input: 120 Vac, 60 Hz and 220/230/240 Vac, 50 Hz
   i. Output Protection: The amplifier will include multiple automatic protection

circuits to protect against thermal damage, current limiting, overload detection, and short circuit protections.

j. Power amplifier equipented with an IQ-PIP-USP2 module to monitor audio output levels.

4. Manufacturer: Crown, Model # CTs600 equipped with a model IQ-PIP-USP2 DSP module or approved equal

G. NFPA Monitoring

1. The PA systems at Gateway, North Side and Allegheny stations shall include input signals from local fire control panel microphones which shall be monitored in accordance with NFPA 130.

2.04 SPEAKERS

A. The VMS/PA System speakers, used at the NSC station platforms and mezzanine, shall be Bogen Communications, Model A2T or approved equal with the following specifications:

1. The speaker shall be 8 inch, equipped with a mounting bracket that facilitates field adjustment. The loudspeaker shall rotate about its axis a minimum of 180 degrees to allow for proper platform coverage.
2. Speaker cone material shall be of a metallic composition.
3. The speaker shall have a continuous power capacity of up to 16 watts RMS (Root Mean Square) on a 70 volt line.
4. The frequency response shall be 45 to 20,000 Hz nominal, and be flat (± 5 dB) between 700 and 5,500 Hz.
5. The sound pressure level shall be 104 dB at 39 inch on axis with 1 watt input power.
6. The speaker shall have a voice coil with 8 ohm impedance.
7. The speaker shall provide a minimum sound dispersion angle of 100 degrees horizontal and 80 degrees vertical.
8. The speaker shall have a variable tap transformer that uses 70.7 V line voltage on the primary tap. Taps shall be available to provide 4, 8 and 16 watts to the speaker at 70.7 V line level.
9. The speaker shall meet or exceed Mil-Std-810E environmental requirements.

B. Speaker Mounting Hardware shall be installed as shown on Reference Drawings: Gateway Station Finishes Contract NSC-010, North Side Station Finishes Contract NSC-011 and Allegheny Station Finishes Contract NSC-012.

C. Audio output levels shall be verified per the test requirements indicated in Specification 16901, "Communication System Inspection and Test", Section 3.14, "Variable Message Sign/PA Inspections and Tests".

2.05 VARIABLE MESSAGE SIGNS

A. Variable message signs shall be used to display visual information from the VMS/PA System. Each station shall have a minimum of two double-sided, ADA compliant signs. The new NSC signs shall be compatible with the existing VMS equipment, such that messages can be downloaded, and controlled from the single VMS/PA head-end system at the OCC Facility. The new NSC signs shall have the following minimum specifications:
   1. Each sign shall be a high resolution, microprocessor based, LED unit consisting of the housing and the interior electronics.
   2. Each sign shall be composed of 2 lines having a minimum of 16 characters per line. Each sign display shall consist of amber colored LEDs. Each character shall be nominally 4.0 inches in height and 3.0 inches in width composed of an equally spaced monolithic dot matrix utilizing one amber 0.197 inch encapsulated LED per pixel, with a maximum spacing of 0.3 inch center-to-center. LEDs shall be arranged in blocks of 8 x 8 LEDs. LED block centered spacing shall be 0.236 inch.
   3. The LED blocks, or discrete LEDs, shall be capable of being grouped into rows and columns forming a matrix. The total matrix shall be a nominally 32 x 192 LEDs (i.e. the 8 x 8 blocks arranged into 4 rows, each row containing 24 blocks).
   4. The LED matrix shall have a viewing angle of at least 30 degrees with a brightness rating of >500 mcd min., and 135 degrees with a brightness rating of > 100 mcd using non-diffused LEDs.
   5. Each sign shall be capable of being connected to another sign and/or to the VMS/PA station controller for synchronization with the audio portion of messages. Programmable display effects shall include static, pause, flash, blink, scroll, center, open, wipe, up, down, jump, and time. The speed of the effects shall be adjustable. Characters to be displayed shall include the entire 128 ASCII character set along with the selected internal characters, and shall support pixel-based graphics. Message memory shall be 16 kilobytes, minimum.
   6. Each sign shall operate in the range from –40 to 120 degrees F, with humidity ranging from 5 to 95 percent non-condensing. The signs shall be UL listed.
   7. Each sign housing enclosure shall be provided by the NSC station reference contractor. A drawing of each sign enclosure is shown in the "ALSO" plans for this contract.
   8. Communications with each sign shall be by means of an RS-485 protocol. Each sign shall have a unique address, selectable by an internal dipswitch. There shall be a minimum of 99 different addresses. Each sign shall operate at a communications rate of 9600 bps minimum.
   9. Each LED pixel shall have a minimum full strength intensity of 10 mcd and have a minimum MTBF (Mean-Time-Between-Failure) of 5 years. Each sign shall be operational between 105 VAC to 130 VAC and be equipped with a disconnect switch for removing AC power for maintenance purposes. Line filtering shall be part of the design to minimize faults due to power line transients.

B. Manufacturer: Data Display Model # DL315 or approved equal.

2.06 CABLING AND CONNECTIONS

A. Contractor shall provide system wiring materials as follows:
   1. Power Amplifier: Conductors shall have a minimum cross sectional area of stranded conductor as is required to limit signal loss between the pre-amplifier and power amplifier to a maximum of 0.5 dB.
   2. Ambient Noise Sensor: All wiring between the ALC control units, pre-amplifier, and the power amplifiers shall use telephone cable specified herein. The wire between the ALC control units and microphone modules shall be low level cable specified herein.

B. Contractor shall furnish all equipment, hardware, accessories, terminal blocks, cabinets, conduits, raceway, cable racks, cables, and wire required for mechanical and electrical installation of the VMS/PA System as defined in the Contract Documents.

2.07 WIRE AND CABLE

A. Telephone Cable
   1. UL Listed Type MPR/CMR, conforming to ANSI/ICEA S-80-576.
   2. Conductors shall be solid tinned annealed copper.
   3. Insulation shall have color code that complies with the requirements of EIA RS-359.
   4. Minimum specifications:
      a. Conductor gauge: 24 AWG.
      b. Shield: aluminum.
      c. Capacitance: 22 pF per 1 ft.
      d. Resistance: 45 ohms per 1000 ft.
      e. Insulation: plenum rated, low flame, no smoke.
      f. Jacket: plenum rated, low flame, no smoke.
      g. Pairing: two twists per 1 foot.
      h. Temperature rating: 220 degrees F.
      i. Voltage rating: 300 volts.

B. Data Cable, Extended Distance
   1. Twisted Pair, RS-232 / RS-422 / RS-485 / DS-0, extended distance, quiet (industrial shielded).
   2. Minimum specifications:
      a. Conductor gauge: 24 AWG.
      b. Shield: foil around each pair with drain wire.
      c. Distance: Provide error-free communications up to 4000 feet at 9600 bps.
      d. Capacitance: 12 pF/ft.
      e. Resistance: 16 ohms per 1000 ft.
      f. Insulation: plenum rated, low flame, no smoke.
      g. Jacket: plenum rated, low flame, no smoke.
      h. Temperature rating: 220 degrees F.
      i. Voltage rating: 300 volts.

C. Wiring For Status Inputs, Analog Inputs, and Control Points
   1. The wire shall be class B stranded tinned copper per ASTM Standards B-3 and B-33.
   2. Minimum specifications:
      a. Conductor gauge: 14 AWG.
      b. Insulation: plenum rated, low flame, no smoke.
      c. Jacket: plenum rated, low flame, no smoke.
      d. Temperature rating: 194 degrees F.
      e. Voltage rating: 600 volts.

D. ANS Microphone Cable
   1. 2 Conductor Shielded Cable
   2. Minimum specifications.
      a. Conductor gauge: 22 AWG.
      b. Shield: aluminum polyester, tinned copper drain wire.
      c. Insulation: plenum rated, low flame, no smoke.
      d. Jacket: plenum rated, low flame, no smoke.
      e. Temperature rating: 220 degrees F.
      f. Voltage rating: 300 volts.

E. Speaker Wire
   1. 1 Twisted Pair
   2. Minimum specifications.
      a. Conductor gauge: 18 AWG.
      b. Shield: aluminum polyester, tinned copper drain wire.
      c. Insulation: plenum rated, low flame, no smoke.
      d. Jacket: plenum rated, low flame, no smoke.
      e. Temperature rating: 220 degrees F.
      f. Voltage rating: 300 volts.

F. LAN Cable
   1. 4 pairs of conductors.
   2. Minimum specifications:
      a. Conductor gauge: 24 AWG.
      b. Category: ANSI/TIA/EIA-568-A Category 5.
      c. Frequency: 100 MHz.
      d. Insulation: plenum rated, polymer alloy jacket, FEP insulation, low flame spread, no smoke.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Contractor shall install all system equipment in accordance with all Contract requirements, with approved Contractor Submittals and consistent with good commercial practices.

B. Contractor shall refer to Section 16901, "Communication System Inspection and Test" for testing requirements of VMS/PA System.

3.02 COMMUNICATION ROOM INSTALLATION

A. Contractor shall furnish and install VMS/PA equipment in the communication room at each passenger station, connect all appropriate station wiring to the rack-mounted interface terminal panel, connect interface carrier wiring to the proper wiring-frame terminals and, after testing both the VMS/PA System and carrier installations, complete the cross-connects on the wiring frame to the assigned carrier terminals.

B. Contractor shall furnish and install 120 VAC power conduit and cables within the communication room to the Communications System Power Supply (CSPS) as specified in Section 16705, "Communications System Power Supply" and as required for the VMS/PA equipment. This shall include 120 VAC conduit and cables for the operation of the variable message signs located at the station platforms.

3.03 STATION EQUIPMENT INSTALLATION

A. Contractor shall provide and install the following equipment listed below at the new NSC stations.
1. Station Controller
2. Pre-amplifier
3. Power Amplifier, one for each zone shown in Table II
4. ALC including ambient noise sensor
5. PA speakers
6. Variable Message Signs
7. Microphones at fire panels
8. Cabling and connectors
9. Racks and cabinets

B. Speaker Installation
1. Contractor shall provide and install and locate new speakers at all NSC stations. Contractor shall refer to the Contract Drawings for details regarding speaker installation.
2. Contractor shall assure that the polarization of all speakers, and proper audio cable shielding, is maintained throughout the station to insure that no distortion or noise is introduced into any VMS/PA component. The speaker transformer taps shall be adjusted to provide the sound pressure levels specified herein.

C. VMS/PA Sign Installation
1. Contractor shall provide and install new VMS LED signs at the platform and mezzanine locations indicated on the Contract Drawings.

2. Contractor shall refer to the Contract Drawings for details regarding LED sign installation.

3.04 OCC INSTALLATION

A. VMS Console Installation
   1. Contractor shall bridge the Ethernet circuits together from the existing and NSC head-end SONET Multiplexers to provide Ethernet LAN connectivity to the existing VMS control consoles at the OCC along with the existing and NSC variable message sign systems at the stations.
   2. Contractor shall also connect the live audio input circuits from the NSC Channel Bank to the VMS control console to permit live audio announcements at the NSC stations.

3.05 PITT TOWER

A. VMS/PA Workstation
   1. Contractor shall bridge the Ethernet circuits together from the existing and new NSC SONET Multiplexers at Pitt Tower to provide Ethernet LAN connectivity to the existing VMS/PA Workstation at Pitt Tower and the NSC variable message signs at the stations.
   2. Contractor shall also connect the live audio inputs from the NSC Channel Bank to the VMS/PA Workstation at Pitt Tower to permit live audio announcements at the NSC stations.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16741.001 – Variable Message Sign/PA System shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16741.001 – Variable Message Sign/PA System will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16742

SCADA SYSTEM

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the SCADA system, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the design coordination and implementation of the following activities:
1. Communications Equipment Room (CER) Remote Terminal Units (RTU)
2. Traction Power Substation, Circuit Breaker and Tie-Breaker Substation Alarm and Control System (SACS) RTUs
3. Tunnel ventilation Remote Indication and Control System (RICS) RTUs
4. Intrusion devices and wiring
5. Alarm/Indication wiring
6. Contractor shall furnish all labor, material, equipment, supervision, transportation, and miscellaneous services, whether or not explicitly identified herein, to provide a completely tested and fully functional SCADA system.
7. The work of this Section includes the installation of all SCADA equipment located in the Communications Equipment Rooms (CER), Traction Power Substations, switching stations and circuit breaker rooms, and Motor Control Centers (MCC).
8. The work of this Section includes the installation of the serial modems where used and the interconnection between the modem and the PLC as well as the 4W analog channel bank card and the modem.
9. The work of this Section also includes the installation of the control and indication wiring between the RTU and the remotely controlled and monitored device.
10. Contractor to provide a system integration test plan, which is coordinated with the OCC system. Refer to Section 16901, "Communications System Test and Inspection."
11. The work of this Section also includes the integration of all new SCADA equipment into the existing SCADA network and testing with the OCC.

C. The Contract Documents provide the performance parameters and design criteria to complete the SCADA system. The Contractor shall be responsible to provide a complete design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16700, "Communications."

B. Section 16703, "Carrier Transmission System"

C. Section 16901, "Communication System Inspection and Test."

D. Section 16950, "OCC Upgrade"

1.03 REFERENCE STANDARDS

A. EIA Standards 310 and RS-359, RS-232, RS-422 and RS-485.

B. IEC Standard 529, 68-2-6, 68-2-27, 1000-4-5, 1000-4-11, 1000-4-12 and 664.

C. UL Standards 508, 664 and 1604.

D. NFPA Standard 130, "Standard for Fixed Guideway Transit Systems"

E. NFPA Standard 72, "National Fire Alarm Code"

1.04 SUBMITTALS

A. Submit shop drawings, product data, printed installation instructions, manufacturer's literature, manufacturers' printed testing and adjusting instructions. Submittals shall include, but not be limited to, the following:
   1. Product Data: Manufacturer's catalog cuts, material specifications, and installation instructions and other pertinent data for all equipment to be furnished. Product data for the RTU shall include the following:
      a. Central processing unit (CPU)
      b. Power supplies and inverters
      c. Modems
      d. Input/output modules
      e. Mounting racks/panels
      f. Power source (surge) protection
      g. Connectorized terminal interfaces
      h. Test and diagnostic fixtures
   2. SCADA Equipment Cabinet Shop Drawings:
      a. Fabrication and assembly details: Enclosure assembly drawings showing the location of all components, such as power supplies and printed circuit card chassis, and subassemblies comprising the components to the level of printed circuit cards. The drawings shall identify each component and subassembly by part number and revision level. Each drawing shall include interconnection wiring diagrams showing all interconnecting cables, including earth and power distribution cables. An individual drawing shall be produced for each enclosure (including equipment cabinets and consoles), and a copy of each appropriate drawing shall be stored inside each enclosure, preferably on the door of the enclosure.
      b. Installation details showing layout, mounting, fastening and grounding details.

c. Rack elevation drawings for all rack-mounted equipment showing mechanical details, mounting, indicators, interconnecting cables, interconnection devices, arrangement plans and assembly drawings with complete keyed parts lists.

3. RTU/PLC Shop Drawings:
   a. Block and signal level diagrams for the Traction Power Substation, Life Safety and Communications SCADA PLCs, including detailed cross-reference to other connections.
   b. All input/output (I/O) connections.
   c. Power distribution wiring for all input and output data points, PLC's, central processing units and any other electronic equipment provided by the Contractor.
   d. Data point I/O connections and assignments for each remote PLC location. Each data point shall be listed along with its associated I/O cable, terminal plug coupler and the I/O circuit card.
4. Wiring diagrams shall show all interconnecting cables between system components and panels. Wiring diagrams and plans shall show wire numbers, wire identification, wire origination point, and wire destination point for each wire.
5. List of qualified PLC programmers/integrators to be assigned to this project for execution of this task.
6. Bill of materials that includes a complete list of all cable, equipment and installation materials furnished.
7. Manufacturer's manuals that define equipment operation, contain schematic diagrams of all circuitry, and define maintenance and alignment procedures for each item of equipment provided.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Contractor shall ensure that equipment has not been damaged during shipping or storage. Equipment shall be shipped separately from the equipment racks in which they are to be installed. Equipment shall remain in the original packaging until the time of installation. All equipment shall be stored in a protected area until installed.

1.06 EXISTING CONDITIONS

A. Authority's existing OCC SCADA System provides for the control and monitoring of Authority's tunnel ventilation system and traction power system. The control and monitoring of the tunnel ventilation system is known as the Remote Indication and Control System (RICS). The control and monitoring of the traction power system is known as Substation Alarm and Control System (SACS).

B. Authority's OCC SCADA System also monitors alarm and security points in the communications equipment rooms (CER). The Carrier Transmission System (CTS) provides the communications channels that are used by the OCC SCADA System to communicate with all three types of RTUs as shown on Contract Drawing CM043.

1.07 QUALITY ASSURANCE

A. Material shall conform to the latest IEEE, ASTM, ICEA, UL, NEMA, and ANSI standards. Contractor shall submit evidence to the Port Authority that the material furnished in accordance with these Specifications conforms to the specified standards and recommendations. The labeling of, or listing by UL will be acceptable evidence that material conforms to the requirements of UL. A certification or published specification data statement by a manufacturer, listed as a member of NEMA, to the effect that material conforms to the specified NEMA standards and to these Specifications will be acceptable evidence.

B. Electrical work shall conform to NFPA 70 (NEC). Codes referred to are minimum standards. Where the requirements of these specifications or drawings exceed those of the codes and regulations, the drawings or specifications shall govern.

C. Establish and maintain an effective quality control program to ensure compliance with contract requirements; maintain records of the control. The program shall include, as a minimum, submittals, materials, installation, and testing.

D. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification.

1.08 QUALIFICATIONS

A. The programmer/integrator must have a minimum of five (5) years' experience in the installation, programming, configuration, and software integration of similar PLC equipment.

ARTICLE 2 PRODUCTS

2.01 SYSTEM REQUIREMENTS

A. The SCADA System consists of Remote Terminal Units (RTUs) and ancillary equipment as shown on Contract Drawing CM043 and as specified herein, to form an integral part of the Communications System. Contractor shall provide CER RTUs for the three new North Shore Connector stations.

B. The SCADA System will monitor alarms and indications from communications equipment rooms (CERs). The flow of data to and from the CER RTUs will be controlled by the Operations Control Center (OCC) System which shall be expanded to accommodate the additional NSC RTUs under Section 16950, "OCC Upgrade" of this contract.

C. Monitoring of CERs shall include but not be limited to the following:
   a. Intrusion and Security Alarm
   b. Room High Temperature Alarm
   c. Cabinet High Temperature Alarm
   d. UPS System Failure

e. 48VDC Power Supply Failure
f. Emergency Egress Door Alarm
g. Radio System
   1 Base Station Power Meter – Low Power
   2. Base Station Power Meter – High VSWR
   3. Bidirectional Amplifiers Power Meter – LRT Low Power
   4. Bidirectional Amplifier Power Meter – LRT High VSWR
   5. Bidirectional Amplifier – Major Alarm
   6. Bidirectional Amplifier – Minor Alarm
   7. Fiber Optic Transceivers Summary Alarm
   8. GPS Master Oscillator – Major Alarm
   9. GPS Master Oscillator – Minor Alarm
h. Ticket Vending (future).

D. RTU(s) shall be installed in the Communications Equipment Room, Motor Control Center and Traction Power facility at each NSC location as indicated on the Contract Drawings.

E. The SCADA System shall interface to the OCC SCADA System at the OCC Facility. The OCC SCADA System shall serve as the central controller for the SCADA System.
   1. RTUs shall be configured to interface properly with the OCC SCADA System.
   2. NSC CTS communications channels shall be used to connect the OCC SCADA System to each remote NSC RTU.

F. RTUs shall be equipped with the number of I/O points to support the point lists as indicated on the Contract Drawing.

G. Intrusion detectors and associated wiring shall be installed in the CERs as indicated on the Contract Drawings and Reference Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012.

H. Wiring shall be installed between the RTU and up to 16 contact closure alarm/indication points of other communications subsystems at each CER.

2.02 REMOTE TERMINAL UNITS (RTUS)

A. The RTU shall be compact, expandable, and equipped with a run/stop switch. The RTU shall be equipped with removable, screw-type terminal strips for inputs and outputs.

B. The RTU may be comprised of a main RTU unit and expansion units. The expansion units shall be designed specifically for use with the main RTU unit and made by the same manufacturer as the main RTU unit. The RTU shall be equipped with all cabling and hardware required for the main RTU unit and the expansion units to function as an integral unit. The main RTU unit shall be equipped with a minimum of 16 status inputs.

C. The RTU shall be equipped with the quantity of status inputs shown in the Provisioning Table contained herein at minimum. All RTUs shall be capable of accommodating up to 48 status inputs through the addition of expansion units. Status inputs shall meet the following requirements at minimum:
   1. Voltage Range: 0 to 130 VDC
   2. Typical Input Current: 7.5 mA
   3. Input Resistance: 2.8 Kohms
   4. Input Threshold Voltage ON: 15 VDC minimum
   5. Input Threshold Voltage OFF: 5 VDC maximum
   6. Input Threshold Current ON: 4.5 mA maximum
   7. Input Threshold Current OFF 1.5 mA minimum
   8. Response Time: 0.5 to 20 ms configurable as regular input

D. The RTU shall be equipped with a minimum of 11 relay outputs. Relay outputs shall meet the following requirements at minimum:
   1. Operating Voltage: 5 to 130 VDC and 5 to 250 VAC
   2. Leakage Current: 15 mA
   3. Maximum Pilot Duty Rating: 2 A at 24 VDC and 240 VAC
   4. Maximum Resistive Load Rating: 2 A at 24 VDC and 240 VAC
   5. Minimum Load: 1 mA
   6. On/Off Response Time: 15 ms maximum

E. The RTU shall be equipped with 1 DC output at minimum. DC outputs shall meet the following requirements at minimum:
   1. Voltage Rating: 24 VDC, +20%, -79%
   2. Maximum Pilot Duty Rating: 0.75 A at 24 VDC
   3. Maximum Resistive Load Rating: 0.75 A at 24 VDC, 0.5 A at 12 VDC, 0.25A at 5 VDC
   4. Output Voltage Drop: 0.3 VDC maximum
   5. On/Off Response Time: 0.1 ms maximum (24 VDC, 0.2 A)
   6. Off State Leakage: 0.1 mA maximum

F. The RTU shall be equipped with a minimum of two single ended analog inputs and four differential analog inputs. Analog inputs shall meet the following requirements at minimum:
   1. Input ranges:
      a. 0 to 10VDC (10.23 VDC max.)
      b. -10 VDC to +10 VDC (10.23 VDC max.)
      c. 0 to 20mA and 4 to 20mA (20.47 mA max.)
   2. Resolution:
      a. 0 to 10VDC Range – 12 bits (1LSB=2.5 mV)
      b. -10 to +10VDC Range – 12 bits (1LSB=2.5 mV)
      c. 0 to 20mA and 4 to 20mA Range – 12 bits (1LSB=5 microamps)

3. Accuracy +/- 1% of full scale over full operating temperature range
4. Linearity +/-3 LSB maximum
5. Common mode voltage +/-40 V maximum
6. Current input impedance 249 Ohm
7. Voltage input impedance 200 K ohms
8. Input Filter Time 20 ms to reach 1% error for step input.

G. The RTU shall be equipped with minimum of one RS-232 serial port. The RS-232 serial port connector type shall be a DB-15 connector. The RTU shall be modem compatible through connection to the RS-232 serial port.

H. The RTU shall be equipped to store and execute calculation and control algorithms. The RTU program storage shall be battery backed to provide typical memory retention of two months.

I. The RTU shall be equipped to be powered by 110 VAC. The RTU shall meet the following requirements at minimum:

1.	Inrush Current:	15 A maximum
2.	Input Current:	0.1 A typical
3.	Input Power Supply Rating:	35 VA

J. The RTU shall be equipped to provide 24 VDC user power to be used by the contact closure alarm points. The 24 VDC user power shall provide up to 200 mA of current.

K. The RTU shall be capable of being mounted to a blank panel on an equipment rack, either by being mounted directly to the panel or through use of a 35 mm DIN rail.

L. The main RTU shall be no larger than 6 inches wide x 3.5 inches high. Expansion units shall be no larger than 3.7 inches wide by 3.5 inches high.

M. The RTU shall be compliant with the following environmental and agency specifications:

1.	Safety:	UL508 and UL1604
2.	Vibration:	2G @ 57-500 Hz, 0.15 mm p-p @ 10-57 Hz, per IEC 68-2-6
3.	Shock:	15G, 11 ms, per IEC 68-2-27
4.	Operating Temperature:	0 to 120 degrees F
5.	Humidity:	5% to 95%, non-condensing
6.	Enclosure protection from dust and splashing water, per IEC 529	
7.	EMC Emissions Radiated, Conducted:	47 CFR 15 part 15, subpart J
8.	Surge Withstand, Power Supply:	0.5 KV line to ground, 0.5 KV line to line, per IEC 1000-4-12
9.	Surge Withstand, Communications Port and Inputs:	1 KV, per IEC 1000-4-5 and IEC 1000-4-12
10.	Power Supply Input Variations:	±10%, per IEC 1000-4-11

N. The RTU shall be equipped and configured to operate properly with the OCC SCADA System. Changes in status of the connected alarm contacts shall be communicated to the OCC SCADA System so that the change is accurately portrayed by the OCC SCADA System. The RTU shall be equipped and configured to use the same communications protocol as the OCC SCADA System.

O. The RTU shall be comprised of GE Fanuc VersaMax Micro Controller, Part Number IC200UDR005 as a main RTU unit and GE Fanuc VersaMax Expansion Unit, Part Number IC200UEX011 as expansion units, or approved equal.

2.03 MODEM

A. Modems shall provide point-to-point transmission of four-wire full duplex or 2 wire half duplex operation over a voice grade line.

B. Modems shall provide an EIA RS-232 data interface to the OCC equipment the RTUs, Central Traffic Control (CTC), and Train to Wayside Controller (TWC) equipment.

C. Supported data rates shall include QAM 9600 or 4800 bps asynchronous (+1% -2.5%) mode, 0-1800 bps asynchronous Bell 202T mode and 0-1200 bps asynchronous V.23 mode.

D. Automatic equalization shall be provided to adjust to local cable conditions.

E. Data format shall be 8 or 9 data bits with one or more stop bits supported.

F. Transmit signal levels shall be adjustable between +3 dbm and -14 dbm. Receive levels shall be adjustable between +3 dbm and -30 dbm.

G. Modems shall come in stand-alone and rack mount versions.

H. Modems shall be powered from 110VAC.

I. Operating temperature range shall exceed -40 to +158 degrees F.

J. Modems shall be the Telenetics Model DSP9612 or approved equal.

2.04 WIRE AND CABLE

A. Telephone Cable
   1. UL Listed Type MPR/CMR, conforming to ANSI/ICEA S-80-576.
   2. Conductors shall be solid tinned annealed copper.
   3. Installation shall have color code that complies with the requirements of EIA RS-359.
   4. Minimum specifications:
      a. Conductor gauge: 22 AWG
      b. Shield: aluminum

c. Capacitance: 22 pF per 1 ft
d. Resistance: 45 ohms per 1000 ft
e. Insulation: plenum rated, low flame, no smoke
f. Jacket: plenum rated, low flame, no smoke
g. Pairing: two twists per 1 foot
h. Temperature rating: 220 degrees F
i. Voltage rating: 300 volts

B. Data Cable, Extended Distance
1. Twisted Pair, RS-232 / RS-422 / RS-485 / DS-0, extended distance, quiet (industrial shielded)
2. Minimum specifications:
a. Conductor gauge: 22 AWG
b. Shield: foil around each pair with drain wire
c. Distance: provide error-free communications up to 4000 feet at 9600 bps
d. Capacitance: 12 pF/ft
e. Resistance: 16 ohms per 1000 ft
f. Insulation: plenum rated, low flame, no smoke
g. Jacket: plenum rated, low flame, no smoke
h. Temperature rating: 220 degrees F
i. Voltage rating: 300 volts

C. Wiring for Status Inputs, Analog Inputs and Control Points
1. The wire shall be class B stranded tinned copper per ASTM Standards B-3, B-33.
2. Minimum specifications:
a. Conductor gauge: 18 AWG
b. Insulation: plenum rated, low flame, no smoke
c. Jacket: plenum rated, low flame, no smoke
d. Temperature rating: 194 degrees F
e. Voltage rating: 600 volts

2.05 SOFTWARE

A. Contractor shall provide and install software and firmware required for the proper operation of the SCADA System. Software and Firmware to be employed shall be submitted in the Software and Firmware Plan. Refer to Section 16700, "Communications" for software requirements.

B. Contractor shall provide and install software required to run on the RTUs.

C. Contractor shall provide a minimum of two copies of RTU programming software. RTU programming software shall meet the following requirements at minimum:
1. Designed to configure, administer and program the make and model of RTU to be provided

2. Windows based - Designed to install and run under all currently supported versions of Microsoft Windows.
3. Creates and edits RTU logic and associated information
4. Configures RTU hardware
5. Creates, edits and monitors the execution of ladder or instruction list logic
6. Creates motion and local logic programs
7. Checks syntax
8. Supports serial communications connection to the RTU
9. Views fault tables in the RTU
10. Displays results of actions performed in the programming software in a separate information window
11. RTU programming software shall be GE Fanuc VersaPro Programming Software or approved equal.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Contractor shall coordinate installation requirements through the Engineer to develop and define the interface between the OCC SCADA System and the RTUs installed in the CER, MCC and Traction Power facilities. The interface definition shall address both hardware and software.

B. Contractor shall furnish and install all auxiliary equipment necessary for the SCADA System to function properly, including, but to limited to racks, mounting panels, mounting rails, hardware, terminal blocks, wire, cables and connectors.

C. Contractor shall furnish and install analog modem where required by local conditions.

D. All components of the RTUs installed in the communications equipment rooms shall be powered by the Communications System Power Supply.

E. All components of the RTUs shall be grounded in accordance with the manufacturers' recommendations and the requirements of Section 16700, "Communications."

F. All wiring shall be secured into harnesses. All wiring including harnesses shall be routed in such a manner as not to obstruct the installation or removal of communications system components, and shall be secured to the rack or cabinet where appropriate for neatness and to reduce strain on components.

G. Contractor shall arrange the main RTU unit and expansion units on the equipment rack panel so that minimum rack space is occupied while providing sufficient space around components for wiring. Layout of main RTU and expansion units shall be similar for each application of RTU.

3.02 RTU INPUTS AND OUTPUTS

A. Contractor shall install wiring between the RTU and alarm/indication points at each CER.

B. Refer to the Contract Drawings for a list CER SCADA of alarm/indication points to be wired by Contractor.

C. Any unassigned input points shall be reserved for future use by Authority. A connection terminal for each input shall be provided. Input terminals shall be clearly identified in documentation.

D. All RTU inputs are to be tested in local and system testing.

E. All RTU outputs shall be reserved for future use by Authority. A connection terminal for each output shall be provided. Output terminals shall be clearly identified in documentation.

F. All RTU outputs are to be tested in local and system testing.

3.03 CTS RTU INTERFACE

A. RTUs shall be connected to OCC SCADA System via RS-232 serial data channels on the NSC CTS.

B. Where the distance between the RTU and the CTS channel bank exceeds 50 feet, RTU connections shall be made via a 4 wire analog modem connected to a 4W E&M channel interface as described in Section 16703, "Carrier Transmission System" of these Specifications.

C. All cables and associated hardware including, but not limited to, adapters, connectors and terminal strips required for proper operation of the SCADA Systems are to be provided and installed by Contractor.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16742.001 – SCADA System shall be measured as a lump sum unit, complete in place.

B. Item 16742.002- Alarm/Indication Wiring shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16742.001 – The SCADA System will be paid at the lump sum price, and shall include the cost of all related work specified in this Section.

B. Item 16742.002 - Alarm/Indication Wiring will be paid at the lump sum price, and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 16750

DIGITAL VIDEO SYSTEM

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, the design coordination and provisioning of all labor, materials, tools, equipment, and incidentals necessary for the Digital Video System, in accordance with the contract documents.

B. Scope:
  1. Provide a Digital Video System at Pitt Tower to augment the existing analog CCTV system operations at Pitt Tower. The new digital system shall monitor, record and control the new digital IP video cameras to be installed as part of this contract at the NSC stations.
  2. Provide a Digital Video System consisting of IP video cameras, a video signal transmission system, network video recorders, video management system software, video management system server, PTZ control stations, video viewing workstations, digital video decoders and video monitors.
  3. Provide a transmission system for video image and control signals, using a self-healing Gigabit Ethernet ring over fiber-optic media.
  4. Provide video-management system, which manages the archiving, video viewing and camera control rights, display and control interface of the video system.
  5. Provide graphic Video Selection Displays, which show the location of each camera at the NSC stations on a plan view of each station. The camera icons shall be used by the Video Management System software to select a camera for viewing on any monitor or display in the system and for PTZ control functions.
  6. Provide system cabinets with 19-inch equipment rack in the communication room in the three new NSC stations and the equipment room in Pitt Tower. The system cabinets shall be used to house the transmission system, servers, archiving systems, and appurtenances for the video system.
  7. Provide monitor racks and video monitors and LCD display panels in the operations center at Pitt Tower.
  8. Provide an upgraded UPS system to supply backup power at Pitt Tower for the existing analog CCTV system and the new Digital Video System to be installed as part of this specification.
  9. Provide a Portal Surveillance Detection system and integrate the detection status signals in the video management system for annunciation on the designated video management client workstations.
  10. Provide the capability for an OCC operator to select digital IP video cameras for display at the OCC via the existing analog CCTV system interface.

1.02 RELATED SECTIONS

A. Section 01300, "Submittals."

B. Section 01777, "Construction Certification Program"

C. Section 016111, "Conduits"

D. Section 016701, "Fiber Optic Outside Plant."

E. Section 16901, "Communication System Test and Inspection."

F. Section 16950, "OCC Upgrade"

1.03 REFERENCE STANDARDS

A. The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

1. ELECTRONIC INDUSTRIES ALLIANCE (EIA).

a.	EIA 170	Electrical Performance Standards - Monochrome Television Studio Facilities.
b.	ANSI/ EIA- 330	Electrical Performance Standards for Closed Circuit Television Camera
c.	ANSI/EIA-375-A	Electrical Performance Standards for Direct View Monochrome Closed Circuit Television Monitors
d.	ANSI/EIA/TIA-232-F	Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.
e.	ANSI/TIA/EIA-568-A	Commercial Building Telecommunications Cabling Standard.

2. INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE).

a.	IEEE C2	National Electrical Safety Code.
b.	IEEE C62.41	Surge Voltages in Low-Voltage AC Power Circuits.
c.	IEEE Std 802.3	Local and Metropolitan Area Network: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications.
d.	IEEE Std 802.4	Information Processing Systems - Local Area Networks - Part 4: Token-Passing Bus Access Method and Physical Layer Specifications
e.	IEEE 802.3u	Fast Ethernet
f.	IEEE 802.1w	Rapid spanning tree standard.
g.	IEEE 802.1p	Priority Queuing: assign priority to transmitted data based on related criticality in the system.
h.	IEEE 802.1Q	VLAN: segregation

3. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA).
    a. NFPA 70 — National Electrical Code.
    b. NFPA 130 — Standard for Fixed Guideway Transit Systems.

B. Code of Federal Regulations, Title 47, Part 15.

1.04 SUBMITTALS

A. Submit the following sets for approval by the Port Authority:
1. Shop Drawings:
    a. The System Drawings shall be delivered together as a complete submittal. System documents shall include all or part of the following as applicable:
        1) Analysis on system requirement: The data package shall include system descriptions, analyses, and calculations used in sizing equipment specified. Descriptions and calculations shall show how the equipment will operate as a system to meet the performance of this specification. The data package shall include the following:
            a) Start-up operations.
            b) Expansion capability and method of implementation.
            c) Sample copy of each report specified.
            d) Color print representative of typical graphics.
            e) System throughput calculation.
        2) Drawing Index, System Legend.
        3) System Schematic Schedule: The system schematics shall show all control and mechanical devices associated with the system. A system schematic drawing shall be submitted for each sub-system.
        4) Narratives on Sequence of Operation. The sequence of operation shall reflect the language and format of this specification, and shall refer to the devices by their unique identifiers as shown on Contract Plans. Sequences of operation shall be submitted for each sub-system and shall include as minimum the following:
            a) Description on how the CCTV cameras will operate with the Portal Surveillance Detection system.
            b) Alarming operations: annunciation, acknowledgement by operator, logging and printing, etc.
            c) Portal activity recording and retrieval functions.
        5) Complete Communication-System Architectures.
        6) Panel Installation and Block Diagram.
        7) The System Drawing Index shall show the name and number of the location or other similar designation. The Drawing Index shall list System Drawings, including the drawing number, sheet number, drawing title, and computer filename when used. The System Legend shall show generic symbols and the name of devices shown on the System Drawings.
        8) The sequence of operation shall reflect the language and format of this specification, and shall refer to the devices by their unique identifiers as shown on Contract Plans. No operational deviations from specified

sequences will be permitted without prior written approval of the Port Authority. Sequences of operation shall be submitted for each sub-system including each type of terminal unit control system.

b. Product Data: data related to proposed products shall include the following:
    1) The product data shall consist of, but not be limited to, data sheets and catalog cuts which document compliance of all devices and components with the specifications. This document shall include a Bill of Materials for each System. The Bill of Materials shall function as the Table of Contents for this document and shall include the device's unique identifier, device function, manufacturer, model/part/catalog number used for ordering.

2. Factory Acceptance Test (FAT) procedure:
    a. Submit the following at least 21 days prior to the related tests for approval by the Port Authority, which shall include the following as minimum:
        1) Description of all proposed test methods, required tools and facilities, detailed test scripts and check-off lists. The test scripts and check-off lists shall be designed to demonstrate and document that the performance of the system satisfies the requirements of this specification.
        2) The proposed test methods for testing the communication links between the assembled sub-systems and intelligent devices.
3. Commissioning and Performance Verification Test Procedures:
    a. Submit the system commissioning procedures 30 days prior to the scheduled start of commissioning. Commissioning procedures shall be provided for each control system, and for each type of terminal unit control system. The Commissioning procedures shall reflect the format and language of this specification, and refer to devices by their unique identifiers. The Commissioning procedures shall be specific for each system, and shall give detailed step-by-step procedures for commissioning of the system.
    b. Submit the System Performance Verification Test Procedures 30 days before the scheduled test dates. The performance verification test procedures shall refer to the devices by their unique identifiers, shall explain, step-by-step, the actions and expected results that will demonstrate that the system performs in accordance with the sequences of operation, and other contract documents. A system performance verification test equipment list shall be included that lists the equipment to be used during performance verification testing. The list shall include manufacturer name, model number, equipment function, the date of the latest calibration, and the results of the latest calibration.
4. Training:
    a. Submit an outline for the system training course with a proposed time schedule. Approval of the planned training schedule shall be obtained from the Port Authority at least 60 days prior to the start of the training.
5. Test Reports:
    a. Factory Acceptance Test:
        1) Submit the FAT reports within 21 days after the related tests. The test reports shall be arranged so that commands, responses, and data acquired

are correlated in a manner which will allow for logical interpretation of the data.

b. Commissioning Report.
    1) Submit the System Commissioning Report within 30 days after completion of the system commissioning. The commissioning report shall include data collected during the system commissioning procedures and shall follow the format of the commissioning procedures. The commissioning report shall include all configuration check sheets with final values listed for all parameters, setpoints, time delays, constants, calibration data for all devices, results of adjustments, and results of testing.
c. Performance Verification Test.
    1) Submit the System Performance Verification Test Report within 30 days after completion of the tests. The system performance verification test report shall include data collected during the system performance verification test.

6. O&M (Operation and Maintenance) manuals.
    a. Submit printed documents for the furnished software systems 30 days before the date scheduled for the training course:
        1) Color prints of Software screens on 8 1/2 x 11 inch paper.
        2) System Database on 8 1/2 x 11 inch paper.
        3) Scripts developed for the screen displays.
        4) Diagram showing how screens are linked together.
        5) Furnish two sets of the final software files on CD-ROM.
    b. Submit the "As-Built" record documentation on paper media and one set of the "As-Built" record documentation on CD 30 days before the date scheduled for the training course. Drawings shall be stored in Microstation 2007 format or newer version, text files shall be stored in Microsoft Word format of 2007 or newer version. Each Record Document shall reflect the final and actual status of the installed systems, and shall be marked "Record Document". The "As-Built" record documentation shall include the following as minimum:
        1) Drawing Index, System Legend.
        2) System Schematic and Equipment Schedule.
        3) Sequence of Operation.
        4) Complete Communication-System Architectures, with information on applicable network addressing, dip switches, jumpers.
        5) Floor plan with information on the location of key system components, and routing of the Communication-System trunk lines.
        6) Floor plan with detection pattern of related intrusion detectors.
        7) Enclosure drawings segregated by enclosure, with the following details:
            a) Bill of material, including required spares,
            b) Component layout plans,
            c) Wiring schematics complete with information on applicable network addressing, dip switches, jumpers.

d) Slot layout plans on multi-module system racks,
e) Rack layout plans on multi-rack system frames,
f) Port/connector layout plans on cross-patch termination assemblies.

8) I/O –point listing, including all software and hardware points, complete with configuration details for each point, segregated by enclosures.
9) Schedules and related drawings documenting usage/assignments of each of the following assemblies:
    a) Multi-conductor cable bundle: unique conductor number, related termination points at both ends.
    b) Multi-strand FO (Fiber Optic) cable bundle: unique strand number, related termination points at both ends.
    c) Cross-patch panel bulkheads: unique bulkhead number, tag information and/or description of related FO strand at both ends.
    d) Multi-equipment system rack: unique rack position number (s), model number of installed system, and application information of installed system.
    e) Multi-card (multi/module) system cage: unique card slot number, model number of related card/module, information on applicable hardware/software address (addresses) related to the connection(s) at the card/module.
    f) Multi-channel module: unique port/connector number, tag information and/or description of connected signal (FO, coaxial or Ethernet) medium, tag information and/or description of the port/connector/unit connected to the other end of the related signal medium.
10) Cable lists specifying cable, wire pair and connector and pin assignments for all signal, power and ground leads.
11) All operating parameters of individual devices including, where applicable:
    a) Dip switch settings
    b) Jumper connections
    c) Software configurations
12) Tabulation of node addresses on data transmission system of all devices (and other network addressing where applicable), and where fixed communication is configured among nodes in pairs/groups, the tabulation of node addresses of all member of each pair/group.
13) Where camera with PTZ function is provided:
    a) Submit documents listing the camera PTZ viewing presets for each camera, and the preset titles as configured on the digital video recorder, related video management software, or other video system controllers such as video matrix switch.
    b) Submit documents listing applicable tour settings, including order of presets, and related dwell duration.

c. Submit hard copy of software programs and configuration settings with documentation 4 weeks prior to shop testing, including the following:

1) Tag name
2) Description
3) Rack addressing

d. Manufacturer's installation certificate for each device, each sub system.
e. Test reports on Fiber Optic cables over 2000 feet long, after installation, including as minimum:
   1) Bandwidth of each FO strand.
   2) OTDR (Optical Time Domain Reflectometer) image and report of each FO strand, end to end (before installation of connectors), and connector to connector.
   3) Attenuation of each FO strand, end to end (before installation of connectors), and connector to connector.
   4) Optical power tests on each spliced FO line, before and after each splice. Insertion loss of each splice shall not exceed 0.3dB.
f. Operation Manual: Provide the System Operation Manuals for the whole system, 30 days before the date scheduled for the training course. This manual shall fully explain all procedures and instructions for the operation of the system, including:
   1) Computers and peripherals.
   2) System start-up and shutdown procedures.
   3) Use of system, and applications software.
   4) Recovery and restart procedures.
   5) Graphic alarm presentation.
   6) Use of report generator and generation of reports.
   7) Data entry.
   8) Operator commands.
   9) Alarm and system messages and printing formats.
   10) System entry requirements.
g. Hardware Manual: Provide the Hardware Manuals for the whole system, 30 days before the date scheduled for the training course. This manual shall describe all furnished equipment including:
   1) General description and specifications.
   2) Installation and checkout procedures.
   3) Equipment electrical schematics and layout drawings.
   4) System schematics and layout drawings.
   5) Alignment and calibration procedures.
   6) Manufacturer's repair parts list indicating sources of supply.
   7) Interface definition.
h. Software Manual: Provide the Software Manuals for the whole system, 30 days before the date scheduled for the training course. The software manual shall describe the functions of all software and shall include all other information necessary to enable proper loading, testing, and operation. The manual shall include:
   1) Definition of terms and functions.
   2) Use of system and applications software.

3) Procedures for system initialization, start-up and shutdown.
4) Alarm reports.
5) Reports generation.
6) Data base format and data entry requirements.
7) Directory of all disk files.
8) Description of all communication protocols, including data formats, command characters, and a sample of each type of data transfer.

i. Maintenance Manual: Provide the Maintenance Manuals for the whole system, 30 days before the date scheduled for the training course. The maintenance manual shall include descriptions of maintenance for all equipment including inspection, periodic preventive maintenance, fault diagnosis, and repair or replacement of defective components.

j. Where applicable, full documentation on the procedural and access-protection measures instituted to keep the SYSTEM database tamper resistant.

B. Submit as part of the shop drawing: data on lens assembly focal length and view angle of each stationary camera. Provide illustration of the camera view coverage of each camera (in combination with the proposed lens assembly) on location plan.

C. Submit the "As-Built" record documentation on paper media and one set of the "As-Built" record documentation on CD 30 days before the date scheduled for the training course. Drawings shall be stored in Microstation CAD format of 2007 or newer version, text files shall be stored in Microsoft Word format of 2007 or newer version. Each Record Document shall reflect the final and actual status of the installed systems, and shall be marked "Record Document". The "As-Built" record documentation shall include the following as minimum:

1. Where camera with PTZ function is provided:
    a. Submit documents listing the camera PTZ viewing presets for each camera, and the preset titles as configured on the digital video recorder, related video management software, or other video system controllers such as video matrix switch.
    b. Submit documents listing applicable tour settings, including order of presets, and related dwell duration.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Contractor shall ensure that equipment has not been damaged during shipping or storage. Equipment shall be shipped separately from the equipment racks in which they are to be installed. Equipment shall remain in the original packaging until the time of installation. All equipment shall be stored in a protected area until installed.

1.06 QUALIFICATIONS

A. Contractor shall have a minimum of five years of experience in supplying and installing video security equipment comparable to that specified herein.

1.07 DESCRIPTION OF WORK

A. This Section presents an outline of the communications work to be performed under this Contract. It does not supersede requirements detailed elsewhere. Contractor is responsible for complying with the Contract Documents in their entirety.

B. Contractor shall furnish all labor, material, equipment, supervision, transportation, and miscellaneous services, whether or not explicitly identified herein, to provide a completely tested and fully functional Digital Video system.

C. The work of this Section includes furnishing and installing dome mounted fixed position IP Video CCTV cameras at the platform, mezzanine, elevators and other public areas at Gateway Station, North Side Station, and Allegheny Station at the locations indicated on Reference Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012.

D. The work of this Section also includes furnishing and installing dome mounted IP Video CCTV cameras equipped with PTZ drives at the station platform levels in Gateway Station, North Side Station and Allegheny Station as indicated on Reference Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012.

E. The work of this Section also includes furnishing and installing dome mounted IP Video CCTV cameras equipped with PTZ drives at the portal entrances to the bored tunnel at the Gateway and North Side Stations as shown on the Contract Drawings.

F. The work of this Section also includes furnishing and installing fiber optic modems, fiber optic cables, and other equipment as shown on Contract Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012 and as specified herein, to form an integral part of the Communications System.

G. The work of this Section also includes furnishing and installing additional monitors, Digital Video Recorders, Video Management Consoles, video interface equipment and miscellaneous hardware in the Pitt Tower operations center control room to monitor and support the new digital video cameras installed at the NSC stations as part of the Project.

H. The work of this Section also includes upgrading the Pelco CM9760 Matrix Switcher to accommodate additional analog video inputs by installing a CM9760-VCC input card.

I. The work of this Section also includes furnishing and installing the Portal Surveillance Detection system, which includes installing IR detectors at the portal entrances of the bored tunnel and all power and CAT5 wiring to hub processors in the Gateway and North Shore communication rooms.

J. The work of this Section also includes furnishing and installing all miscellaneous hardware required to build a functional, reliable and maintainable CCTV system.

1.08 EXISTING CONDITIONS

A. The existing CCTV System at Pitt Tower is based on an analog video system design, which will be difficult to expand and maintain due to equipment obsolescence.

B. The existing equipment at Pitt Tower is used to monitor and control the cameras at the existing stations and transmit selected video images to the OCC.

C. The existing CCTV System will remain in place and operate in parallel with the new Digital Video System.

1.08 SYSTEM REQUIREMENTS

A. Contractor shall install Gigabit Switches at Pitt Tower and the NSC stations to create a self-healing Gigabit Ethernet Ring to support the exchange of video data between these locations. The Gigabit Ring shall use two fibers on the existing Fiber Plant and two fibers in the new 96 fiber cables to be installed between the NSC stations.
   1. Contractor shall install a Digital Video System at Pitt Tower using a video management client/server configuration to manage and display IP video data. The Digital Video System shall incorporate Network Video Recorders to save the video from all NSC station cameras in MPEG-4 format for 30 days and permit playback at the rate of eight-frames/second. Video output at the Pitt Tower Control Room shall be operator selectable in various multi-image formats and displayed digitally on LCD flat panel displays and on analog monitors.
   2. All CCTV cameras at the NSC stations shall be IP video dome cameras, some configured for PTZ with the remainder configured as fixed lens as indicated on the architect drawings for these stations. All CCTV cameras for portal surveillance detection shall be IP video PTZ dome cameras.
   3. The Contractor shall provide the capability for an OCC operator to select digital IP video cameras for display at the OCC via the existing analog CCTV system interface.
   4. The alarm generated by the Portal Surveillance Detection system shall be polled and processed by the Video Management System software at Pitt Tower and annunciated at the client workstations. The response time between detection and annunciation shall not exceed one second.

B. Contractor shall provide all video management software, database initialization, and maintenance software for all components (servers, workstations, network recorders, etc.) of the Digital Video System to insure a fully functional and operational system.

C. In addition to the cameras and digital video system equipment, Contractor shall provide all equipment racks and cabinets, mounting hardware, and all necessary cables, and connectors at Pitt Tower and the NSC stations.

D. All equipment supplied under this Section shall comply with FCC limits for Class A radio frequency emission ratings as defined in Code of Federal Regulations, Title 47, Part 15.

1.09 TRAINING

A. Contractor shall provide System Administrator training for <u>four</u> of the Port Authority's employees. As a minimum the training shall provide:

1. Training shall be conducted in a class room environment at the vendor's facility with hands-on instruction by the manufacturer's certified instructor.
2. One working administrative console for each Port Authority trainee shall be provided.
3. The training shall cover all administrative and maintenance reports provided for the system.
4. Training shall cover system traces available for all installed equipment.
5. Training shall cover moves, adds, and changes for all installed equipment
6. Training shall cover all user, installer, and system programming available on all installed equipment.
7. The Contractor shall provide one copy of each manual used in the training for each trainee, plus one set of manuals for the OCC.
8. The Contractor shall provide the Port Authority with additional copies of the any administrative manuals for the duration of the warranty period and any subsequent maintenance contract periods at no additional charge.
9. The Contractor shall cover any and all training costs associated with travel, meals, and lodging for Port Authority employees if training is done outside of the local area. Local being defined as any area within thirty miles of the Manchester Office location.

B. Administration Manual Updates

1. The Contractor shall provide, at no cost to the Port Authority, any revisions to administration or maintenance manuals required due to system upgrades and/or changes in software for the duration of the warranty period and any subsequent period covered by maintenance contracts.

ARTICLE 2 PRODUCTS

2.01 FIXED DOME IP CAMERA

A. Fixed Dome IP Camera

1. The Contractor shall provide fixed position dome IP cameras at the three NSC stations as indicated on the architectural contract drawings.
2. Each dome camera assembly shall include a day/night camera, appropriate lens to support viewing angles, and an enclosure with heater & blower suitable for outdoor use.
3. Each camera shall support simultaneous Motion JPEG and MPEG-4 video at resolutions of up to 640x480 pixels.
4. Each camera shall be equipped with a Varifocal lens to support viewing angles specified on the contract drawings.
5. Minimum illumination: 1 lux in color mode, 0.2 lux in black/white mode.
6. Each camera shall be able to deliver high-quality video in a least 15 different resolutions up to 640x480 pixels over IP networks.
7. Each camera shall provide at least 11 different compression levels and be capable of providing bit rates between 1Kbps and 12 Mbps per video stream.
8. The camera shall contain a built-in-web server making video and configuration available in a standard browser environment using HTTP, without the need for additional software.
9. When accessed from a browser, the built-in-web server shall provide users with online, context-sensitive help.
10. The camera shall not require any additional software to operate, and shall support full functionality when operating in the following environment: Windows2000 or Windows XP and with MS Explorer 6.x and higher.
11. Each camera shall support simultaneous viewing by up to 20 clients from the web server.
12. The cameras web server shall provide support for defining usernames and passwords, for a minimum of three different types of users.
13. The camera shall provide the ability to control network traffic by limiting the maximum bandwidth to a selected value and limit the frame rate per viewer to a selected value, as well as the duration of each viewing session.
14. The camera shall provide embedded on-screen text in the video, with support for time & date and camera name.
15. The camera shall be equipped with one 100baseTX Fast Ethernet-port, using an RJ-45 socket and shall support auto sensing of the network speed.
16. The camera enclosure shall meet IP-66 rating as an assembled unit.
17. Operating Temperature Range: -20 to +50 degrees C with built-in heater.
18. Operating Humidity Range: 20-80% RH (non-condensing)

B. Acceptable Manufacturer and Model

1. AXIS 225FD Fixed Dome Network Camera or equal.

2.02 PTZ DOME IP CAMERA

A. PTZ Dome IP Camera

1. The Contractor shall provide fixed position dome IP cameras at the three NSC stations as indicated on the architectural contract drawings.
2. Each camera dome assembly shall include a day/night camera and shall support an optical zoom of 35X and a digital zoom of 12X.
3. Each camera dome assembly shall include a heater & blower suitable for outdoor use.
4. Each camera shall support simultaneous Motion JPEG and MPEG-4 video at resolutions of up to 640x480 pixels.
5. Each dome camera assembly shall support high-speed pan-tilt (0.05-450degrees/sec) and shall provide for 100 preset positions.
6. Minimum illumination: 0.5 lux in color mode, 0.008 lux in black/white mode.
7. Each camera shall be able to deliver high-quality video in a least 5 different resolutions up to 640x480 pixels over IP networks.
8. Each camera shall provide at least 11 different compression levels and be capable of providing bit rates between 1Kbps and 12 Mbps per video stream.
9. The camera shall contain a built-in-web server making video and configuration available in a standard browser environment using HTTP, without the need for additional software.
10. When accessed from a browser, the built-in-web server shall provide users with online, context-sensitive help.
10. The camera shall not require any additional software to operate, and shall support full functionality when operating in the following environment: Windows2000 or Windows XP and with MS Explorer 6.x and higher.
11. Each camera shall support simultaneous viewing by up to 20 clients from the web server.
12. The cameras web server shall provide support for defining usernames and passwords, for a minimum of three different types of users.
13. The camera shall provide the ability to control network traffic by limiting the maximum bandwidth to a selected value and limit the frame rate per viewer to a selected value, as well as the duration of each viewing session.
14. The camera shall provide embedded on-screen text in the video, with support for time & date and camera name.

15. The camera shall be equipped with one 100baseTX Fast Ethernet-port, using an RJ-45 socket and shall support auto sensing of the network speed.
16. The camera enclosure shall meet IP-66 rating as an assembled unit.
17. Operating Temperature Range: -20 to +50 degrees C with built-in heater.
18. Operating Humidity Range: 20-80% RH (non-condensing)

B. Acceptable Manufacturer and Model
   1. AXIS 233D Network Dome Camera or equal.

2.03 DOME CAMERA PENDANT MOUNT

A. Gooseneck Wall Mount

   1. The Contractor shall mount the IP Dome Camera specified in Sections 2.01 & 2.02 above to the NSC station walls & columns using a Gooseneck Wall Mount and Pendant Kit.
   2. The gooseneck mounting hardware shall be an AXIS 25736 Gooseneck Wall Mount kit or equal.

B. Pendant KIT

   1. The Pendant Adapter Kit shall be an AXIS 5500-381 Pendant Kit.

2.04 FIBER MODEM

A. The Fiber Modem shall be used to convert the 10/100 Base T Ethernet signal at the Axis Dome Cameras to an Ethernet fiber signal and convert the fiber signal back to 10/100 Base T Ethernet at the Ethernet LAN Switch. The Fiber Modem shall meet the following requirements:
   1. Copper Interface: RJ45 Connector
   2. Fiber Interface: SC Connector
   3. Fiber Media: Singlemode Fiber
   4. Input Power: 12Vdc, 400mA

B. Acceptable Manufacturer and Model
   1. Videolarm, Model EOF2N/SM or equal.

2.05 GIGABIT ETHERNET BACKBONE SWITCH

A. The Gigabit Ethernet Backbone Switch shall be installed at the three NSC stations and Pitt Tower to form the Gigabit Ethernet Ring. This ring shall provide the communications connectivity required to support video communications between locations for the Digital Video System. Each Gigabit Ethernet Switch shall support the following ring requirements:
   1. Provide two Gigabit ports initially with expansion to nine ports.

2. Support Singlemode fiber up to 70km between switches
3. Simple plug and play operation – automatic learning, negotiation, and crossover detection.
4. RSTP (802.1w) and Enhanced Rapid Spanning Tree (eRSTP) network fault recovery (<5ms).
5. Quality of Service (802.1p) for real-time traffic.
6. Multi-level user passwords
7. Enable/disable ports, MAC based port security
8. Web-based, Telnet, CLI management interfaces
9. SNMP v1/v2/v3
10. Remote Monitoring (RMON)
11. Diagnostics with logging and alarms.
12. Integrated dual-redundant power supplies
13. Input Power: 120Vac
14. Operating Temperature: -40 to 85degrees C

B. Acceptable Manufacturer and Model
   1. RuggedCom RSG2200 or equal

2.06 GIGABIT ETHERNET LAN SWITCH

A. The Gigabit Ethernet LAN Switch provides 10/100 base T Ethernet handoff between the various components of the Digital Video System and the Gigabit Ethernet Backbone Switch. The Gigabit LAN Switch shall support the following requirements:
   1. The Ethernet Switch shall provide one 1000Base-T.
   2. The Ethernet Switch shall provide for 24 - 10/100Base-T ports with auto-sensing connectivity.
   3. Status Indicators: Link activity, port transmission speed, port duplex mode, power.
   4. Features: Flow control, full duplex capability, layer 2 switching, auto-negotiation, auto-uplink.
   5. Enable/disable ports, MAC based port security
   6. Web-based, Telnet, CLI management interfaces
   7. Operating Temperature: 32 to 122 degrees F

B. Acceptable Manufacturer
   1. Cisco or equal

2.07 VIDEO-MANAGEMENT SOFTWARE SYSTEM

A. The Video Management Software system shall be specifically designed for managing the processing, storage, video viewing and camera control access rights and display of large number of streaming video images from IP cameras and recorder sources. The Video Management Software system shall be compatible with the server and client computers, and video storage devices as specified further in this Section. The software system shall be a complete functional entity and be supplied with all required interface modules and cable. Pertinent parts of the software system, as supplied, shall be installed and configured on the server, and client computers as applicable.

B. Special Requirements:
   1. The Video Management Software system must be compatible with the PTZ control system of the cameras used on the NSC project, and the Pelco cameras (Pelco Spectra III and Spectra IV series) currently used by the Authority. At some future date the existing Pelco cameras may be transition to the Digital Video System.
   2. Provide interface arrangement, and appurtenances, for interfacing the Video Management software (installed on the related client computers), with the camera (PTZ) control keyboard/joystick assembly used for the cameras installed on this project. This requirement shall be applicable for each of the client workstations mounted outside of the equipment racks.
   3. If licensing is applicable to the Video Management software, provide for a Video Management software package with a license which shall remain valid indefinitely with the installed system; a software package requiring recurring license fee payments, except for payments relating to the acquisition of software updates, shall not be acceptable. Any license for optional features, such as seat license for a number of concurrent clients, once acquired, shall similarly remain valid indefinitely when used in the existing system. The installed Video Management software system, and all optional packages, shall remain fully operable without the need for renewal of the license on a periodic basis.
   4. Provide software license, if applicable, for up to 80 cameras for this project, and optional license for groups of 25 additional cameras. Provide software license, if applicable, for up to 10 client seats for this project, and optional license for groups of 5 additional client seats.

C. Performance Criteria:
   1. Supports Multi-Site/Multi-Server deployments using third-party computer and recording hardware.
   2. Support multiple video clients on different platforms: Web access and client workstations
   3. Support infinite number of concurrent video streams (CCTV cameras), and infinite number of concurrently active client sessions.
   4. Supports management scheme for user authentication, in which read/write access rights to different levels of software settings are individually assignable.
   5. Supports management scheme for user authentication, in which video view access and camera control access rights are individually assignable.
   6. Support communication protocol with camera PTZ system and digital video encoder manufactured by third parties. Supported manufacturers and models shall include those used in the project.

7. Provides intuitive map-driven user interface, with both point & click, and external joystick PTZ control
8. Supports CIF to over 32CIF image sizes, in user-selectable combination of MPEG-4 part 2, Motion JPEG, and H.263 video compression formats.
9. Support operations mimicking conventional multi-input/multi-output video matrix switch (virtual video matrix switch).
10. Compatible with standards-based, open architecture on non-proprietary hardware
11. Support event logging functionalities, and related investigation tools, including scrollable events timeline and synchronous playback from multiple servers.
12. Supports sequenced display of video stream of selected video sources.
13. Supports schedulable execution of PTZ presets multiple CCTV cameras.
14. Supports schedulable multiple PTZ patrolling sequences
15. Supports and manages network-based archiving of video streams
16. Supports multiple video monitors per client workstation
17. Supports configurations and generation of composite video image consisting of video images from up to 16 video streams, for display on client workstation.
18. Support generation of encrypted, tamper-evident video export to CD or DVD
19. Accept and process alarm input and output integration
20. Makes available open APIs for integration by third parties with other systems
21. Support features such as video motion detection.

D. Acceptable Manufactures and model:
   1. On-Net Surveillance System Inc., NetDVMS series
   2. Genetec Inc., Omnicast series
   3. Approved equal

2.08 SERVER COMPUTER

A. Server Computers shall be computers used as "Server" units in conjunction with a software system based on a "Server-Client" topology. Server Computers shall be 64-bit computers based on Intel, or AMD CPU design. Each computer shall be a complete functional entity with all necessary accessories and parts. The computer shall be designed for continuous round-the-clock operations, for temperature, humidity, vibration, shock and other conditions as normally expected in the related installation environment. The computer housing shall be suitable for equipment rack mounting.

B. Special Requirements:
   1. For computer installation in equipment rack, provide the keyboard and touchpad (cursor pointing device) as a slide-out drawer assembly suitable for rack mounting.
   2. Provide software packages for the sub systems and communication components included in this project, supplied or sanctioned by the related sub system manufacturer. These software packages shall be installed and fully configured to provide two-way interface with all installed devices connected to the same computer network.

3. Provide Internet browser, Hyper Terminal, network management software, configuration software for the Ethernet switches, all of the latest versions.
4. Provide warranty for two years, starting from the date of formal approval of the Integrated System Acceptance Test.

C. Hardware Requirements:
   1. CPU: 64-bit x86 processor 1.7GHz or better, or comparable processor from AMD, with combination fan/heat sink.
   2. Memory: minimum 2 GByte 3.3V SDRAM, 400MHz or higher bus speed.
   3. Cache: minimum 512KB L2 cache.
   4. System clock: Real time clock/calendar with battery backup.
   5. Bus interface: minimum bus speed 400MHz, accepts minimum five 8/16-bit option cards and at least one 32-bit option card.
   6. Temperature Range: 32 to +104 degrees Fahrenheit or beyond. Refer also to special requirements for outdoor installation.
   7. Humidity Range: 5% to 90%, non-condensing.
   8. Power module: 120V/60Hz, 300Watt minimum.
   9. Cooling: Positive pressurization with at least one intake fan and one exhaust fan in power supply, at least one cooling fan dedicated to the CPU assembly, each with minimum 42CFM capacity.
   10. Expansion slots: minimum one 32-bit AGP slot, six 32-bit PCI slots, two 16-bit ISA shared slot.
   11. Operating system: Microsoft Windows 2000 Server or Microsoft Windows 2003 Server (preferred), or as required for use with the related application software packages.
   12. Video interface: Advanced Graphics cart with minimum 32-MB on-board memory.
   13. Drive bays: minimum three 5.25-inch bays, shock mounted.
   14. Basic Disk drive: one SCSI (or faster) hard drive for the operating system and application software, minimum 40 gigabyte, minimum 5400RPM with hard drive access time 12ms maximum. The hard disk drive shall not be partitioned to run any other operating system.
   15. Data Disk drive: one Level-1 RAID controller/interface and integral or rack-mounted RAID storage assembly with minimum three hot swappable SCSI (or faster) drives, each having a capacity of minimum 40GByte, complete with required software, appurtenances.
   16. Optical drives: minimum one 40x-24x (or better) CD/DVD ROM drive.
   17. Sound card: complete with integral or external speakers. The speaker, augmented with additional amplification where required, shall have an audio output of 2Watts minimum.
   18. Serial port: minimum two DB9-shell RS232 serial ports, the serial ports shall be configured with 16550 UARTs, and shall have a data bandwidth of 57.6kbps minimum.
   19. PS/2 ports: minimum two PS/2 ports.
   20. USB port: minimum two USB type-A ports.

21. Dial-up modem: one 56kbaud V.90 dial-up modem, with dedicated modem processor, RJ11 port. The modem shall meet the requirements of ITU V.34, ITU V.42 for error correction and ITU V.42 for data compression standards, and shall be suitable for operating on unconditioned voice grade telephone lines in conformance with 47 CFR 68.
22. LAN interface: auto-sensing dual-speed 10BaseT/100BaseTX network interface module with RJ45 port, and related driver software.
23. Keyboard: 101-key AT type QWERTY keyboard, rated for minimum 50 million keystrokes. Refer also to special requirements for outdoor installation and computer installation in equipment rack.
24. Pointing device: Microsoft Intellimouse compatible optical (infrared) pointing device, with dedicated mouse port. The pointing device shall have a resolution of 400 dots per inch minimum. Refer also to special requirements for outdoor installation and computer installation in equipment rack.

D. Acceptable Manufactures:
  1. Dell
  2. IBM.
  3. Hewlett Packard.
  4. Approved equal.

2.09 CLIENT COMPUTER

A. Client Computers shall be computers used as workstations in conjunction with a software system based on a "Client/Server" topology. Client Computers shall be 64-bit computers based on Intel, or AMD CPU design. Each computer shall be complete functional entity with all necessary accessories and parts. The computer shall be hardened for temperature, humidity, vibration, shock and other conditions as normally expected in the related installation environment. Where the computer is used for mounting in an equipment rack, its denotation is appended with the description "(RACK MOUNTED)", the related computer housing shall be suitable for equipment rack mounting; where the computer is used as stand-alone unit at a desk or similar environment, its denotation is appended with the description "(TOWER)", the computer housing shall be suitable for stand-alone placement.

B. Special Requirements:
  1. For computer installation in equipment rack, provide the keyboard and touchpad (cursor pointing device) as a slide-out drawer assembly suitable for rack mounting.
  2. Provide software packages for the sub systems and communication components included in this project, supplied or sanctioned by the related sub system manufacturer. These software packages shall be installed and fully configured to provide two-way interface with all installed devices connected to the same computer network.

3. Provide Internet browser, Hyper Terminal, network management software, all of the latest versions.

C. Hardware Requirements:
   1. CPU: 64-bit processor 1.7GHz or better, or comparable processor from AMD, with combination fan/heat sink.
   2. Memory: minimum 2 GByte 3.3V SDRAM, 400MHz or higher bus speed.
   3. Cache: minimum 512KB L2 cache.
   4. System clock: Real time clock/calendar with battery backup.
   5. Bus interface: minimum bus speed 400MHz, accepts minimum five 8/16-bit option cards and at least one 32-bit option card.
   6. Temperature Range: 32 to +104 degrees Fahrenheit or beyond.
   7. Humidity Range: 5% to 90%, non-condensing.
   8. Power module: 120V/60Hz, 300Watt minimum.
   9. Cooling: Positive pressurization with at least one intake fan and one exhaust fan in power supply, at least one cooling fan dedicated to the CPU assembly, each with minimum 42CFM capacity.
   10. Expansion slots: minimum one 32-bit AGP slot, six 32-bit PCI slots, two 16-bit ISA shared slot.
   11. Operating system: Microsoft Windows 2000, XP Professional, of the latest version, or as required for use with the related application software packages.
   12. Video interface: Advanced Graphics cart with minimum 32-MB on-board memory.
   13. Drive bays: minimum three 5.25-inch bays, shock mounted.
   14. Basic Disk drive: one SCSI (or faster) hard drive for the operating system and application software, minimum 40 gigabyte, minimum 5400RPM with hard drive access time 12ms maximum. The hard disk drive shall not be partitioned to run any other operating system.
   15. Optical drives: minimum one 40x-24x (or better) CD/DVD ROM drive.
   16. Sound card: complete with integral or external speakers. The speaker, augmented with additional amplification where required, shall have an audio output of 2Watts minimum.
   17. Serial port: minimum two DB9-shell RS232 serial ports, the serial ports shall be configured with 16550 UARTs, and shall have a data bandwidth of 57.6kbps minimum.
   18. PS/2 ports: minimum two PS/2 ports.
   19. USB port: minimum two USB type-A ports.
   20. Dial-up modem: one 56kbaud V.90 dial-up modem, with dedicated modem processor, RJ11 port. The modem shall meet the requirements of ITU V.34, ITU V.42 for error correction and ITU V.42 for data compression standards, and shall be suitable for operating on unconditioned voice grade telephone lines in conformance with 47 CFR 68.
   21. LAN interface: auto-sensing dual-speed 10BaseT/100BaseTX network interface module with RJ45 port, and related driver software.

22. Keyboard: 101-key AT type QWERTY keyboard, rated for minimum 50 million keystrokes. Refer also to special requirements for outdoor installation and computer installation in equipment rack.
23. Pointing device: Microsoft Intellimouse compatible optical (infrared) pointing device, with dedicated mouse port. The pointing device shall have a resolution of 400 dots per inch minimum. Refer also to special requirements for outdoor installation and computer installation in equipment rack.

D. Acceptable Manufactures:
   1. Dell
   2. IBM.
   3. Hewlett Packard.
   4. Approved equal

2.10 NETWORK VIDEO RECORDER

A. Network video recorders (NVRs) shall be computers with high-speed communication interface, optimized internal data bus system, and large data storage devices designed and used for storing high-bandwidth data streams on continuous basis. Network video recorders shall be 64-bit computers based on Intel, or AMD CPU design. Each network video recorder shall be complete functional entity with all necessary accessories and parts. The network video recorders shall be designed and hardened for continuous round-the-clock operations, for temperature, humidity, vibration, shock and other conditions as normally expected in the related installation environment. The network video recorders housing shall be suitable for equipment rack mounting.

B. Special Requirements:
   1. Provide the keyboard and touchpad (cursor pointing device) as a slide-out drawer assembly suitable for rack mounting.
   2. Provide software packages for the sub systems and communication components included in this project, supplied or sanctioned by the related sub system manufacturer. These software packages shall be installed and fully configured to provide two-way interface with all installed devices connected to the same computer network.
   3. Provide warranty for two years, starting from the date of formal approval of the Integrated System Acceptance Test.
   4. Provide nominally 1 Terabytes of data storage space per connected camera, for up to sixteen cameras per NVR. Number of cameras actually configured for recording per NVR shall be as recommended by the related NVR manufacturer, based on the limitation on the internal bus bandwidth and optimal drive sizes.
   5. The bank of NVR shall be expandable to accommodate the addition new cameras and the transitioning of existing analog camera to the Digital Video System.
   6. Configure each NVR to record all video streams assigned to the NVR. Where both MPEG4 and MJPEG streams are available from a camera, record only the MPEG4 stream. The default recording setting shall be 4CIF at 8 frames per second.

C. Hardware Requirements:
   1. CPU: 64-bit processor 1.7GHz or better, or comparable processor from AMD, with combination fan/heat sink.
   2. Memory: minimum 2 GByte 3.3V SDRAM, 400MHz or higher bus speed.
   3. Cache: minimum 512KB L2 cache.
   4. System clock: Real time clock/calendar with battery backup.
   5. Bus interface: minimum bus speed 400MHz, accepts minimum five 8/16-bit option cards and at least one 32-bit option card.
   6. Temperature Range: 32 to +104 degrees Fahrenheit or beyond. Refer also to special requirements for outdoor installation.
   7. Humidity Range: 5% to 90%, non-condensing.
   8. Power module: 120V/60Hz, 300Watt minimum.
   9. Cooling: Positive pressurization with at least one intake fan and one exhaust fan in power supply, at least one cooling fan dedicated to the CPU assembly, at least one cooling fan set dedicated to the hard disk drives, each with minimum 42CFM capacity.
   10. Expansion slots: minimum one 32-bit AGP slot, six 32-bit PCI slots, two 16-bit ISA shared slot.
   11. Operating system: Microsoft Windows 2000, XP Professional, of the latest version, or as required for use with the related application software packages.
   12. Video interface: Advanced Graphics cart with minimum 32-MB on-board memory.
   13. Drive bays: minimum three 5.25-inch bays, shock mounted.
   14. Basic Disk drive: one SCSI (or faster) hard drive for the operating system and application software, minimum 18 gigabyte, minimum 5400RPM with hard drive access time 12ms maximum. The hard disk drive shall not be partitioned to run any other operating system.
   15. Data Disk drive: Level-1 RAID controller/interface and integral or rack-mounted RAID storage assembly with hot swappable SCSI (or faster) drives, drive quantity and storage capacity as per manufacturer's standard, and as limited by the special requirements listed above, minimum 7200RPM with access time 8ms maximum, complete with required software, appurtenances. All disk drives for data storage shall be of the same specifications; no mixing of drive models is permitted.
   16. Optical drives: minimum one 40x-24x (or better) CD/DVD ROM drive.
   17. Sound card: complete with integral speaker.
   18. Serial port: minimum one DB9-shell RS232 serial ports, the serial ports shall be configured with 16550 UARTs, and shall have a data bandwidth of 57.6kbps minimum.
   19. PS/2 ports: minimum two PS/2 ports.
   20. USB port: minimum two USB type-A ports.
   21. LAN interface: network interface module with dual RJ45 ports, 10/100/1000 Mbps autosensing, and related driver software.
   22. Keyboard: 101-key AT type QWERTY keyboard, rated for minimum 50 million keystrokes. Refer also to special requirements for computer installation in equipment rack.

23. Pointing device: Microsoft Intellimouse compatible optical (infrared) pointing device, with dedicated mouse port. The pointing device shall have a resolution of 400 dots per inch minimum. Refer also to special requirements for computer installation in equipment rack.

D. Acceptable Manufactures:
1. Dell, IBM, HP or equal
2. IBM.
3. Hewlett Packard.
4. Approved equal.

2.11 KVM ASSEMBLY

A. Keyborad-Video-Mouse (KVM) assembly shall serve as a keyboard/monitor/mouse set for shared use among multiple computers (and/or computer-like devices). The KVM assembly shall consist of a keyboard/monitor/mouse set, and an electronic switching device (the KVM switch), which switches the keyboard/monitor/mouse set to one of the connected computers. For use with rack-mounted computers, the keyboard/monitor/mouse set shall consist of integral LCD monitor, keyboard and touchpad (cursor pointing device) assembly similar to arrangement used with a laptop computer, and be mounted on a slide-out drawer assembly suitable for rack mounting. When not used, it shall be possible to fold down the monitor so that the integral keyboard/monitor/mouse set can be stored in the equipment rack, occupying no more than 3U rack space.

B. Special Provisions:
1. Provide appurtenances for mismatched connectors, and termination cables to all connected computers.
2. Install and configure interface software for the KVM switch, if applicable, on the connected computers.
3. Provide warranty for two years for the KVM switch, starting from the date of formal approval of the Integrated System Acceptance Test.

C. Performance Criteria – keyboard and mouse:
1. 101-key AT type QWERTY keyboard, rated for minimum 50 million keystrokes.
2. Cursor pointing device: 400 dots per inch minimum resolution.

D. Performance Criteria - monitor:
1. As per specification of LCD video monitor specified elsewhere in this Section, except where otherwise stated below.
2. Pixel resolution: minimum 640x480 pixels for 15-inch monitor, and minimum 800x600 pixels for 19-inch monitor.
3. Monitor size: minimum 15-inch standard trade size for mounting in equipment rack, minimum 19-inch standard trade size for other installations.
4. Support: hinged at the bottom for folding down when used in equipment rack.

E. Performance Criteria – KVM Switch:
   1. PC connections: four, eight, 12 or more computers as applicable.
   2. K/V/M connections: coordinate with related devices.
   3. Video resolution: support minimum 1600x1280, non-interlaced, at 60Hz, at cable distance of up to 100 feet.
   4. Audio interface: 3.5mm stereo, if required.
   5. Cable distance: minimum 100 feet without additional transmission aid.
   6. Form factor: no more than 3U high
   7. Temperature Range: 32 to +105 degrees Fahrenheit or beyond.
   8. Humidity Range: 5% to 95%, non-condensing.
   9. Power requirement: 120V/60Hz, or supplied with suitable power module.

F. Acceptable Manufactures:
   1. Raritan Computer Inc
   2. Rose Electronics
   3. Black Box Corporation
   4. Network Technologies Inc
   5. Avocent
   6. Approved equal.

2.12 CCTV CAMERA PTZ CONTROL STATION

A. A CCTV camera PTZ control station shall be a keyboard/joystick combination unit designed to select and communicate with each of the IP CCTV cameras in the Digital Video System, and is used to control the PTZ actions, and presets of the selected CCTV camera.

B. Special Requirements:
   1. Provide appurtenant hardware and software for distributing the control signals to multiple camera types, and to integrate control signals from multiple camera PTZ control stations to the same group of cameras.
   2. Provide PTZ code conversion for communications with different cameras of multiple models and manufacturers, which shall include Pelco Spectra III and Spectra IV series currently used by the Authority.
   3. Provide warranty for two years, starting from the date of formal approval of the Integrated System Acceptance Test.

C. Technical requirements and Performance Criteria:
   1. The CCTV camera PTZ control station shall support two-way communication with a minimum of 200 CCTV cameras, which are assigned unique IP address identifiers.
   2. The CCTV camera PTZ control station shall be capable of controlling the PTZ action, configure PTZ presets, and affecting the selected preset of the selected CCTV camera.

D. Acceptable Manufactures:
   1. Axis Communications
   2. Approved equal

2.13 DIGITAL VIDEO DECODER

A. Digital video decoders shall convert digitized, compressed video images transported through the Ethernet computer network to an analog NTSC video signal.

B. Technical requirements and Performance Criteria:
   1. Video output signal of the digital video decoder shall be in NTSC format, 1 Vp-p, with 75 ohms impedance.
   2. LAN interface shall be 10BaseT or 100BaseTx, using RJ45 connector, or 100BaseFx.
   3. Operating temperature range shall be 32 to 122 degrees Fahrenheit, or beyond.
   4. Operating humidity range shall be 90% maximum relative humidity, non-condensing.
   5. Power requirement shall be 120V/60Hz, or be supplied with appropriate power adapter.

C. Acceptable Manufactures:
   1. Axis Communications
   2. Approved equal.

2.14 LCD VIDEO MONITOR

A. LCD Video monitors shall be LCD type color video monitor as per Contract Plans and as specified herein.

B. Special Provisions:
   1. Where applicable provide adapter and appurtenances to interface the monitor to the related signal source.
   2. Where applicable provide extender unit and appurtenances to transmit the video signal from the related signal source to the monitor over extended cable length.

C. Technical requirements and Performance Criteria:
   1. Panel Type: color TFT active matrix SXGA LCD
   2. Aspect ratio: 4 to 3 (horizontal to vertical), or 16:9 (HDTV).
   3. Monitor (diagonal) trade size: 15" 17", 18", 19", 20", 21" as applicable; 15" minimum for mounting in a slide-out drawer in EIA 19-inch rack, 17" minimum for fixed mounting in EIA 19-inch rack, 19" for desk/shelf top application, or as specifically specified.
   4. Optimum Resolution: 1280x1024 or higher.
   5. Contrast Ratio: minimum 400:1.
   6. Viewing Angle: minimum 160 degrees horizontal, 160 degrees vertical.
   7. Response Time: minimum 35ms.

8. Light Source life expectancy: minimum 50,000 hours.
9. Brightness: minimum 250 cd/m2.
10. Panel Surface: provide Anti-glare treatment.
11. Video Input: Analog RGB Analog (75 ohms, 0.7/1.0 Vp-p), and 15-pin D shell VGA.
12. Frequency: Fh:31~82kHz, fv:50~75 Hz.
13. Sync: H/V Separated.
14. Bandwidth: 135MHz.
15. Compatibility: from VGA up to 1280x1024 non-interlaced.
16. Connector: 15-pin mini D-sub integrated, composite analog video (refer to Special provision above for interface adapter).
17. Power requirement: 120V/60Hz, or supplied with suitable power module.
18. Operating Temperature 32 to 104 degrees Fahrenheit or beyond.
19. Operating Humidity 10 to 90% (non-condensing).

D. Manufacturers:
   1. ViewSonic Corporation
   2. NEC-Mitshubishi Electronic Display of America
   3. Sony Corp. of America
   4. Approved equal.

2.15 PLASMA VIDEO MONITOR

A. Plasma Video monitors shall be plasma type color video monitor as per Contract Plans and as specified herein.

B. Special Provisions:
   1. Where applicable provide adapter and appurtenances to interface the monitor to the related signal source.
   2. Where applicable provide extender unit and appurtenances to transmit the video signal from the related signal source to the monitor over extended cable length.

C. Technical requirements and Performance Criteria:
   1. Monitor (diagonal) trade size: minimum 50" or as specifically specified.
   2. Aspect ratio: 16 to 9 (horizontal to vertical)
   3. Nominal Resolution: 1920x1080 (1080i HDTV).
   4. Video Input: Analog RGB Analog (75 ohms, 0.7/1.0 Vp-p), DVI, and 15-pin D shell VGA.
   5. Refer to LCD video monitor for other requirements.

D. Acceptable Manufactures:
   1. Panasonic.
   2. Toshiba.
   3. Sharp.
   4. Approved equal.

2.16 PORTAL SURVEILLANCE DETECTION SYSTEM

A. The Portal Surveillance Detection System shall be installed a both ends of the Bored Tunnel to detect unauthorized personnel entering the tunnel. The detection system consists of wall mounted IR barrier transceivers, which will detect any one entering the tunnel and PTZ cameras monitored at Pitt Tower to verify if the person entering the tunnel is PAAC or an unauthorized person.

The IR barrier transceivers will consist of multiple barriers mounted at different heights to distinguish between trains and personnel. For each portal (left and right), two pairs of barriers will be mounted so the IR beams will detect any object breaking the beams up to six feet above ground level. A third pair of barriers will be mounted at ten feet above ground level to detect a train entering or leaving the tunnel. See the communications contract drawings for details.

The barrier signals from all three pairs, six pairs for left and right portals, will be sent to a Hub Processor in the Gateway communications room for the Gateway end of the Bored Tunnel and likewise to the North Side communications room for the North Side end of the Bored Tunnel. The Hub Processor will determine if a train or personnel are entering/leaving the tunnel by processing all barrier inputs to see if the upper barrier beam has been interrupted thus eliminating false alarms if a train has entered the tunnel.

If the Hub Processor determines that a person has entered the tunnel, it will close the intrusion alarm contact for the left or right portal for a predetermined time interval. The alarm condition will be sent to Pitt Tower by the Ethernet Discrete I/O Module described in the next subsection.

B. Hardware Requirement
   1. IR Detector Bar
      a. Pre-assembled bar with 2, 4, 6 or 8 bi-directional beams (2 & 4 beams required for this project)
      b. Emitters and receivers for every beam
      c. Infrared wavelength: 940nm
      d. Emitters max radiant power: 3000mW/sterad for single beam
      e. Beams synchronized by remote hub on RS485 bus
      f. An alarm occurs when one or more beams are interrupted for 100msec
      g. Water and dust protection IP65 grade
      h. ROTAX allows the +/- 90degree horizontal alignment of all beams of a bar with a single rotation movement. Vertical alignment not needed.
      i. Anti-opening and anti-removal tampers
      j. Operating Temperature: -4 to 140degrees F
      k. Relative Humidity: 0 to 100%

   2. HUB Processor
      a. Hub controls up to 4 barrier pairs connected by 4 twisted pair cable

b. Provides power to barrier bars
c. Manages all synchronization of beams and processes the digital information from the barrier bars to set alarm decision
d. Provides output contacts for integration with external control system (2 relay outputs for alarm and tamper).
e. Program via PC connection to RS232 port.

C. Acceptable Manufacturer and Model Numbers:
1. Safeguards Technology, Photon Infrared System
2. Model PHO-2505-02 (2 Beam IR Barrier Bar)
3. Model PHO-2505-04 (4 Beam IR Barrier Bar)
4. Model PHO-HUB-TC (Hub Processor)

2.17 ETHERNET DISCRETE INPUT/OUTPUT MODULE

A. Ethernet Discrete Input/Output (DI/DO) Module shall be used to communicate, via the Gigabit Ethernet Ring, the status of the Portal Surveillance Detection System Hub module intrusion alarm contacts to the Video Management System software at Pitt Tower. Upon detection of an intrusion alarm the Video Management System software shall sound an audible alarm at the client workstations.

B. Special Requirements:
1. Provide software package for configuring the unit, and for interfacing the processor with the Video-Management system, for representation of the status of the DI points. Provision for the software shall include a mySQL-compatible relational database software system, which serves as an interface between the Ethernet DI/DO processor and the Video Management Software system. The database shall be configured to store time-stamped status of the DI points at a regular interval. Sampling rate of the DI and DO points shall be user adjustable, and shall be tentatively set at one sample per second.

C. Performance Criteria:
1. Supported protocols: IEEE 802.3/802.3u 10BaseT/100BaseTx and IEEE 802.3/802.3u 10BaseFl/100BaseFx, Modbus over IP or equal.
2. Ethernet signal: RJ45/Cat.5 UTP cable, minimum 100 meters.
3. Discrete Input signal: up to 30VDC/VAC, up to 10 Hz; minimum four DI points per module
4. Ethernet address assignment of DI/DO points, and other unit configuration data shall be retained in non-volatile memory in the I/O module processor, or be maintained by internal battery.
5. Temperature range: -30 to +70 degrees Fahrenheit.
6. Power requirement: 120V/60Hz, or supplied with appropriate power adapter.

D. Acceptable Manufactures:
1. Sixnet

2. Moxa Inc.
3. Perle Systems Inc.
4. Approved equal.

2.18 UPS SYSTEM (PITT TOWER)

A. The existing UPS System at Pitt Tower supplies backup power to the existing analog CCTV system. The new UPS System specified here in will replace the existing UPS system and supply backup power to both the existing analog CCTV system and the new Digital Video System.

B. The new UPS system shall be as specified in Section 16705 "Communications System Power Supply".

2.19 LAN CABLE

A. LAN CABLE shall be Category-6 LAN cables for all Gigabit Ethernet, 10BaseT and 100BaseTX LAN connections. All patch cord length cables shall be supplied with factory-installed connectors.

B. Special Provisions:
   1. Use TIA/EIA568-B termination standard throughout the project. The use of TIA/EIA568-A standards is prohibited.

C. Performance Criteria:
   1. Standards: TIA/EIA568-B Cat.6 horizontal cable, or better.
   2. Conductors: minimum solid 23AWG, four-pair UTP's or multiple of four-pair UTP's.
   3. Delay skew: Maximum 45nsec/100m @ 100MHz.
   4. Attenuation: Maximum 20dB/100m @ 100MHz, 33dB/100m @ 250MHz.
   5. Return loss: minimum 20dB @ 100MHz.
   6. ELFEXT: minimum 24dB @ 100MHz.
   7. NEXT: minimum 44dB @ 100MHz., 38dB @ 250MHz.
   8. PSELFEXT: minimum 21dB @ 100MHz.
   9. PSNEXT: minimum 42dB @ 100MHz, 36dB @ 100MHz..
   10. Impedance: 100 +/- 15 Ohms @ 100MHz, 100 +/- 32 Ohms @ 250MHz.
   11. Connector: 8-conductor, 8-position modular connector unless otherwise specified, or to suit connected device.
   12. Temperature rating: minimum +140 degrees Fahrenheit.
   13. Voltage rating: minimum 300V.

D. Acceptable Manufactures
   1. Alpha Wire
   2. Belden
   3. Avaya
   4. Or equal

2.20 WIRE AND CABLE

A. Data Cable, Extended Distance
   1. Twisted Pair, RS-232 / RS-422, extended distance, quiet (industrial shielded).
   2. Minimum specifications:
      a. Conductor gauge: 24 AWG.
      b. Shield: foil around each pair with drain wire.
      c. Distance: up to 4000 feet.
      d. Capacitance: 12 pF per foot.
      e. Resistance: 16 ohms per 1000 ft.
      f. Insulation: plenum rated, low flame, no smoke.
      g. Jacket: plenum rated, low flame, no smoke.
      h. Temperature rating: 220 degrees F.
      i. Voltage rating: 300 volts.

B. CAT 5 Cable
   1. Portal Surveillance System cabling between detectors and Hub Processor
   2. Minimum specifications.
      a. Conductor gauge: 22 AWG.
      b. Unshielded Twisted Pairs: 4 pair, UTP
      c. Insulation: plenum rated, low flame, no smoke.
      d. Jacket: plenum rated, low flame, no smoke.
      e. Temperature rating: 194 degrees F.
      f. Voltage rating: 600 volts.

C. Coaxial Cable
   1. RG59 low loss cable for CCTV and computer applications.
   2. Minimum specifications:
      a. Conductor gauge: 20 AWG.
      b. Dielectric: Foam fluorinated ethylene propylene.
      c. Shield: 95% tin-coated copper.
      d. Insulation: plenum rated, low flame spread, no smoke.
      e. Jacket: plenum rated, low flame spread, no smoke.
      f. Nominal impedance: 75 ohm.

D. Coaxial Cable
   1. RG11/U for extended CCTV applications.
   2. Minimum specifications:
      a. Conductor gauge: 14 AWG.
      b. Dielectric: Foam fluorinated ethylene propylene.
      c. Shield: 95% tin-coated copper.
      d. Insulation: plenum rated, low flame spread, no smoke.
      e. Jacket: plenum rated, low flame spread, no

		smoke.
f.	Nominal impedance:	75 ohm.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Contractor shall refer to Section 16901, "Communication System Inspection and Test" for testing requirements of Digital Video System.

B. Contractor shall provide all equipment, hardware, accessories, terminations, cabinets, conduits, raceways, cable trays, and cables required for the installation of the IP Video cameras at each station and the Digital Video System hardware at Pitt Tower.

C. Installation of all IP Video cameras shall be in accordance with the approved Contract Documents and consistent with industry standard practices.

D. Installation of IP Video cameras and associated equipment shall be consistent from site to site to provide uniformity throughout the Digital Video System installation.

E. Contractor shall assure that installation of new equipment in Pitt Tower is properly integrated with the existing equipment.

F. Contractor shall provide IP addressing for all IP based equipment, which matches the Port Authority's current IP addressing scheme. The Port Authority shall provide details of their IP addressing scheme to the successful bidder.

3.02 INSTALLATION

A. Contractor shall install IP Video cameras at locations specified on NSC station Contract Drawings and Reference Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012 as per the manufacturers mounting instructions.

B. Contractor shall install fiber cable and power cabling in conduit between camera locations and the communications equipment room per the Contract Drawings and on Reference Drawings: Gateway Station Finishes Construction Contract NSC-010, North Side Station Finishes Construction Contract NSC-011 and Allegheny Station Finishes Construction Contract NSC-012.

C. Verification: Following completion of the installation of all Digital Video System equipment at a site, Contractor shall inspect all equipment wiring to verify that all mechanical connections are made and properly secured, all hardware is installed in its proper location, and all wiring is properly terminated. This inspection shall include conductor and shield continuity and isolation verification of all installation wiring. Data sheets containing evidence of such inspection, certified as correct by Contractor for the project, shall be delivered to the Engineer for approval. Contractor shall receive approval of such inspection certification before applying power to the Digital Video System equipment covered by such certification.

3.03 ADDITIONAL INSTALLATION REQUIREMENTS

A. PITT TOWER

1. Video Wall Additions
   a. Install 19" LCD Monitors in spare monitor positions on video wall
   b. Install RG-59 Coax Cable with BNC connectors between Digital Video Decoder and LCD Monitors
   c. Install new monitor rack to extend video wall
   d. Install 37" LCD Display on video wall

2. Plasma Video Monitor
   a. Provide mounting hardware to the wall studs to support the monitor. Restore the drywall to match the existing condition after preparation for the installation is completed.
   b. Install the monitor on indicated wall space with the top edge located at about 1 inch below the related ceiling tile.

3. Video Management Client Workstation
   a. Install Client Workstation on existing console per Pitt Tower police direction.
   b. Install Client Workstation in Police Chief's office

4. Pelco CM9760 Matrix Switcher Upgrade/Digital Video Decoder Setup
   a. Install an analog video input card (CM9760) in the existing Matrix Switcher.
   b. Install seven Digital Video Decoder Units on equipment rack shelf.
   c. Install RG-59 Coax Cable with BNC connectors between Digital Video Decoder and Matrix Switcher analog video input card.
   d. Select appropriate IP addresses for the digital video decoders to output the seven PAAC selected camera images to the Matrix Switcher.

5. Ethernet LAN Cable
   a. Use TIA/EIA568-B termination standard throughout all LAN cabling. The use of TIA/EIA568-A terminations standards is prohibited.

6. Equipment Cabinets
   a. Install new equipment cabinets in the Video System Equipment Room per the Contract Drawings.
   b. Install Video Management Server, Network Video Recorders, KVM Switch, Gigabit Ethernet Switch, Digital Video Decoders, and the Ethernet LAN Switches in the new equipment cabinets.
   c. Provide additional rack space for 100% Network Video Recorder expansion.

7. Ethernet LAN Switches

a. Coordinate with the Authority for the IP address assignments.
b. Assign static IP address for each IP Video camera assembly, Video Management Server, Video Management client workstation, Network Video Recorder, Digital Video Decoder, Ethernet DI/DO Processor, KVM Switch, and Ethernet LAN Switch.

8. UPS System
   a. Install new UPS System in the Video Equipment Room per the Contract Drawings.
   b. Upon successful startup and stand alone testing of the new UPS system, disconnect the existing UPS from the analog CCTV System and reconnect to the new UPS System.
   c. Upon the successful cutover of the analog CCTV System to the new UPS System, connect and power up the Digital Video System.

B. NSC STATIONS
1. IP Video Cameras
   a. For Fixed Position Dome Cameras, provide mechanical means to adjust vertical and horizontal camera aiming angles, and to lock the camera aiming position securely.
   b. Configure the cameras and related transmission system to transmit 4CIF video images in both MPEG4 part 2 and Motion JPEG format. Make allowance to adjust video frame rate as per instruction of the Authority during commissioning period.
   c. Configure subtitles for each camera view position. For cameras with PTZ function, configure subtitle for each PTZ preset. The subtitle shall be displayed with the related video image. The subtitle shall include the camera number, and a brief description for the covered area. Make allowance to configure up to 8 presets per camera during commissioning period.

2. Fiber Optic Cable
   a. Ensure that all fiber cables as delivered to the project site are without splices.
   b. All fiber cable runs between IP cameras and the station communications room shall be installed in conduit and equipped with SC fiber connectors with ten (10) feet of slack at the communications room end.

3. IR Barrier Transceivers
   a. Install IR barrier transceivers on opposite sides of side walls of tunnels, one pair (2 beams) will be installed below the walkway, the second pair (4 beams) just above the walkway, and the third pair (2 beams) approximately ten feet above ground level. See contract drawings for location details.
   b. Wire IR barriers for the left and right portals into separate junction boxes for each portal as indicated on the contract drawings. CAT 5 cable will be used for all wiring between IR barriers and the Hub Processor in the communications room.

c. Install Hub Processor and power supply for IR barriers in the equipment cabinet in the communications room.

4. Ethernet DI/DO Processor
   a. Configure the unit as required, assign unique data point address to correspond with the individual DI points.

C. OCC
   1. IP Video Camera Selection
      a. No changes required at the OCC to view the seven preselected Digital IP video cameras on the analog CCTV system monitors at the OCC.

3.04 HARDWARE DOCUMENTATION

A. System Manual
   1. A System Manual shall be provided which includes a complete summary list of deliverable items: remote stations, spares, test equipment, consumables, and all documentation manuals and drawings.

B. Digital Video System Manuals
   1. The Digital Video System manual shall include as a minimum the following items:
      a. Installation and startup instructions.
      b. Instructions for expansion of the Digital Video System.
      c. Theory of operation.
      d. Maintenance and trouble shooting guidelines.
      e. Functional block diagrams.
      f. Layout drawings and interconnect drawings.
      g. Replacement parts list.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16750.001 – Digital Video System shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16750.001 – Digital Video System will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16751

OCS SUPPORTING DEVICES

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for OCS supporting devices, in accordance with the Contract Documents.

B. The work in this section includes, but is not limited to, the following activities:
1. Pull-off and push-off single track cantilevers.
2. Reduced height pull-off and push-off single track cantilevers.
3. Non-riding and support-only single track cantilevers.
4. Push-Pull single track cantilevers.
5. Tunnel Supports.
6. Cross-span registration assemblies.
7. Headspan registration assemblies.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 01910, "Operations, Maintenance and Repair Data"

C. Section 16602, "General Requirements Overhead Contact System."

1.03 REFERENCE STANDARDS

A. ASTM
1. A36 Steel Plates, Shapes and Bars.
2. A47 Malleable Iron Castings.
3. A123 Zinc Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars and Strips.
4. A153 Zinc Coating on Iron and Steel Hardware.
5. A588 High-Strength, Low Alloy Structural Steel.
6. A484 General Requirements for Stainless and Heat-Resisting Wrought Steel Products.
7. A530 General Requirements for Specialized Carbon and Alloy Steel Pipe.
8. B150 Aluminum Bronze Rod.

B. If other types of materials are proposed, the Contractor shall, along with the product description, include the relevant standards and information on that material in the submittal.

1.04 SUBMITTALS

A. Certification: Furnish a certification verifying that all material included in the assemblies has been designed, manufactured, inspected and tested in accordance with the Contract Documents.

B. Test Reports: Furnish copies of reports of all factory tests required by the Contract Documents.

C. Manufacturer's Data: Furnish complete manufacturer's data and drawings. Furnish calculations for each component to demonstrate adequate load capacity of each item in the configuration.

D. Shop Drawings: Furnish a complete set of assembly and component drawings showing dimensions, weights, bill of materials and related product data.

E. A complete submittal package of design calculations, installation instructions, field measurements of existing structures, and component Shop Drawings or catalog cuts shall be submitted to the Engineer for review and acceptance.

F. Operation and maintenance data shall be provided.

G. Contractor shall fabricate, furnish and install all applicable cantilever assemblies for the overhead wires. The cantilevers shall be installed, as shown on the Contract Drawings.

H. Contractor shall fabricate, furnish and install all applicable messenger suspension, and cross-span registrations, as shown on the Contract Drawings.

1.05 DELIVERY, STORAGE AND HANDLING

A. All support and registration assemblies, components and materials shall be protected against damage during handling and shipping, storage and installation.

B. Deliver the assemblies to the site at intervals to ensure uninterrupted progress of the Work.

C. Store material to permit easy access for inspection and identification. Protect steel members and packaged materials from corrosion and deterioration.

D. All packaged components and/or assemblies shall have a strong waterproof tag securely fastened to the package showing the assembly or component name, number, or identification code.

E. Packaging and/or packing methods of all assemblies or components shall be in accordance with the best commercial practice, adequate to ensure acceptance and safe delivery.

ARTICLE 2 PRODUCTS

2.01 MATERIALS

A. All materials used in the components of the support and registration assemblies shall be of sufficient strength and durability to withstand the loads as shown on the Contract Drawings, with the addition of a factor of safety of 2.5.

B. The material shall be light in weight and reliable to ensure a 30 year minimum life period.

C. The assemblies shall be of a proven and tested design, which shall have been used on other overhead electrified railroad systems.

D. Contractor shall furnish all labor, tools, equipment, apparatus and facilities as required to perform all fabrication and installation work as required.

2.02 METAL CHARACTERISTICS

A. Malleable Iron: Fittings or components made of malleable iron shall be grade 32510 or better and shall conform to ASTM A47. All components and fittings shall be galvanized in accordance with ASTM A153.

B. Structural Steel: Material for structural steel shall comply with ASTM A36 or A588. A36 material must be galvanized in accordance with ASTM A123.

C. Stainless Steel: Stainless Steel material shall conform to ASTM A484.

D. Aluminum components shall conform to ASTM B150.

E. All cotter pins, roll pins, spring clips, and hitch pins shall be made out of stainless steel.

F. Structural steel for miscellaneous devices shall conform to ASTM A36 or ASTM A588 to generally conform to the structure receiving the attachment, or as directed by the Engineer. Non-weathering steel applications shall be provided with an approved 3-coat paint system

ARTICLE 3 EXECUTION

3.01 INSTALLATION REQUIREMENTS

A. All supporting devices including steady arms, messenger supports and cross-span assemblies shall be installed as shown on the Contract Drawings.

B. All connections, bolts, and nuts shall be properly tightened in accordance with the manufacturer's recommendations.

C. All items shall be inspected for fit, damaged coating or bent/kinked members. Any piece found to be defective shall be rejected and a replacement shall be installed at the Contractor's expense.

D. Cantilevers shall be installed as shown on the Contract Drawings and in accordance with the manufacturer's instructions. Contractor shall take field measurements immediately prior to cantilever fabrication, to determine the as-built dimension from centerline of track to face-of-pole at either contact wire height or messenger wire height. Due allowance shall be made, during cantilever fabrication, for dead load deflection of the pole.

E. For stability during stringing, the cantilevers shall be temporarily restrained to prevent collapse due to swinging. The details of the restraint shall be submitted to the Engineer for approval.

F. Cotter pins and nuts on each cantilever shall be located on the same side of the structure to assure uniformity along the line and ease of maintenance.

G. Assemblies fitted with pins, cotters, bolts and nuts shall be oriented where possible in such manner as to lock these components together by gravity if the pins or nuts should become detached under service conditions.

H. Components employing a hinge or swivel shall be greased with approved grease before assembly of the rubbing surfaces.

I. After installation of cantilevers and final stringing of conductors, component adjustments must be possible for the final stagger, all heel settings, contact wire height and cantilever inclination, so that the OCS alignment is within the specified design tolerances.

J. Conductor interfaces of all clamps for feeder terminations, equalizing jumpers and continuity jumpers shall be coated with conductive grease.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16800

OVERHEAD CONTACT SYSTEM INSTALLATION

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work in this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for overhead contact system installation, in accordance with the Contract Documents.

B. This Section includes the installation of the Overhead Contact System (OCS), which is broadly defined as those conductors, and related items, forming the overhead power distribution system, and comprises the messenger and contact wires, hangers, feeder cables, sectioning devices, tensioning systems, and ground connections, together with their related supports and insulation.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 16602, "General Requirements Overhead Contact System."

C. Section 16805, "Interface Requirements for OCS"

1.03 REFERENCE STANDARDS

A. NEMA

B. Port Authority of Allegheny County, Light Rail Transit Program Manual of Design Criteria

1.04 SUBMITTALS

A. Contractor shall prepare and submit a tabulated allocation of all parts for the overhead contact system (OCS) based on the design shown on the Contract Drawings.
   1. Design Criteria - The basis for the construction shall be as shown on the Contract Drawings and in accordance with the latest edition of the Port Authority of Allegheny County, Light Rail Transit Program Manual of Design Criteria. Any deviation from this criteria shall be expressly approved by the Engineer before proceeding with the design.
   2. Details - The Contract Drawings indicate details where in some cases, such as conductor sizes and types, variations will not be accepted, and in other cases, such as OCS hardware, proven designs may be substituted for that which is shown.

B. The application engineering which shall be performed by Contractor shall adhere to the following program and sequence of submittals to the Engineer:

1. An initial submittal that explains the divisions of work among Contractor's forces shall be prepared. The submittal shall also indicate the suppliers of all OCS equipment, style of equipment. This submittal shall be revised and approved by Engineer prior to the final submittal.
2. Contractor shall assemble a complete package of component Shop Drawings, assembly and sub-assembly drawings for the OCS. All drawings for load carrying components must have an indication as to the component's load capacity. Fabrication of components shall not proceed until the Engineer has accepted these submittals.
3. Contractor shall submit for approval by the Engineer, the proposed installation tensioning methods of the OCS conductors to eliminate "creep." This proposal should indicate the amount of over tensioning and time frames required to significantly reduce the creep in the conductors.

C. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

1.05 GENERAL WORK

A. Contractor shall be responsible for coordinating the OCS installation with the staging and interface requirements set forth in the Section 16805, "Interface Requirements for OCS." Contractor shall submit Working Drawings for all temporary anchorage, guying, electrical isolation and protection required to turn over discrete sections of the system to Authority for its use as required. Contractor shall also coordinate outage requirements for connecting adjacent sections of the OCS to those portions in use by Authority. Such outages may be limited to night or weekend work due to the Authorities need to provide revenue service to the patrons of the light rail system.

ARTICLE 2 PRODUCTS

2.01 MATERIALS

A. Inhibitor for copper and bronze shall be T&B "Kopr Shiel," Fargo "Fargolene," Penn-Union "Cual-Aid," Burndy "Penetrox A," or approved equal.

B. The material for miscellaneous products, such as insulators, hardware, connectors and conductors is specified in other sections.

ARTICLE 3 EXECUTION

3.01 INSTALLATION OF MISCELLANEOUS ITEMS

A. Insulators
1. All insulators shall be cleaned before installation. Only clean rags, free from any abrasive material shall be used for cleaning insulators. Wire brushes shall not be

used for cleaning any parts, metal or otherwise. In the completed line, all insulator assemblies and hardware shall be clean, bright and free from nicks, chips or other mars.

B. Hardware

1. All pole-line hardware shall be installed as shown and as recommended by the manufacturer. Bolts and nuts shall be properly tightened in accordance with the manufacturer's recommendations. All bolts shall be of sufficient length for a full thread beyond the nut and/or locknut, but shall not protrude beyond the nut and/or locknut more than 1/2 inch, excluding foundation bolts. Bolt ends shall not be cut off. Where locknuts are not used, lock washers shall be provided.
2. Hardware shall be installed using tools and methods specified and/or approved by the manufacturer.
3. Hardware shall be inspected for cleanliness and damage. Any item that does not fit, creates scraping of galvanizing during installation, or is found defective shall be rejected.
4. Cotter pins shall be installed with the open end toward the ground.

C. Connectors

1. Current-carrying connectors, shall be as shown on the Shop Drawings and shall be installed in accordance with the manufacturer's recommendations. Connectors for copper wire shall be copper.
2. Bolts in bolt-type connectors shall be lubricated as recommended by the manufacturer and torqued to the manufacturer's recommendation, using a calibrated torque wrench.
3. Where practicable and available, the connectors shall be factory-loaded with a corrosion inhibitor which is made for the specific purpose.
4. Wire surfaces which are in contact with conducting surfaces of the connector shall be thoroughly wire brushed and an inhibitor applied. Where connectors are not factory-loaded, the same inhibitor shall be applied in the field to the connector.
5. Corrosion inhibitors shall be stable over a wide temperature range, adhere to cold metal surfaces, be water-repellent, weather resistant and inert to copper, aluminum, zinc, tin, cadmium, steel and neoprene rubber. Grit-bearing inhibitors shall be used except for flat lugs, sliding surfaces or where recommended by the connector manufacturer. Grit shall be compatible with the connector and wire metal
6. One typical full-tension test of each type of splice for each type of conductor shall be fabricated independent of the OCS and shall be tested by an independent testing laboratory approved by the Engineer The tensile strength and electrical conductivity of full-tension line splices shall be at least equal to the values specified in NEMA Standard CC3 for Class 1, Full-Tension connectors. Copper and bronze line splices shall conform to the specified standard of 95 percent tensile strength and 100 percent conductivity (minimums).
7. Contact wire splices shall be designed to avoid the formation of "hard spots" in the OCS. Maximum separation of spliced contact wires shall be 1/32 inch.

D. Conductors
   1. For each length of conductor installed, a record shall be kept of the reel number from which the conductor was used. Partially used reels shall be recorded as such.
   2. All conductors shall be handled in accordance with good overhead line practice and the manufacturer's recommendations.
   3. Conductors shall normally be ordered with several lengths of conductors on one reel to satisfy several anchor to anchor runs. They shall be supplied in one length. As each anchor to anchor length is removed, the length remaining on the reel shall be recomputed and properly recorded both on the reel and on substantiating documentation.
   4. Care must be taken with reels so as not to prejudice the stringing operation.
   5. Cables in manholes shall be arranged on Contractor furnished racks and secured with cable ties with ends of cables sealed against moisture if connections or splices are not completed.

3.02 INSTALLATION OF OVERHEAD CONTACT SYSTEM

A. Wires shall not be erected without the OCS guy anchor assemblies being in place, tied-back where necessary and ready to receive loads.

B. The method of erecting the messenger and contact wires shall be submitted to the Engineer for approval.

C. Care shall be taken to prevent kinks in the wires and cables. The Engineer reserves the right to reject any contact wire in its entirety if it is judged that any kink will prejudice current-collection performance. Bird caging of stranded wire shall be cause for rejection.

D. Tensions in all conductors shall be as given in temperature-tension charts, ± 5 percent.

E. Splicing of conductors is not acceptable in any in- running contact wire (one which is in contact with the LRV pantograph) except with the approval of the Engineer.

F. No splice will be permitted within 5 feet of a support clamp.

G. Any damage to the conductors shall be reported, in writing, to the Engineer. Remedial action must be approved by the Engineer and will be performed as directed.

H. Contractor shall provide any temporary anchors and down guys required to facilitate system installation and construction staging at its own expense.

3.03 ERECTION OF BALANCE WEIGHT ANCHOR (BWA) DEVICE

A. The BWA device shall be installed as shown on the approved Shop Drawing and as recommended by the manufacturer.

B. It is suggested that the Balance Weights are positioned at the mean temperature 68 degrees F position on the pole and locked during OCS installation so that vertical travel is prevented. Tensioning of the messenger and contact wires can then be effected in accordance with the Erection Tensions as shown on the Contract Drawings. This method permits cantilevers and pull-offs to be set perpendicular to track for messenger suspension clamp tightening. It avoids the need to calculate along-track offsets, resulting from temperature variation or cantilever setting and clamping, if the conductor tensioning is effected with the weights free to move.

3.04 PREPARATION FOR STRINGING MESSENGER WIRE

A. Roller-bearing sheaves of the closed type shall be used at all support points for stringing of the messenger wire. Sheaves shall be of sufficient size to accommodate the conductor without damage.

B. Stringing of the messenger shall start from an anchor location. After the initial termination is made, the conductor shall be pulled from the reel and lifted into the sheaves at each support. Sufficient tension must be maintained in the conductor during stringing to ensure that, under no circumstances, does the conductor touch the ground or track between support points.

C. When the second anchor location is reached, the messenger conductor shall be tensioned above the specified final erection tension. This tension shall be held for a minimum of 48 hours and then slackened to the specified erection tension, and the dead-end assembly attached.

D. Erection tensions shall be governed by tables furnished for the purpose, based on the equivalent span for the tension length and temperature of the conductor.

E. At OCS structures adjacent to overhead obstructions, when there is a possibility of interference, the conductors shall be lowered temporarily clear of those obstructions. Acceptable clearances shall be maintained at all times to the track.

3.05 ADJUSTING MESSENGER WIRE STRINGING TENSION

A. Final adjustment to the specified stringing tension shall be made progressively, working any slack from the first anchor location toward the second anchor location at the other end of the run.

B. The tension shall be adjusted so that it will be within ±5 percent of the erection tension derived from the tables.

C. When the proper tension has been obtained, the suspension clamps shall be tightened in permanent position on the strand.

3.06 INSTALLING HANGERS

A. As-installed span lengths between messenger support points are to be measured during construction and hanger lengths for each span of OCS fabricated from the hanger lengths given in the Contract Drawings.

B. Hangers shall be manufactured to a tolerance of 1/4 inch in length.

C. The along-track position of each hanger shall be within ± 2 inches of the design position.

3.07 STRINGING AND TENSIONING CONTACT WIRE

A. Contact wire shall be erected in temporary wire loops attached to the ends of the hangers. "Figure Eight" loops made of No. 9 iron wire annealed, or other approved loops, may be used. In any case, the contact wire shall not be restrained from longitudinal movement during tensioning (aluminum temporary hanger wire shall not be permitted).

B. Contact wire shall be held in proper lateral position, in relation to the centerline of track, using temporary rollers to prevent kinking.

C. Contact wire shall be tensioned in accordance with the tensions shown on the Contract Drawings for the appropriate equivalent span and temperature. The contact wire should be over tensioned and held for a minimum of 48 hours before reducing to the specified tension and making the final termination.

3.08 TENSION CONDITIONS

A. Conductor temperatures shall be measured by thermometer. The bulb of the thermometer shall be in direct contact with the conductor and shall be closely taped to the conductor to prevent drafts around the bulb. The thermometer shall be read after 5 minutes of contact.

B. A record of temperature and the tension recorded at both ends of the tension sections shall be kept for all catenaries.

3.09 ATTACHING HANGER CLIPS AND REGISTRATION ARMS

A. As the hanger clips are fastened and steady arms attached, any twist in the contact wire shall be removed by working from one anchor to the other.

B. As far as practicable, bolts shall be installed in the various clips so that the nuts will be on the same side giving a uniform appearance. On curves, the nuts shall be placed on the inside of the curve to provide the best clearance to the LRV pantograph.

C. Saddles for loop-type hangers shall clamp the messenger tightly. The loops shall have a loose fit around the saddle, permitting free rise and fall without binding.

D. Wire pull-offs shall be installed in locations designated on the approved layout drawings.

3.10 INSTALLATION OF BRIDLE WIRES

A. Bridle wires shall be installed in pulley wheel supports as shown on the Contract Drawings.

B. The messenger wire, messenger wire loop and fittings shall be capable of accommodating the full messenger wire current and mechanical along track movement induced by temperature changes.

C. The messenger wire loop and fittings shall not restrict the along track movement of the OCS throughout the full temperature range.

D. The tension division between the messenger and bridle wire shall be as recommended by the manufacturer. In no case shall the bridle wire tension exceed 75 percent of the normal unbridled messenger tension.

E. Contractor shall submit, for approval by the Engineer, installation methods for the bridle wires prior to proceeding with the work.

3.11 INSTALLATION OF WIRE CROSS ASSEMBLIES

A. Crossed-contact wire assemblies shall be fitted at all in-running contact wire crossings as shown on the Contract Drawings.

3.12 INSTALLATION OF JUMPERS

A. Jumpers shall be installed at locations shown on the Contract Drawings.

B. Before fitting jumper clamps, the conductors shall be wire-brushed to ensure a good electrical connection beneath the jumper clamps and manufacturer recommended inhibitor applied.

C. Jumpers shall protrude through their clamps a minimum of 1/2 inch and a maximum of 1 inch.

D. The configuration of jumpers shall make due allowance for the relative movement between OCS for all temperatures.

3.13 CONTROL OF SCRAP

A. Scrap components shall be segregated from usable components, and collected and removed daily.

B. Scrap components shall not be left alongside the track.

C. Scrap components shall become property of Contractor and shall be removed from the Worksite.

3.14 FINAL ADJUSTMENT

A. After tensioning has been completed and any temporary stops at the balance weight anchors removed, hangers and clips fastened, steady arms erected, and pull-offs installed, a check of the construction and adjustment to final position shall be made.

B. Construction at overhead obstructions shall be checked for proper contact wire height, and for clearance from the messenger to the underside of the obstruction.

C. Any hangers with improper fit shall be replaced with hangers of proper length.

D. Height of contact wire and lateral position of wire shall be checked in accordance with the Contract Drawings and adjusted where necessary and is to be measured normal to the track along the projected/super elevated centerline.

E. The contact wire height given in the Contract Drawings is to be the height of the wire over its auto tensioned temperature range.
   1. Where the normal height of contact wire is 16 feet and above, a tolerance of +2 inches, -0 inch from the height shown on the Contract Drawings will be permitted.
   2. Where the wire is shown less than 16 feet, a tolerance of +1/2 inch, -0 inch, will be allowed.
   3. Midspan heights must be at the average of the support heights at the structures at each end of the span; a tolerance of 1 inch will be allowed.

F. The staggers of the contact wire shown in the Contract Drawings are relative to the inclined centerline of track which coincides with the nominal centerline of the static LRV pantograph.

G. Generally, on tangent track, the stagger of the contact wire will be alternately to the right or left of the center line of LRV pantograph at consecutive structures.
   1. The lateral position of the contact wire on curved track will vary with the curvature and span length. The stagger at each support will be as shown in the Contract Drawings.
   2. The installation tolerance for contact wire stagger shall be ±1/2 inch on the values specified in the Contract Drawings. When required to achieve acceptable midspan offset, this tolerance may be increased with the approval of the Engineer.
   3. If the construction indicates that changes are required, the subject shall be brought to the attention of the Engineer at once.

H. The messenger wire shall be installed vertically above the final contact wire stagger with an allowance of ±1/2 inch for system heights of 1.5 feet or less, increasing to ±2 inches for system heights of 3 feet or greater.

3.15 MEASUREMENT OF THE CONTACT WIRE AT STRUCTURES AND AT MIDSPAN

A. The following measurements shall be made and recorded with the OCS in its final position.
   1. Contact wire height above each track at each messenger support point and at midspan.
   2. Wire temperature and air temperature including time of day.
   3. Contact wire stagger relative to design super-elevated track centerline at each registration point and at midspan.
   4. Track centerline to face of pole at rail level at each structure location, actual track superelevation and pole rake.

B. A complete set of the final height and stagger dimensions, as accepted, shall be available at the Final Inspection, and incorporated into the final as-built documents.

3.16 PRECAUTIONS IN HANDLING CONDUCTORS

A. Conductors shall be handled in such a manner that it will not be scratched, cut, or nicked with tools or clamps.

B. Conductors shall not lie upon, or be dragged across, sharp or rough surfaces.

C. Conductors shall not be annealed.

D. Sharp bends shall not be put in the Conductors.

E. Conductors shall not be looped to form dead-ends of either a temporary nature or a permanent nature.

F. Conductors shall not be wrapped around poles or other anchorages.

G. Conductors shall not be marred with temporary wire or hook hangers.

H. Only approved parallel jaw clamps shall be used in tensioning all conductors. The grooves of the clamps must be free from burrs, fins, or any roughness, and the ends of the grooves must be flared (bell-shaped).

I. Vertical kinks in the contact wire shall be removed. A leather or copper-faced hammer shall be used, beating against a smooth flat surface. A 4 inches by 4 inches by 4 feet hardwood block is recommended.

J. Lateral kinks in the contact wire shall be removed if they affect the fit of any parts.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16805

INTERFACE REQUIREMENTS FOR OCS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work in this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for interface requirements for OCS, in accordance with the Contract Documents.

B. This Section includes, but is not limited to various interfaces between Contractor work and work performed by other Authority contractors, as well as for interfaces between the existing Stage I revenue service route and the new North Shore Connector routes.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 01739, "Quality and Configuration Management"

C. Section 01781, "Maintenance and Protection of Authority Traffic"

D. Section 16602, "General Requirements Overhead Contact System."

E. Section 16830, "Overhead Contact System Test and Inspection."

1.03 SUBMITTALS

A. Contractor shall submit an installation and cut-over sequence plan for all areas of new construction which affect existing LRT operations.

B. Contractor shall develop and submit an interface plan, during the preliminary submittal stage of the extension lines' Overhead Contact System into the existing system.

C. Contractor shall be responsible for the development of the interfaces between Contractor work and work performed by other Authority contractors, and for Contractor work at all interface locations between the existing Stage I route and the new North Shore Connector routes.

1.04 COORDINATION

A. Interface between Contractor and other Authority contractors shall be through the Engineer. Cooperate with the Engineer and respond appropriately within a timely manner following receipt of any request on behalf of the other Authority contractors.

1.05 QUALITY ASSURANCE

A. Comply with the requirements of Section 01739, "Quality and Configuration Management".

1.06 BASIC INTERFACES

A. Environment
   1. The OCS equipment shall be capable of being operated, stored and maintained without impairment resulting from the impact of the environment of the LRT System throughout the range of worst-case conditions specified in Section 16602, "General Requirements Overhead Contact System."
   2. Contractor is reminded that part of the work is to be performed on the existing LRT operations.
   3. All work interfacing with the existing LRT shall be scheduled with the approval of Authority and in accordance with the Contract Documents to minimize disruption of train service.

B. Authority Interface
   1. Contractor will be permitted access to operating portions of the system on a prearranged basis. Access requests must be submitted in writing, in accordance with Section 01781, "Maintenance and Protection of Authority Traffic".
      a. Access requirements will be approved by the Engineer and the Authority. These requirements will include scheduling, work staging, construction interfacing and the environment under which the work will be accomplished.
      b. Contractor shall attend weekly meetings with the Engineer and shall describe the work plan for the next two weeks. These meetings will be used to effect coordination and to resolve issues.
      c. Any installation or testing which affects existing light rail operations must be done during the hours to be specified by the Engineer and must be completed in sufficient time to allow for normal light rail service TO BE RESTORED. It is the Contractor's responsibility to supply sufficient competent employees and reserves to assure restoration of scheduled service within the allotted time. Contractor shall furnish all equipment such as, but not limited to, flags, safety vests, flares, phones, and radios.
   2. Any work crew interfacing with the existing LRT operations must be supervised by a Contractor's employee(s) who has attended and been certified by Authority. Contractor shall coordinate with the Engineer for times, dates and locations to attend this class.
   3. Work which does not affect train operations may be performed, with the authorization of the Engineer, during LRT operation hours. Contractor will furnish such flagmen, watchmen or other employees as may be deemed necessary for safe and continuous operations at no additional cost. Detailed plans of the Contractor's procedures, including an itemized time schedule and breakdown of the labor force shall be submitted to the Engineer at least 10 working days prior to

implementation. Authority reserves the right to determine the number of flagmen necessary, based on Contractor's work plan.

4. Lighting and electric power, where not specifically provided by others, shall be provided by Contractor.
5. Cooperate with the Engineer and respond within a timely manner following receipt of any request for information on behalf of Authority. .

C. Operating Rail Line Interface

1. Contractor shall submit an installation and cut-over sequence plan for all areas of new construction which affect existing LRT operations. The plan shall be submitted, to the Engineer, 90 days prior to commencing any field installation work, and shall include, at a minimum, the following:
   a. Narrative descriptions and schematics for temporary or interim circuits and materials.
   b. Descriptions for the implementation and sequencing of tests as specified in Section 16830, "Overhead Contact System Test and Inspection."
   c. Installation methods and sequencing implementation.
   d. Narrative descriptions and schematics to maintain existing operations and rail traffic.
2. OCS conductors shall, immediately after installation, be grounded in a manner subject to the approval of the Engineer, and remain grounded until such time as they are placed in service. Contractor shall ground, in a similar manner, other aerial conductors which have been removed from service.
3. Coordinate all interface work with the Engineer.
4. Excavations made in the trackwork area shall not remain open more than 48 hours.
5. Contractor shall be responsible for the protection of existing equipment and facilities while working on the system.

D. Passenger Vehicle Interface

1. The passenger vehicle and LRV pantograph characteristics can be made available to the Contractor from the Engineer upon request.
2. Train consist
   a. The standard train for the purpose of testing will consist of one or 2 cars coupled together.
   b. Under normal operations the train will consist of 2 cars coupled together during rush hours and 1 car at all other times.
3. The passenger vehicle dynamic profile will be provided to the Contractor upon NTP.
4. All Contractor-furnished equipment shall be fully compatible with the passenger vehicles and vehicle equipment, including Electro Magnetic Influence.

1.07 INTERFACES TO EXISTING OVERHEAD CONTACT SYSTEM

A. Contractor shall develop and submit an interface plan of the North Shore Connector OCS into the existing Stage I OCS. The plan shall cover detail implementation, staging sequence, and cut-over requirements for Wood Street Crossover and overlaps with Stage I OCS System at Gateway.

B. Existing Stage I OCS layouts at interface locations will be made available to the Contractor from Authority upon request for information only.

1.08 INTERFACES WITH NEW SIGNAL SYSTEM

A. Contractor shall coordinate its OCS design, construction and installation with the remainder of the Work.

ARTICLE 2 PRODUCTS

[NOT USED]

ARTICLE 3 EXECUTION

[NOT USED]

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16810

STAGGER AND HEIGHT GAUGE

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for stagger and height gauges, in accordance with the Contract Documents.

B. This Section includes design, manufacture and supply of the stagger and height gauge and associated components and gauges for checking the Overhead Contact System (OCS), as shown on the Contract Drawings and specified herein, and shall include the following:
   1. Contact wire height gauges.
   2. Stagger gauges.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 01910, "Operations, Maintenance and Repair Data"

C. Section 16602, "General Requirements Overhead Contact System."

1.03 SUBMITTALS

A. Contractor shall submit Shop Drawings detailing all gauge components and dimensions, including a bill of materials, for approval prior to supply and/or fabrication.

B. Contractor shall submit a Certificate of Performance prior to acceptance for use on the Project.

C. Operation and maintenance data shall be provided.

D. Manufacturer's spare parts list shall be provided with gauge.

1.04 QUALITY ASSURANCE

A. Contractor shall obtain a Certificate of Performance from a certified testing laboratory, which attests to the accuracy and performance of the gauge, as required by this Section.

1.05 DELIVERY, STORAGE AND HANDLING

A. Contractor shall insure the gauge is protected from damage throughout the duration of the Project.

B. Contractor shall deliver two operational and calibrated height and two operational stagger gauges in new condition to the Engineer at the completion of the Project.

ARTICLE 2 PRODUCTS

2.01 FABRICATION

A. The stagger gauge, marked in ½ inch increments for the entire width, shall be used to measure the distance (stagger) between the contact wire and the superelevated LRT pantograph centerline at contact wire height.

B. The height gauge, marked in ½ inch increments for the entire length, shall be used to measure the height between the contact wire/messenger wire and the top of rail at superelevated track centerline.

ARTICLE 3 EXECUTION

3.01 APPLICATION

A. All surfaces shall be maintained clean and free of all foreign matter, and all parts shall be in good working condition when in use for the duration of the Work, in accordance with the gauge manufacturer's instructions.

B. The stagger gauge shall be treated as an accurate, sensitive engineering instrument and shall be used to verify all relevant OCS dimensions as specified herein.

3.02 ADJUSTING AND CLEANING

A. The stagger gauge shall be field calibrated by Contractor at the start of every day that it is utilized, and shall be adjusted in accordance with the gauge manufacturer's instructions.

B. Under no circumstances shall the gauge be used if out of calibration, damaged, or in an inoperable condition.

C. The height gauge shall be cleaned frequently, as recommended by the manufacturer, to ensure it retains the 25 kV insulation properties, even if it is used for unenergized wires.

3.03 PROTECTION

A. Contractor shall use the stagger and height gauges in accordance with all Authority Safety Regulations and Requirements as specified in the Safety and Security Manuals .

B. Under no circumstances shall the gauge be used if wet, moist or otherwise contaminated if the Overhead Contact System is energized or in an unknown state.

3.04 SPARE PARTS

A. The gauges shall be supplied with a manufacturer's spare parts list, and the necessary replacement components to allow the continuous use of the equipment, considering reasonable wear and tear by Contractor.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16820

OCS SPECIAL TOOLS

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for OCS special tools, in accordance with the Contract Documents.

B. This Section includes, but is not limited to furnishing OCS special tools required for the work, grounding jumpers, live line tools, slings, hoists, ladders, etc.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 16602, "General Requirements Overhead Contact System."

C. Section 16830, "Overhead Contact System Test and Inspection."

1.03 SUBMITTALS

A. Shop Drawings and catalog cuts shall be submitted for approval showing details and dimensions of all products and assemblies, together with complete specifications of materials proposed for components.

ARTICLE 2 PRODUCTS

2.01 MATERIALS

A. All materials proposed for use shall meet the applicable performance requirements, and shall be non-corrosive and durable.

2.02 MANUFACTURED ITEMS

A. The above tools are the minimum requirements to be furnished to Authority. Contractor shall also provide any special tooling required for the installation and maintenance of any specialized components.

B. This requirement shall not restrict Contractor from selecting and providing the tools and equipment used for construction.

ARTICLE 3 EXECUTION

3.01 GENERAL REQUIREMENTS

A. All OCS special tools specified herein shall be purchased as new for this Project, and then may be used by Contractor, and shall remain as the Contractor's property throughout the work of the Overhead Contact System, and during its subsequent testing as specified in Section 16830, "Overhead Contact System Test and Inspection." Following acceptance of all segments of the completed system, all special tools shall become the property of Authority, and shall be delivered to Authority, in good working condition.

B. Fabrication and assembly procedures shall not start until the required submittals have been reviewed and accepted.

C. Contractor shall deliver the assembled special tools complete and ready for use to Authority in sufficient time for OCS adjustment purposes.

D. Contractor shall be responsible for and protect all special tools from damage during the duration of the project and shall deliver all items in good working condition to Authority at the acceptance and completion of the project. All special tools and equipment required by this section which are damaged and rendered useless for this intended purpose, or lost or stolen during the execution of the work, shall be replaced by Contractor at no extra cost to Authority.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16830

OVERHEAD CONTACT SYSTEM TEST AND INSPECTION

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for overhead contact system test and inspection, in accordance with the Contract Documents.

1.02 RELATED SECTIONS

A. Section 01300, "Administrative Requirements"

B. Section 16602, "General Requirements Overhead Contact System."

1.03 SUBMITTALS

A. Inspection and Test Plan.

B. Factory Inspection and Test Procedures.

C. Field Inspection and Test Procedures.

D. Acceptance Measurement Tables

E. Test Reports.

1.04 TESTING

A. This Section includes testing and inspection to be performed at points of manufacture and installation of the Overhead Contact System (OCS).

B. Through testing and inspection Contractor shall verify that the OCS meets Contract Document requirements.

C. Tests and inspections shall be conducted according to procedures submitted by Contractor and approved by the Engineer.

D. Contractor shall furnish all labor and materials necessary to perform tests, record data, and prepare reports.

E. Changes required to bring the system into compliance shall be at no additional cost to the Authority, including costs for additional testing.

F. Upon completion of each test, all test equipment and temporary facilities shall be removed and the system restored to full operational status.

1.05 STATISTICAL SAMPLING PLANS

A. Sampling plans may be proposed for use when tests are destructive, or when quality trend data, inherent characteristics of the product, or the non-critical application of the product indicate that a reduction in testing or inspection can be achieved without jeopardizing quality.

B. Contractor shall provide details on any sampling plans and submit the proposed sampling plan to the Engineer for approval prior to its use.

C. Any sampling plan used shall provide valid confidence and quality levels, as solely determined by the Engineer.

1.06 TEST EQUIPMENT AND CALIBRATION

A. Contractor shall supply all test equipment required for factory and field testing.

B. Each item shall have its own permanently affixed identification number and shall be calibrated, adjusted and maintained at prescribed intervals, or prior to use, against certified equipment having known valid relationships to nationally recognized standards.

C. The method and interval of calibration for each item shall be defined, based on type of equipment, stability, characteristics, required accuracy, intended use and other conditions affecting measurement control.

D. When measuring and test equipment are found to be out of calibration, an evaluation of the validity of previous inspection and test results, to determine the acceptability of items previously inspected and tested, shall be made and documented.

E. Out-of-calibration tools and equipment shall be tagged and not used until they have been re-calibrated and verified.

F. If any tools or equipment are consistently found to be out of calibration, as determined by the Engineer, they shall be repaired or replaced by Contractor.

G. A calibration shall be performed when inaccuracy is suspected.

H. All calibrations/certifications shall be recorded and become part of the quality assurance records.

ARTICLE 2 PRODUCTS

2.01 INSPECTION AND TEST PLAN

A. Contractor shall develop an Inspection and Test Plan for the overall OCS. The purpose of this plan is to:

1. Identify all of the inspections and tests to be performed.
2. Ensure that testing is in compliance with the overall Quality Assurance Program.
3. Achieve mutual understanding between the Contractor and the Engineer on the range, depth, and other aspects of tests to be conducted.

B. The Inspection and Test Plan shall contain the following as a minimum:
1. Flow diagram showing the logical sequence of inspections and tests starting with factory tests and concluding with field demonstration tests.
2. List of factory and field test procedures, proposed submittal schedule, and proposed test schedule.
3. Outline and format of procedures and test data sheets for each type of test.
4. Requirements (if any) for Authority furnished material, personnel, or equipment.
5. Requirements and recommendations for witnessing by the Engineer or designated representative.
6. Organization chart and description of the Contractor's factory and field test organizations.
7. Diagram showing the flow of quality assurance and test data and its use within Contractor's Systems Engineering and Quality Assurance functions.

2.02 TEST PROCEDURES

A. Test procedures shall include, as a minimum, the following information:
1. Objective and scope.
2. Test setup.
3. Test prerequisites.
4. Test equipment to be used.
5. Personnel required for the test.
6. Estimated duration of the test.
7. Pass/fail criteria.
8. Samples of data sheets

B. Test procedures shall include block diagrams depicting test setup for each test method, test equipment to be used, procedures, and method for recording data in all cases except where tests are to be performed in full accordance with published standards.

C. Submit all test procedures to the Engineer for approval at least 60 days before the scheduled test

2.03 TEST REPORTS

A. Test reports shall contain, as a minimum, the following information:
1. All data obtained during tests.
2. Analysis of the data.
3. Conclusions relating to the pass/fail criteria outlined in the test procedure.
4. Discrepancies found and corrective action taken.

5. Date of test.
6. Signature of person conducting the test.
7. Space for signature of witness.
8. Specific test equipment used by name, type, serial number, and calibration details.

B. Submit signed test reports from Contractor, Subcontractors or suppliers no later than 10 days after completing each test.

2.04 FACTORY INSPECTIONS AND TESTS

A. Contractor shall inspect and test each item to be provided under the Contract Documents. The following inspections and tests are to be included:
   1. Receiving inspection of raw materials or component parts at the factory.
      a. These inspection measures shall be used to preclude the use of incorrect or deficient products and to ensure that only products which are acceptable and in compliance with the Contract Documents are used and installed.
      b. All product certifications and Test Reports used as the basis for acceptance by Contractor shall be preserved, as required by the Contract Documents.
   2. Inprocess inspections of production operations.
   3. Factory qualifications testing, if applicable.
   4. First article inspection test, if applicable.
   5. Environmental testing, if applicable.
   6. Factory acceptance tests.
   7. System level inspections and tests.

B. General requirements for factory inspections and tests
   1. All subsystems, equipment, and components of the OCS shall be tested at the factory to verify that they meet their design and nameplate ratings for adequate and proper performance.
   2. All systems, subsystems, and equipment shall be 100 percent factory inspected and tested to assure compliance with specifications.
   3. Other components or units that are not used in a failsafe circuit may be inspected and tested using a sampling plan approved by the Engineer.
   4. The Engineer shall have the right to witness inspections or tests in Contractor's or suppliers' plants.
   5. Contractor shall obtain the Engineer's approval of test results prior to making any shipment from its or its suppliers' plants.
   6. When approved by the Engineer, suppliers' existing factory test procedures may be used.

C. Submit the suppliers' test procedures to the Engineer for review and approval 30 days before testing.

ARTICLE 3 EXECUTION

3.01 FIELD INCOMING INSPECTIONS AND TESTS

A. Contractor shall provide a receiving inspection activity at the Worksite for incoming products. These inspection measures shall be used to preclude the use of incorrect or deficient products and to ensure that only products which are acceptable and in compliance with the Contract Documents are used and installed. All product certifications and Test Reports used as the basis for acceptance by Contractor shall be preserved, as required by the Contract Documents.

B. Contractor shall maintain a receiving inspection log for all items received at the Worksite. Contractor shall propose the content of the log for the Engineer's approval.

3.02 FIELD ACCEPTANCE MEASUREMENTS

A. Upon completion and acceptance by the Engineer of each segment of construction, Contractor shall measure the contact wire height, stagger, and other required dimensions and record the readings on an Acceptance Measurement Form, in the presence of the Engineer.

B. Tests shall be scheduled in advance with the Engineer, and shall only be made in times of calm, dry weather, with either steady sunshine or continuous cloud cover.

C. Contractor shall furnish the height and stagger gauge, and all other equipment necessary to make Acceptance Measurements. All measuring equipment will be approved by the Engineer.

D. The Acceptance Measurement Table shall be prepared and shall include the following information:

1. Track designation.
2. Wire Run Number as indicated on the Contractor's Layout Schedule.
3. Drawing number(s) where the structures of the Wire Run are shown.
4. Name(s) of person(s) responsible for performing the acceptance measurements.
5. Sheet number of a Wire Run set.
6. Equipment or OCS style being measured.
7. Temperature in degree F of the conductor during the time of measurement.
8. Weather conditions during time of measurement (such as windy, raining).
9. The date measurement was made.
10. Station location of the structure as indicated.
11. Distance of the pole to the rail measured from the track centerline to the face of the pole.
12. Cross-level difference of the two rails measured at the structure station (actual superelevation at the structure).
13. Distance measured at the structure from the contact wire to the vertical or superelevated centerline of the track (referred to as stagger).

14. The vertical distance between the contact wire at the structure measured from the mean rail level (referred to as contact wire height at the support).
15. The same as item number 13 except measured at midspan (referred to as actual superelevation at midspan).
16. Distance between the contact wire and the vertical or superelevated centerline of the track measured at midspan (referred to as midspan offset).
17. The same as item number 14 except measured at midspan (referred to as contact wire height at midspan).
18. The average of the contact wire heights at the structures at each end of the span minus the contact wire height at midspan (referred to as sag).
19. The rate of change of contact wire between the structures. This is equal to the difference of contact wire heights at each structure divided by the span length (referred to as gradient).
20. Vertical distance measured at the structure between the contact wire and the messenger wire (referred to as system height).
21. Rise or fall of counterweight from median position.
22. Positions of counterweight stops at ambient temperature.
23. The vertical distance between the tunnel ceiling and the vertical or superelevated centerline of the track measured at each tunnel support.
24. Electrical clearance from messenger or contact wire support to tunnel ceiling with uplift force of 50 lbs on the contact wire at the point of measurement measured at each tunnel support.
25. At overlaps and turnouts: Height of in-running and out-of-running contact wire above rail-referenced level at each structure.
26. Comments or remarks as required.

E. The Engineer will use the Acceptance Measurements to determine compliance with the designs and will inform Contractor of necessary corrections to be performed.

F. Contractor shall execute corrections at no further cost to the Authority, except for adjustments required by the Engineer which are changes beyond the requirements specified in the Contract Documents.

G. After execution of corrections, Contractor shall re-measure and record affected data and submit the results to the Engineer.

H. The work of this Section shall not be complete until corrections are completed and approved by the Engineer.

3.03 VISUAL INSPECTION OF COMPLETED OCS

A. At Contact Wire Level, Contractor shall make the following checks, and remedy unsatisfactory conditions detected:
1. Check fit and tightness of all components.
2. Check split pins and locknuts are secure.
3. Check contact wire for kinks, rolls, and damage.

4. Check messenger wire for damage to strands.
5. Check correct steady arm fittings.
6. Check heel settings.
7. Check that jumpers are of correct type, have adequate travel capability, are properly fitted, and are well formed to avoid fatigue failure.
8. Check posture of pulley plates.
9. Check that hinge fittings have freedom to move under load.
10. Check that a wire passing through a cantilever and not attached to it will clear any part of this cantilever by at least 3 inches throughout the range of from 0 degrees F to +122 degrees F.
11. Check for clearance and insulation between adjacent or crossing wires.
12. Check installation for locations of possible interference with passage of LRV pantographs, including spots where pantographs could tangle with wires or suspension assemblies.

B. From the ground, Contractor shall make the following checks:
   1. Check the counterweights have freedom to travel and that counterweight band does not bear on guide pipe.
   2. Check that cantilevers have correct along-track offset.
   3. Check that hangers are plumb and within design position.

3.04 CLEARANCE ENVELOPE TESTS FOR LRV PANTOGRAPH

A. General: The purpose of these tests is to verify the mechanical and electrical clearances of the LRV pantograph on each section of the system. The tests shall be conducted after all installations are complete. Any section found to have insufficient clearance shall be adjusted to provide the required clearance.

3.05 OVERHEAD CONTACT SYSTEM (OCS) ELECTRICAL TESTS

A. Circuit Continuity and Loop Resistance
   1. General: The purpose of this test is to obtain the dc loop resistance of each OCS section. This test checks both the OCS and the rail return system for electrical continuity and the absence of high resistance connections or inadvertent ground connections.
   2. Procedures: The test entails short circuiting a discrete section of the OCS by connecting the OCS to its rails at one end, and applying a dc voltage at the other end.
      a. Feeders which are electrically common to the OCS shall be connected to the OCS.
      b. A DC source is required which will provide a current of nominally 100 amperes with an applied voltage of 24 VDC (such as two car batteries in series).
      c. Measurements shall be made of the DC voltage and DC current, the circuit resistance calculated from the measured values of voltage, and current shall be compared with the design value.

d. Any section having a discrepancy of more than 20 percent between the design value and the measured value shall be rechecked to ensure that all electrical connections are correctly made, or that there are no inadvertent ground connections to the OCS which are reducing the total length of the loop.
e. The following items shall be recorded for each section:
1) Length of section (ft).
2) DC volts.
3) DC amps.
4) Ohms.
5) Ohms/mile.

3. Precautions: The tests required for the loop resistance require passing relatively high dc currents through OCS and rails. Proper regard must be paid to safety. Test zones shall be clearly identified. All safety requirements established by the Contractor concerning the public, work personnel, and equipment shall be strictly enforced. Personnel not directly associated with the tests should be clear of the tracks. The section of OCS and associated feeders under test must be isolated from the adjacent sections of the system.

B. Hi-Pot Insulation Testing

1. General: DC hi-pot test shall be performed on discrete sections of the OCS. The hi-pot tests serve the following purposes:
a. Components such as insulators and feeders are checked for leakage.
b. The electrical withstand of minimum clearance areas, such as overhead bridges, are verified under static conditions.
c. The electrical withstand of section insulators and disconnect switches are verified.
d. The test provides a means of periodically checking for any reduction in the insulation level of the OCS sections, by comparing voltage and leakage current with previously measured values.
e. A nominal DC hi-pot voltage of 2.5 kV shall be used for the test. Hi-pot tests shall be carried out on the OCS sections as soon as possible after the continuity tests have been completed, in order to ensure that all of the section being tested is electrically continuous and is subjected to the test voltage.

2. Procedure for Main Line Tracks: Adjacent OCS sections which are electrically isolated from the section under test shall be grounded by connecting the OCS to the rails. All surge arresters shall be disconnected from the section under test. A DC test voltage shall be applied to each OCS section in 1 kV increments up to the nominal test voltage. The test voltage shall be held for 30 seconds at each increment. The leakage current at each value shall be measured and recorded together with the weather conditions and temperature.

3. Precautions: The hi-pot measurements require application of high voltage to the OCS. Proper regard must be paid to safety. Test zones shall be clearly identified. All safety requirements established by Contractor concerning the public, work personnel, and equipment shall be strictly enforced. Personnel not directly associated with the tests should be clear of the tracks. Sections of OCS and

associated feeders under test shall be isolated from the adjacent sections of the system, and all OCS sections adjacent to the section under test shall be grounded.

3.06 INTEGRATED TESTS

A. Following the testing of the OCS as specified in this Section, Contractor shall assist the Engineer in performing integrated tests with other systems.

B. LRV pantograph tests on the OCS will be performed during integrated testing using a transit vehicle with the pantograph in contact with the contact wire. These tests are to assure a smooth, shock-free passage of the pantograph with no interruption to current collection especially at turnouts, section insulators, overlaps, and overhead bridge wire height changes. Particular attention will be focused on wire takeover at overlaps, turnouts, and crossovers, and the lack of arcing at all locations. Contractor shall be responsible for all adjustments required as a result of these tests. Any adjustments required shall be performed at the expense of the Contractor.

C. Contractor shall be required to operate and maintain the OCS until the Certificate of Acceptance of Final Acception.

3.07 LRVS FOR TESTING

A. Authority will provide LRVs and crews to support the testing program. These tests will be scheduled through the Engineer.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16889

TUNNEL SERVICES ELECTRICAL TESTING AND COMMISSIONING

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for tunnel services electrical testing and commissioning, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Electrical testing and commissioning for new tunnel services systems.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel services electrical testing and commissioning portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 15400, "Tunnel Services Scope of Work"

B. Section 15445, "Tunnel Mechanical Drainage Systems"

C. Section 15887, "Tunnel Ventilation and Balancing Dampers"

D. Section 15889, "Tunnel Ventilation Fans"

E. Section 15890, "Tunnel Ventilation Jet Fans"

F. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

G. Section 16890, "Tunnel Services Electrical Requirements of Mechanical Equipment"

H. Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center"

I. Section 16892, "Tunnel Services Uninterruptible Power Supply"

J. Section 16893, "Tunnel Services Power Factor Correction"

K. Section 16894, "Tunnel Emergency Rail Lighting and Lighting Receptacles"

L. Section 16895 "Tunnel Services Low Voltage AC Variable Speed Drive"

1.03 REFERENCE STANDARDS

A. ANSI

B. IEC

C. IEEE

D. NEC

E. NEMA

F. NFPA

G. UL

1.04 SUBMITTALS

A. All submittals shall be sealed by a Professional Engineer.

B. The Contractor shall submit to the Engineer, two (2) weeks prior to proposed commencement of commissioning and site acceptance testing, an Inspection and Test Plan for the Engineer's approval. The plan shall detail each commissioning activity for each particular system in a logical order for site acceptance testing. A list of the control procedures, acceptance criteria and verification documentation, as well as hold and witness points, shall be provided for each activity on the plan. The Engineer shall advise of any additional tests or hold and witness points not expressly mentioned that may be required to prove full compliance and normal operation of the equipment.

C. Test results for equipment associated with energization of supplies shall be presented in separate and discrete packages with the results presented in a logical order to facilitate review.

D. After the submission of each test package, the Contractor shall be available for a review meeting with the Engineer for verification that all required tests have been performed and approval of test results.

E. The review meeting shall be held as soon as possible but no later than the day after receipt of the test package by the Engineer.

F. Test certificates are to be submitted to the Engineer within seven days thereafter of the test being carried out.

G. System performance test results indicating "pass" or "fail".

ARTICLE 2 PRODUCTS

A. NOT USED

ARTICLE 3 EXECUTION

3.01 GENERAL

A. The Contractor shall carry out the testing, setting to work and commissioning of all fire life safety electrical supply systems.

B. The Contractor shall check and correct all interface cabling, indication and interlocks and commission the installation as a whole.

C. The Contractor shall ensure the correct wiring and operation of the Programmable Logic Controllers (PLCs) and field mounted instrumentation.

D. The Contractor shall ensure that all apparatus, material used and completed equipment shall withstand satisfactorily such tests as are specified herein and any additional tests customary in the manufacture and installation of the types of equipment included in the Contract Documents, or which may reasonably be required by the Engineer to prove compliance with this Section.

3.02 TEST INSTRUMENTS

A. All test equipment to enable the tests specified herein to be performed shall be provided by the Contactor. The following is a brief list of the equipment likely to be needed.

1. 1000V "megger" set (Evershed or similar);
2. Ductor ohmmeter test set;
3. 2.5/5kV insulation resistance test set;
4. Primary and secondary current injection equipment;
5. Tachometer; and
6. Phase rotation meter.
7. Light meter for testing lighting installation;
8. Phase rotation meter;
9. Calibration milliamp supply for instrument circuits;
10. Contact thermometer;
11. Pressure calibrator;
12. Temperature calibrator (mV or ohms);
13. Infrared thermometer;
14. Hand held two way radios, and
15. Earth leakage tester (multi-range).

B. The Contractor shall check the condition of the testing equipment at the time of the test and issue a report on its condition to the Engineer.

3.03 WITNESSING OF TESTS

A. All tests shall be carried out in the presence of the Engineer and test certificates are to be submitted to the Engineer within seven days thereafter.

3.04 COMMISSIONING

A. Operation of switches and circuit breakers and energization of cable, motors, busbars and transformers, shall be as coordinated with the Engineer.

B. No switching operations shall be carried out without prior approval from the Engineer.

C. All commissioning is to be carried out in accordance with inspection and test procedure and relevant safety standards. Care shall be taken to ensure that electronic or voltage sensitive equipment is isolated before insulation resistance measuring equipment is connected.

D. All control and protective devices and their operating mechanisms, e.g. float switches shall be adjusted. Relay testing associated with high and low voltage switchgear shall be carried out using equipment supplied by the switchgear vendor. Tests on these relays shall include primary injection tests.

E. Relay settings and required performance test points shall be specified by the Contractor.

3.05 CIRCUIT BREAKER SWITCHBOARDS

A. DC test, at appropriate voltage, phase-to-phase for 1 minute (3 tests); and DC test, at appropriate voltage, phases to ground for 1 minute (1 test) or as recommended by switchgear manufacturer.

B. Insulation resistance tests by megger before and after tests.

C. Circuit breaker operations checks (test for simultaneous closing of all phases, and adjust contacts as necessary, including reduced voltage operation).

D. Operational checks of alarms, annunciators, doors and interlocks, protective relays, instruments and metering.

E. Mechanical tests include, but are not limited to:
   1. Correct making and alignment of moving parts;
   2. Operational checks of mechanical interlocks;
   3. Operational checks of the correct entry and withdrawal of the circuit breaker truck.

3.06 FUSED ISOLATORS

A. Check alignment of switchgear and ensure all bolts are tight.

B. Check all cable connections and glands for tightness.

C. Check operation of switch mechanism and interlocking.

D. Check ground bars are clean and tight.

E. Check insulators for visible defects and busbar connections for tightness.

F. Check fuse mounts and fuses for viability and correct current rating.

G. Insulation test with megger.

H. DC test at appropriate voltage, phase-to-phase for 1 minute (3 tests), and DC test at appropriate voltage, phases-to-ground for a minute (1 test) or as recommended by the switchgear manufacturer.

I. Repeat insulation test.

J. Check door interlocks.

3.07 480 VOLT SWITCHGEAR

A. Check busbar and cable connections for tightness.

B. Check fastening and mounting bolts for tightness.

C. Check racking of circuit breakers and interlocks.

D. Check grounding cables and switchboard ground connections.

E. Check operation of circuit breakers by control switch, protective relays and selective tripping, thereby also proving integrity of closing and tripping supplied.

F. Test insulation resistance with 1000V megger (phase-to-phase, phase-to-neutral, phase-to-ground).

G. Check operation of door interlocks.

H. Set protective relays to data provided (after tests have been completed).

3.08 480 VOLT MOTOR CONTROL CENTERS

A. Check busbar and cable connections for tightness.

B. Check grounding cables and connections.

C. Test insulation resistance with 1000V megger (phase-to-phase, phase-to-neutral, phase-to-ground).

D. Check operations of contactor, isolators, door interlocks, protective relays, instruments and metering.

E. Check integrity of control circuits and correct connection to nominated phase.

F. Check fusing of fuse switches controlling local lighting and power distribution.

3.09 0.6/1KV CABLES

A. Check insulation resistance with 1000V megger (phase-to-phase, phase-to-neutral, phase-to-ground).

B. Check ground continuity, where applicable.

C. Test insulation resistance of all control cores in a cable, as a group, to ground.

D. Check for correct identification of cable markers.

3.10 480 VOLT MOTORS

A. The following tests shall be carried out on all motors where applicable.
   1. A one minute insulation test on the windings and connected power cable taken at the MCC outgoing terminals with a Megger. For low voltage motors the insulation test shall be at 1000V. The temperature at the time of testing shall be recorded. Where required, the motor insulation shall be dried out by an approved method.
   2. Insulation and circuit resistance of motor heaters including connected cable.
   3. Check bearings for brinelling.
   4. Resistance of thermistor circuits.
   5. Check bearing temperature after a four hour run at no load.
   6. Check no load current.

3.11 LIGHTING SYSTEMS

A. The following test shall be carried out on all lighting circuits and equipment.
   1. 500V Megger test to all cables including switch wires.
   2. Ground continuity test.
   3. Operational test of all luminaries.
   4. Lighting levels are to be measured and reported to the Engineer.
   5. A discharge test shall be carried out on all battery operated emergency units to establish the capacity of the batteries.

3.12 INSTRUMENTS

A. At handover, each instrument shall be checked against the instrument data sheet to ensure the correct unit has been supplied.

B. Prior to installation each instrument shall be tested for calibration. Calibration tests shall consist of the application of an input signal and measurement of the output signal. Calibration shall verify the accuracy, range, linearity and hysteresis relative to the Manufacturer's specifications and the instrument data sheets. Any instruments that do not pass calibration tests shall be immediately reported to the Engineer.

C. Each instrument "loop" shall be checked for continuity, completeness and identification up to the control system terminals.

D. Field transmitters shall be manually or otherwise operated to cause a change in input signal and the receiving instrumentation observed for correct magnitude and direction of response.

E. Changes shall be made to setpoints, manual adjustments and like elements on controllers and similar devices and the final operators observed for correct magnitude and direction of response.

F. Load cells, gauges, nucleonic devices and other special equipment shall be tested using Manufacturer's instructions as required to demonstrate correct functional operation.

3.13 BATTERIES

A. Preparation of electrolyte and filling of batteries in accordance with the Manufacturer's instructions.

B. Charging and equalizing of battery charge in accordance with the Manufacturer's instructions.

3.14 GROUNDING

A. Test all grounding conductors for continuity after installation.

B. Check all ground connections for correct termination.

C. Test resistance to ground of every electrode.

3.15 MOTOR STARTERS

A. Operational check on all control devices, with motor leads disconnected from starter terminals.

B. Checking and setting of all protective and measuring devices as instructed, and when required.

C. Calibration and checking of instruments, control valves, meters and relays, and associated voltage and current transformers.

D. Checking of control circuit wiring including internal wiring and field wiring.

E. Checking alarm, annunciator, DCS and PLC (as appropriate) interconnection circuits.

3.16 SYSTEM PERFORMANCE TESTS

A. System performance tests shall be performed as specified in Contract Documents Section 15891, "Tunnel Services Mechanical Testing and Commissioning".

B. In addition to the systems tests above, but not limited to, the following electrical system performance test shall be performed and documented "pass" or "fail".

1. All ventilation modes as per Contract Drawings MC 400 and MC 404.
2. Set ventilation modes via SCADA screen at OCC.
3. Transfer control from OCC to local control touch screens via SCADA screen.
4. Transfer control from OCC to local control touch screen if communication failure to OCC occurs.
5. Manually control individual item of equipment via local control touch screen when it as control.
6. Set ventilation modes via local control touch screen.
7. Mains power failure to PLC/RTU. UPS powers RTU/PLC.
8. Communication failure to OCC, PLC/RTU remains in the last set ventilation mode.
9. Test security of power supply by failure of incoming feeders. Bus ties close and provide power to via the operating feeder.
10. Primary PLC/RTU failure. Transfer control to secondary PLC/RTU. Once primary PLC/RTU is operational again, control is transferred back from secondary to primary.
11. Failure of fan monitoring devices (vibration, RTDs) or communication to these devices. Mode of operation of fans unaffected.
12. Loss of communications between VSD and RTU/PLC. VSD fail to last set speed and direction.
13. Mains power failure (greater than 90 minutes) to tunnel emergency lighting system. The centralized emergency lighting UPS powers lights for at least 90 minutes.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16889.001 – Tunnel Services Electrical Testing and Commissioning shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16889.001 – Tunnel Services Electrical Testing and Commissioning will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16890

TUNNEL SERVICES ELECTRICAL REQUIREMENTS OF MECHANICAL EQUIPMENT

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for electrical requirements of mechanical equipment for tunnel services, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design, manufacture, furnish, install and testing of all electrical requirements of mechanical equipment for tunnel services.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel services electrical requirements of mechanical equipment portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 01910, "Operations, Maintenance and Repair Data"

B. Section 13590, "Housings And Housing Equipment"

C. Section 15400, "Tunnel Services Scope of Work"

D. Section 15445, "Tunnel Mechanical Drainage Systems"

E. Section 15887, "Tunnel Ventilation and Balancing Dampers"

F. Section 15889, "Tunnel Ventilation Fans"

G. Section 15890, "Tunnel Ventilation Jet Fans"

H. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

I. Section 16111, "Conduit"

J. Section 16120, "Low Voltage Power Cables"

K. Section 16130, "Raceways and Boxes"

L. Section 16702, "Copper Outside Plant"

M. Section 16742, "SCADA System"

N. Section 16889, “Tunnel Services Electrical Testing and Commissioning”

O. Section 16891, “Tunnel Services Low Voltage Switchboard and Motor Control Center”

P. Section 16892, “Tunnel Services Uninterruptible Power Supply”

Q. Section 16893, “Tunnel Services Power Factor Correction”

R. Section 16894, “Tunnel Emergency Rail Lighting and Lighting Receptacles”

S. Section 16895, “Tunnel Services Low Voltage AC Variable Speed Drive”

1.03 REFERENCE STANDARDS

A. ANSI

B. British Standards (BS)

C. Deutsches Institut fur Normung (DIN)

D. IEC

E. IEEE

F. NEC

G. NEMA

H. NFPA

I. UL

1.04 SUBMITTALS

A. All submittals shall be sealed by a Professional Engineer.

B. Shop Drawings shall include circuit, connection and instrument loop diagrams which clearly identify all cables, terminations and connections and indicate accurately the numbers of cables, wires, terminals and cable cores marked on the installed plant. Indicate front and side views of enclosures with overall dimensions. Include conduit entrance locations and requirements; nameplate legends; electrical characteristics including voltage, frame size and trip ratings; all termination numbers and identification of purpose; and time-current curves of all equipment and components.

C. Test certificate shall include equipment type test certificates where applicable.

D. Characteristic graphs of drive motor speed/torque/starting current and driven load torque on starting when run-up exceeds 8 seconds.

E. Contractor shall submit proposed mounting details for all electrical equipment for approval by the Engineer.

ARTICLE 2 PRODUCTS

2.01 APPLICATION SPECIFIC REQUIREMENTS

Table 16890-2

ITEM	DESCRIPTION	UNIT	DATA
1	Supply Voltage (Ventilation Fans, Jet Fans, Sump Pumps) Three Phase	VAC	480
2	Supply Voltage (Damper Actuators) Single Phase	VAC	120
3	Supply Voltage (Control) Single Phase	VAC	120
4	Supply Heaters	VAC single phase	120
5	Supply Dry Type Transformer	VAC	480 delta to 208 Y/120
6	Supply Frequency	Hz	60
7	Operating Ambient Temperature	°F (°C)	104
8	Minimum Operating Temperature	°F	32
9	Operating Relative Humidity	%	95.

2.02 GENERAL

A. Should the Contractor propose any deviations from the specified requirements, such variations shall be submitted in writing to the Engineer for evaluation of conformance to the Contract Documents.

B. The Contractor shall be responsible for ensuring that all equipment and materials supplied are in accordance with the requirements of the Contract Documents.

C. Ratings
   1. All equipment and materials supplied by the Contractor shall be suitable for operation under the general service conditions as specified in the Contract Documents.
   2. All equipment and materials shall be rated for continuous full load operation under any combination of the Design Environment Conditions specified in Article 2.01 of this Section.

D. Power System
   1. The equipment shall be designed and manufactured for normal operation on the power supply system as specified in Article 2.01 of this Section.

E. Equipment Protection
   1. All equipment, including panels, junction boxes and terminal boxes, shall have a minimum degree of protection of NEMA 4X, unless otherwise specified in this Section.
   2. All enclosures shall be vermin proof.

2.03 TECHNICAL

A. Design Documentation
   1. All electrical equipment such as motors, heaters and associated control equipment shall be correctly sized in accordance with the various standards and codes for the duty specified.
   2. Design calculations shall be submitted to the Engineer for approval prior to the selection of major items of equipment. In particular on high inertia and reciprocating drives where the driver and drive torque requirements can be critical, speed, run-up time and power supply voltage fluctuation calculations shall be submitted.
   3. Electrical and instrument design calculations shall be included as part of the Project Records Documents.

B. Instrumentation
   1. The Contractor shall be responsible for selection of proper range, pressure rating and materials of construction based on fluid properties, operating conditions and mechanical design constraints for all furnished instruments.
   2. All instrument equipment shall be correctly designed, sized and installed in accordance with the applicable standards included in Article 1.03 of this Section.
   3. Calculations justifying the selection of the various instrument devices shall be approved by the Engineer together with the following Shop Drawings and manuals:
      a. Instrument loop diagrams.
      b. Instrument layout and location drawings.
      c. Interconnection drawings.
      d. Termination diagrams.
      e. Internal wiring diagrams.
      f. Process and instrumentation diagrams (P&IDs).
      g. Operational description of instrumentation and control.
      h. Instrument list complete with model numbers, operating conditions, ranges and switch settings.
      i. Operations and maintenance manuals.

C. Instrument Tag Numbers
   1. Each item of instrumentation equipment shall be allocated a unique tag number. The allocation of tag numbers shall conform to the requirements of Authority tag numbering system. During the design stage, the Contractor shall submit a list of equipment requiring tag numbers to which Authority will allocate the appropriate

tag number. The Contractor shall use these tag numbers in all documentation and drawings pertaining to the equipment package being supplied. No other instrument numbering shall be used.

D. Electrical / Instrument Systems
   1. The Contractor, for the mechanical equipment, shall provide associated electric/instrument equipment and/or services as part of the overall package including all necessary motor starters, control devices and SCADA interface connection points.

E. Facilities for Interface with Local Ventilation Control System PLC
   1. For each item of mechanical plant, the Contractor shall provide a PLC interface termination box to facilitate the connection to Authority's Ventilation Control System PLC network. The PLC interface termination box shall be complete with all terminals, panels, gland plates, etc. necessary to facilitate the interface.
   2. Digital inputs into the Ventilation Control System PLC shall be in the form of volt free contacts wired by the Contractor to the PLC interface termination box. Digital outputs from the Ventilation Control System PLC shall be in the form of volt free contacts wired by other Authority Contractor to the PLC interface termination box. Analogue inputs into the Ventilation Control System PLC shall be in the form of 4-20 mA signals wired to the PLC interface termination box. Analog outputs from the Ventilation Control System PLC shall be in the form of 4-20 mA signals wired by other Authority Contractor to the PLC interface termination box.
   3. Communications interfaces to Instrument shall be RS 485 and Modbus protocol.

F. 480 Volt Electric Motors
   1. 480 volt electric motors shall conform to the Contract Documents.

G. Control Panels
   1. Control panels shall be constructed of material as per Contract Documents shall be to the following classifications:
      a. External design - Dead front
      b. Assembly type - Cubicle type assembly
      c. Method of connection - Front connected
      d. Access - Front access only
      e. Degree of protection - NEMA 3 minimum
   2. Control panels shall be provided with a lockable front access door, chrome plated pintle hinges and padlockable main isolating switch interlocked such that the door cannot be opened unless the switch is in the "OFF" position. The isolating switch door interlock shall be defeatable by the use of a tool such as a screwdriver to allow inspection by a competent tradesperson while the equipment is alive. Live parts on the line side of the main isolating switch shall be shrouded. "DANGER - LIVE ISOLATE ELSEWHERE" warning labels shall be fitted to the shrouds.

3. Live circuits which are exposed when the panel door is opened, shall be shrouded. "DANGER - LIVE ISOLATE ELSEWHERE" warning labels shall be fitted to the shrouds.
4. A removable 1/8 inch brass gland plate shall be provided for bottom entry and termination of all electrical and instrument cables. The gland plate shall be grounded directly to the control panel ground bar.
5. Control panels may house both power and instrument control equipment providing the panel is constructed as two entirely segregated sections:
    a. One section serving power equipment.
    b. The second section housing instrument equipment.
    c. Particular instruments prone to magnetic interference from adjacent power equipment shall be housed in a separate segregated section.
6. Alarm annunciators may be incorporated in the control panel or housed in a separate panel, and panels bolted together to form one assembly.
7. Adequately sized terminal blocks for the termination of all outgoing and incoming cables, with 20% spare terminals, shall be provided inside the panel. The terminal blocks shall accept up to two 14AWG conductors. Wiring and cable ducts shall be provided with covers. Terminal blocks shall have terminal numbers fitted in accordance with the Contract Drawings using the manufacturer's proprietary terminal numbers. Only one wire or cable core shall be connected to each side of a terminal.
8. Control panels shall be provided with manual control equipment such as pushbuttons, selector switches, "ON", "OFF" or other indicating lamps, etc., which are required for the operation of the equipment. Pushbuttons, control switches and indicating lamps shall be fully weatherproof. Pushbuttons and indicating lamps shall be color coded in accordance with NFPA 79 standards. Indicating lamps shall have polycarbonate lenses, and shall be of the L.E.D. type.
9. All relays, pushbuttons, switches, fuses, etc shall be suitably labeled using black on white. Labels shall be fixed to the panel sheet metalwork. They shall not be fixed to equipment items or duct covers and shall not be obscured by wiring. Labels within panels shall have 1/5 inch minimum lettering and otherwise comply with the Contract Documents.
10. Each cubicle and the complete assembly shall be rigidly supported and shall be provided with suitable lifting lugs.
11. Alarm annunciators shall comply with the following general requirements:
    a. Alarm windows approximately 1 inch x 2 inch, black lettering on white.
    b. First up indication.
    c. Flashing alarm condition and pulsating horn/siren.
    d. Steady light and horn silenced on alarm accept.
    e. Alarm light extinguishes on reset of alarm condition.
    f. Test facilities.

H. Remote Terminal Units
    1. Refer to Section 16742, "SCADA System" of the Contract Documents.

I. Internal Wiring
   1. Control panel wiring shall be clearly identified in accordance with the Contract Drawings using cable core markers. Cable core markers shall read left to right or top to bottom.
   2. Wiring shall be enclosed in capped plastic ducts or neatly loomed with nylon ties or spiral binding as required. Wiring ducts shall be filled to a maximum space factor of 50%.
   3. Where wiring is required to connect to devices mounted on doors it shall be arranged such that opening and closing of the door is not impeded while minimizing flexing of the wiring loom. The loom shall be effectively fixed at both ends of the door opening with insulated saddles or clamps.
   4. Wire colors shall comply with the following requirements of NFPA 70 and NFPA 79
   5. Terminals shall be clearly numbered in accordance with the Contract Drawings. Terminals shall be rail mounted, adequately sized to suite wiring size and provided with 20% spare rail space. The bridging of terminals shall be provided by the use of terminal bridging links as supplied by the terminal manufacturer.
   6. Control wiring shall be terminated using pre-insulated pin or spade type crimp lugs. Conductors terminating to stud type terminals shall be fitted with spade type crimp lugs.
   7. A separate ground bar shall be provided for the termination of all ground wires. Only one wire shall be connected into each termination point.
   8. Minimum conductor size shall be 16 AWG (stranded).
   9. Cable glanding plates shall be grounded directly to the control panel ground bar.
   10. Panels shall be fitted with a suitable pocket to contain circuit diagrams and other relevant drawings. An "As Built" set shall be provided with the panel.
   11. A maximum of two control wires shall be terminated on any control device terminal.
   12. Fuse carriers and bases shall be of the fully insulated and shrouded type. Fuses shall be of the bolted connection type.

J. Junction Boxes and Control Equipment
   1. Junction boxes, marshalling panels, control equipment enclosures etc. shall be weatherproof, minimum NEMA 4X and shall be of metallic construction.
   2. Adequately sized terminal blocks shall be included for interconnect wiring, plus 20% spare capacity. No more than one wire shall be connected to each side of a terminal in a junction box or marshalling panel. Bridging links as supplied by the terminal manufacturer shall be used for interconnecting common terminals.
   3. All control equipment including solenoid valves, limit switches and junction boxes, shall be mounted in readily accessible locations and on mounting plates with adequate space to attach equipment identification labels.
   4. Motor terminal boxes or control equipment enclosures shall not be used as a junction box for cabling to other equipment.

K. Conduits and Pull Boxes

1. Conduits and accessories shall comply with Section 16111, "Conduit" of the Contract documents. All conduits for tunnel fire life safety equipment shall be rigid metal conduit and comply with NFPA 130.
2. Pull boxes shall comply with Section 16130, "Raceway and Boxes" of the Contract Documents.

L. Instrumentation Equipment
1. Indicating instruments shall be provided with scales using US customary units of measurements.
2. Standard transmitter outputs shall be 4-20mA for electronic signals. Electronic transmitters shall be 2-wire type unless otherwise approved by the Engineer.
3. All components in contact with the sensed fluid or gas shall be 316 stainless steel unless the process fluid requires otherwise.
4. RTDs (Resistance Temperature Detectors) shall be used for temperature signal transmission to remote panels or control systems. RTDs shall be 3-wire, 100 ohm platinum to BS EN 60751.
5. Instrument capillaries shall have stainless steel armor protection.
6. Dual setpoint switches are not allowed if setpoints are the same value.
7. Alarm and shutdown applications shall use separate switches in separate housings and have separate connections to the sensing points.
8. Instrument enclosures shall be NEMA 4X minimum.
9. Teflon tape shall not be used for thread sealant.
10. Each instrument shall be provided with a permanently fixed stainless steel nameplate containing the instrument identification number (tag number supplied by Authority through the Engineer).

M. Harmonics
1. Harmonics limits shall comply with IEEE 519.

N. Voltage Drop
1. Maximum total voltage drop at the load shall not exceed 5% of nominal voltage in normal operation.
2. During motor start, voltage drop at the motor load shall not exceed 20%. All other loads shall not exceed 5% voltage drop.

ARTICLE 3 EXECUTION

3.01 INSTALLATION OF EQUIPMENT

A. All equipment shall be installed in readily accessible positions.

B. Where equipment is mounted along an access way it shall be positioned such that it does not present a hazard or obstruction to personnel using the access way.

C. All fastenings shall be cadmium plated, zinc plated or galvanized. Spring and flat washers shall be provided under nuts or bolt heads where necessary. Other fastenings shall be securely locked. Each bolt or stud shall be shortest standard length which will show at least one full thread beyond its nut after assembly. Studs shall be screwed home at least 1 ¼ diameters

D. Mounting of electrical equipment including, but not limited, to instrument panels, local control stations, disconnect switches etc shall be mounted in the locations as indicated on the equipment location layout Contract Drawings. The Contractor shall propose mounting arrangement for approval by the Engineer. In general, they shall be mounted to the wall using Unistrut. Disconnect switches for motors and heaters shall be mounted on the wall next to the motor.

E. All instruments shall be installed according to the Manufacturer's instructions in addition to the requirements stated herein.

F. All instruments shall be installed so that accuracy and reliability shall not be impaired due to vibration, pulsation, temperature, or contamination.

G. Instrument piping, tubing, and conduit shall be properly protected and supported. . Pipe, conduit, and larger tubing shall be securely supported by Unistrut channels and clamps or approved equal.

H. Conduit or piping shall not apply stress loads to instrument cases or mountings.

3.02 CABLING

A. To prevent ingress of water, cable entries at each device or junction box shall be arranged bottom entry.

B. Each cable shall be identified at each end with a cable marker and each control cable core shall be identified at each end using cable core markers. Cable and core markers shall read left to right or top to bottom. Cable cores shall be terminated using pre-insulated pin or spade type crimp lugs.

C. Install all cabling for the Fire Life Safety System in rigid metal conduit from the MCC to the equipment in the field.

3.03 CONDUITS

A. Supply and install all conduits and accessories in compliance with Section 16111, "Conduit" and according to Contract Documents and Contract Drawings.

B. Conduits and pull boxes shall be sized in accordance with the NEC.

C. Supply and install pull boxes as required or as shown on the Contract Drawings.

3.04 ISOLATING DEVICES

A. Each electric motor shall be provided with a Lock-Off-Stop hard wired into the control circuit. The Lock-Off-Stop shall be located not more than 10 feet away from, and within sight of the motor.

B. Every enclosure door of switchgear or control gear that provides access to live parts above 50 volts a.c. shall be mechanically interlocked with a padlockable main isolating switch installed on the incoming power supply. The isolating switch shall be interlocked such that the door cannot be opened unless the switch is in the "OFF" position. The isolating switch door interlock shall be defeatable by the use of a tool such as a screwdriver to allow inspection by a competent tradesperson while the equipment is live. Live parts on the line side of the main isolating switch shall be shrouded NEMA 12 minimum. "DANGER - LIVE ISOLATE ELSEWHERE" warning labels shall be fitted to the shrouds.

3.05 CONTROL VOLTAGE

A. The voltage for remote control, indication and interlock circuitry shall not exceed 120 volts a.c.

B. Control transformers shall have a metallic grounded screen between the primary and secondary windings.

3.06 WORKING SPACE

A. Work space shall comply with NEC clause 110.26.

B. Adequate means of access shall be provided for all electrical apparatus. The clear working shall be measured with switchgear and control gear doors in any normal position of operation, opening or withdrawal.

C. Electrical apparatus requiring ready access for maintenance or adjustment shall not be less 12 inches and not greater than 6 ½ feet above the floor or base of the enclosure or fixed working platform.

3.07 PAINTING AND CORROSION PROTECTION

A. The Contractor's standard for painting and corrosion protection shall be subject to approval by the Engineer.

B. The Contractor shall provide full details of the proposed painting and corrosion protection system.

C. Final color shall be as approved by the Engineer.

3.08 LABELING AND MARKING

A. All equipment shall be provided with approved nameplates and information plates permanently secured to equipment in a readily visible area. These shall be stainless steel engraved plates or laminated plastic labels with black lettering on a white background. Lettering shall be 5/16 inch high minimum.

B. Labels and nameplates shall be screw fixed with stainless steel screws. Adhesive fixing shall not be used. Label fixing holes shall be slotted to allow for expansion. Labels larger than 6 ½ x 1 inch shall have a minimum of 4 fixing screws.

C. Labels shall be fixed in such a manner that the integrity of the enclosure classification is maintained.

D. All cables, wires, terminals and control and instrument cable cores shall be clearly labeled in accordance with the Contract Drawings to enable easy identification with the circuit connection and instrument loop diagrams.

3.09 TESTING

A. Electrical and instrument equipment supplied by the Contractor shall be routine tested at the manufacturer's location in accordance with the applicable standards and to the approval of the Engineer. Tests shall include, but not be limited to, the following:
   1. Insulation resistance test.
   2. Point-to-point wire check.
   3. Test of individual control and instrumentation devices.
   4. Functional and operational check.

3.10 PREPARATION FOR SHIPMENT

A. All equipment shall be suitably protected to prevent damage during transport, storage, loading and unloading.

B. Equipment subject to damage due to vibration such as alarm annunciators, PLC cards, plug-in relays, instrument devices and the like, shall be removed and separately packed in clearly marked containers.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16891

TUNNEL SERVICES LOW VOLTAGE SWITCHBOARD AND MOTOR CONTROL CENTER

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for tunnel services low voltage switchboard and motor control center, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design, manufacture, furnish, install, and testing of the new low voltage switchboard and motor control center for tunnel services and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel services low voltage switchboard and motor control center portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 15400, "Tunnel Services Scope of Work"

B. Section 15445, "Tunnel Mechanical Drainage Systems"

C. Section 15887, "Tunnel Ventilation and Balancing Dampers"

D. Section 15889, "Tunnel Ventilation Fans"

E. Section 15890, "Tunnel Ventilation Jet Fans"

F. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

G. Section 16111, "Conduit"

H. Section 16120, "Low Voltage Power Cables"

I. Section 16702, "Copper Outside Plant"

J. Section 16742, "SCADA System"

K. Section 16889, "Tunnel Services Electrical Testing and Commissioning"

L. Section 16890, "Tunnel Services Electrical Requirements of Mechanical Equipment"

M. Section 16892, "Tunnel Services Uninterruptible Power Supply"

N. Section 16893, "Tunnel Services Power Factor Correction"

O. Section 16894, "Tunnel Emergency Rail Lighting and Lighting Receptacles"

P. Section 16895 "Tunnel Services Low Voltage AC Variable Speed Drive"

1.03 REFERENCE STANDARDS

A. ANSI

B. IEC

C. IEEE

D. NEC

E. NEMA

F. NFPA

G. UL

1.04 SUBMITTALS

A. All submittals shall be sealed by a Professional Engineer.

B. Type test certificates from a recognized testing agency.

C. Product Data sheets showing voltage, controller size, ratings and size of switching and overcurrent protective devices, short circuit ratings, dimensions, and enclosure details.

D. Final short circuit coordination study and arc fault study.

E. Provide final settings required for all adjustable/electronic type circuit breakers with long time, short time, ground fault and instantaneous settings.

F. Furnish Time–Current curves of fuses, relays, circuit breaker trip units.

G. Shop Drawings indicating general arrangements, front, side and plan section views of MCC with overall dimensions. Include conduit entrance locations and requirements; nameplate legends; electrical characteristics including voltage, frame size and trip ratings; all termination numbers and identification of purpose; and time-current curves of all equipment and components.

H. Shop Drawings of RTU/PLC Cabinet showing equipment layout and equipment description and list.

I. Label schedule.

ARTICLE 2 PRODUCTS

2.01 APPLICATION SPECIFIC REQUIREMENTS

Table 16891-1

ITEM	DESCRIPTION	UNIT	DATA
1	Supply Voltage ph.ph	VAC	480
2	Supply Frequency	Hz	60
3	Ambient Operating Temperature	°F	104
4	Minimum Operating Temperature	°F	32
5	Operating Relative Humidity	%	95
6	MCC Rated Current (Main Horizontal Bus)	A	2000.
7	Requirement for future expansion	Yes/No	Yes
8	MCC Cable Entry	Top/Bottom	Top
9	MCC Neutral Busbar Position	Top/Bottom	Top
10	MCC Grounding Busbar Position	Top/Bottom	Bottom
11	MCC Busbar Short Time Withstand Current	kA	65
12	MCC Circuit Breaker Fault Rating	kA	65
13	MCC Circuit Breaker Voltage Rating	V	480.
14	MCC Control Voltage	VAC	120
15	Metering Transformer Current	Accuracy Class 0.3B0.3	2000/5 A
16	Ground Fault Protection Relay		Adjustable Ground Fault Pickup and Delay
17	MCC Finish/Color	Powder coated acrylic paint	ANSI 61 Light Gray.
18	Heaters	VAC single phase	120
19	Dry Type Transformer	VAC	480 delta to 208 Y/120

2.02 OPERATING CONDITIONS

A. Ratings
1. All equipment and materials shall be suitable for operation under the specified general service conditions specified in Article 2.01 of this Section.

2. All equipment and materials shall be rated for continuous full load operation under any combination of the design environmental conditions specified in Article 2.01 of this Section.

B. Power System
   1. The equipment shall be designed and manufactured for normal operation on the power supply system as specified in Article 2.01 of this Section.

C. Equipment Protection
   1. All equipment shall have a minimum degree of protection of NEMA 1 unless otherwise specified in Article 2.01 of this Section.
   2. All enclosures and assemblies shall be vermin proof.

2.03 LOW VOLTAGE SWITCHBOARDS

A. General
   1. Low voltage switchboards shall conform to UL 1558 and NEC.
   2. The low voltage switchgear shall be flush fronted, totally enclosed free standing dead front type of construction incorporating molded case circuit breakers, contactors, etc. The equipment shall be suitable for continuous operation and comply with NEC and in particular to Article 384-3(a)-3. The service voltage shall be 480/277Vac, 3 phase, 4 wire 60hz. The equipment shall have a minimum interrupting capacity of 65kA. The switchboard shall comprise separate cubicles for ease of handling and to ensure that maintenance can be carried out with the remainder of the board live.
   3. Busbars shall be hard drawn high conductivity copper air insulated. Bushings shall be manufactured from epoxy resin. All connections shall be identified by insulated (no PVC permitted) sleeving and be adequately supported to withstand the fault capacity specified in Article 2.01 of this Section. Contact surfaces shall be tinned or silver plated and allowance shall be made for extending the busbars at each end.
   4. Spare circuits for future circuit breakers shall be complete with all busbar extensions and fixings necessary to connect a future unit without the necessity to isolate the busbars.
   5. Circuit breakers shall be of the molded case type and shall comply with ANSI C37-16 and C37-17.
   6. Mechanical interlocks using a Kirk key shall be used to prevent incorrect operation of the incoming main circuit breakers and the tie breaker, but the mechanical interlocks shall not inhibit any automatic operation.
   7. Both of the incoming circuit breakers shall be connected to a fireman's disconnect which, when operated, shall cause the breakers to trip.

B. Switchboard Miscellaneous Equipment
   1. All designating labels shall consist of black engraved ¼ inch high lettering on a white background screwed to the front of each cubicle.

2. Labels shall also be fixed adjacent to meters, relays, instrument fuses and other ancillary equipment.
3. A suitable rated main ground, copper bar shall be run the full length at the base of the switchboard. All cable sheaths, armoring and separate cubicles shall be bonded to the ground bar.
4. The switchboard shall be complete with all operating handles and any special tools. A complete set of Shop Drawings shall be installed within a spare compartment of the switchboard and a label fitted to indicate where the Shop Drawings are kept.
5. All small wiring cables within each switchboard shall be color coded throughout their length and marked with ferrules of an approved type at each end for identification.
6. All small wiring cables within the switchboard shall be neatly laced and cleated to the panel structure of each switchboard. Where wiring passes through a hole in the metalwork, suitable grommets shall be provided. Through wiring shall be terminated on terminal blocks in each cubicle.
7. All small wiring associated with remote control and indication circuits shall be segregated from the power wiring circuits and shall be suitably screened either by the use of screened cable or conduit or trunking installed within the cubicles.

C. Arrangement of LV Switchboard
   1. The switchboard shall be separated into two busbar sections, A & B, linked by a bus-tie circuit breaker. The switchboard shall comprise incoming main circuit breakers and individual circuit breakers supplying each load element.
      a. The equipment in the various units shall be as follows:
         1) Incoming Circuit Breaker Units equipped with:
            a) 3P, solid state molded case circuit breaker with a minimum fault level current rating as specified in Article 2.01 of this Section.
            b) 3P, air insulated copper busbars rated for a current and minimum fault level as specified in Article 2.01 of this Section.
            c) Manually initiated close/trip facilities.
            d) Solid state overcurrent / ground fault protection relays complete with voltage and current metering devices.
            e) Solid state undervoltage relay with adjustable time and voltage settings.
            f) Electrical interlocks with second incomer and bus-tie breaker.
            g) Auto/Manual keylock changeover switch.
         2) Bus-Tie Circuit Breaker Unit equipped with:
            a) 4 pole solid state molded circuit breaker for manual and automatic operation at a rated current as specified in Article 2.01 of this Section.
            b) Manually initiated close/trip facilities.
            c) 3P & N air insulated copper busbars with a rated current as specified in Article 2.01 of this Section.
            d) Electrical interlocks with incoming supply units.

e) Auto/Manual keylock change over switch.

3) Sub-main feeder MCCB's.

a) All units shall be complete with lock-out facilities.

b. LV Switchboard arrangement

1) The LV Switchboard shall be arranged in accordance with the One Line Drawing.

D. Interlocking, Tripping and Operating Facilities

1. On the LV Switchboard the two incoming supply circuit breakers shall be electrically interlocked with the bus-tie breaker so that only two out of the three can be closed at any one time. This interlocking shall be applicable in the 'Auto' and 'Manual' mode. All CT's shall be Class C as defined in IEEE Std C37.110 and IEEE Std C57.13.

a. Supply Failure

1) The incoming supply circuit breakers and the bus-tie circuit breaker shall be arranged to operate automatically on mains failure when the selector switch is in the 'Auto' position. If the electronic protective circuitry detects a supply failure, after a time delay to be specified, the circuit breaker relating to the particular transformer shall trip and the bus-tie breaker shall close automatically.

2) The circuit breakers shall automatically return to their normal position after the full electricity supply has been restored after a pre-set time delay.

3) If the selector switch is in the 'Manual' position, the automatic sequence shall be inhibited.

4) Should either of incomer MCCB's trip due to overcurrent or ground faults, the bus-tie MCCB shall not operate.

5) The bus section breaker shall not close if both main incoming supplies fail.

E. Circuits and Labels

1. The circuit classification shall be as shown on the main distribution one line diagram but the nomenclature for the labels of each circuit shall be agreed with the Engineer during the drawing approval period.

F. Finish

1. The finish of the LV Switchboard shall be NEMA 1 enclosure, which shall be finished in a color specified in Article 2.01 of this Section.

2.04 MOTOR CONTROL CENTER

A. Motor-control centers shall conform to NEMA ICS 2, UL 845 and NEC for standard starters.

B. Motor-control centers shall conform to NEMA ICS 2, UL 508 and NEC for special starters.

C. Design
   1. MCC's shall comprise type tested, standardised, freestanding, metal-clad, cubicle type switchgear assemblies complying with the relevant standards and the following requirements:
      a. MCC's shall be designed for indoor operation;
      b. Each MCC cubicle shall consist of a number of functional units arranged in a vertical tier;
      c. The MCC cubicles shall be of a flexible modular design to facilitate future installation of functional units of varying capacity ratings. The cubicles shall be furnished with all accessories necessary to form a complete switchgear assembly;
      d. Rated currents shall be as specified in Article 2.01 of this Section or as shown on the Contract Drawings;
      e. Rated Diversity shall be 1.0 unless specified otherwise in Article 2.01 of this Section;
      f. Motor starter functional units shall be grouped such that all starters for the motors in any one machine, as indicated on the One Line Diagrams, shall be adjacent in the same MCC tier;
      g. Starter functional units for motors 150kW and above shall be located at the bottom of the MCC;
      h. Where specified in Article 2.01 of this Section, space for additional cubicles at one end of the MCC shall be provided for the installation of additional control equipment supplied. The minimum requirement for cubicle dimensions shall be as specified on the Contract Drawings;
      i. All MCC's shall be provided with a minimum of 10% spare functional unit space;
      j. All MCC's shall be suitable for the addition of cubicles and functional units for all motor starters for motors designed as "Future" on the Contract Drawings;
      k. The MCC shall be constructed to provide separation of busbars from the functional units and separation of all functional units from one another, including the terminals for external conductors, which are an integral part of the functional unit.
      l. Manually operated devices such as push buttons, selector switches and the like shall not be mounted higher than 6 ¼ feet or lower than 12 inches above floor level;
      m. MCC's shall be assembled on a base channel of at least 3 inches height with ample holes for bolting to a switch room floor.

D. Construction
   1. Cubicle assemblies shall be formed from rigidly framed structures with additional supporting members provided where necessary for heavier switchgear items.
   2. Cladding shall be fabricated sheet steel panels of folded section with seams continuously welded and ground smooth.

3. Lifting lugs or holes in the base for lifting beams shall be provided to prevent distortion during lifting or off-loading during transport.
4. The MCC construction shall be such as to permit future extensions at either end.
5. Spaces in MCC's for future additional functional units shall be fitted with internal blanking plates and blank doors finished to match the MCC finish.
6. Ventilation ports, where provided, shall be vermin proofed with non-corrosive screen material.
7. All compartment doors shall be hinged and fitted with captive knurled screws. Doors shall open 120° and shall be provided with heavy-duty neoprene dust seals. Doors greater than 15 ¾ inches in height shall be provided with more than single point latching.
8. Door hinges shall be of adequate strength to support the door and shall be fitted with a stainless steel hinge pin. Exposed hinges shall be chromium plated with all fixing screws fully concealed.
9. The main incomer compartment door shall be designed such that the incomer circuit breaker can be racked out to the isolated position and then the door closed and padlocked.

E. Cable Zones
1. Cable zones shall be provided within MCC's in accordance with the following:
   a. Vertical cable zones shall be provided adjacent to each cubicle and shall extend the full height of the cubicle. Zones shall be of sufficient size to accommodate terminal blocks as shown on the Contract Drawings and shall allow front entry via hinged doors or removable covers;
   b. A horizontal cable zone with removable bolted covers shall be provided which shall run the full length of the MCC and connect with the vertical zones. The cable zone shall be fully accessible from the front of the MCC;
   c. Cable zones shall be provided to suit both top and bottom cable entry to the MCC unless specified otherwise in Article 2.01 of this Section;
   d. Cable zones shall have provision for supporting cables between their point of entry and point of termination;
   e. Cable zones shall be of sufficient size to accommodate the required power and control cables in one layer on the cable support provisions;
   f. Cable zones shall be sized to allow power cables to be terminated whilst maintaining at least the minimum bending radius of the cabling as recommended by the cable manufacturer; and
   g. Doors or covers for cable zones shall be fastened by chrome plated, knurled head captive screws.

F. Busbars
1. A main horizontal three phase bus shall be provided at the top of the MCC, within a separate busbar chamber and extending the full length of the MCC. Each end of the main busbar chamber shall be fitted with removable covers for ease of future extension. Adequate busbar drilled for future fish plates and plated for such extension shall be provided in the main busbar chamber;

2. A horizontal neutral busbar shall be provided at either the top or the bottom of the MCC as specified in Article 2.01 of this Section and shall extend the full length of the MCC;
3. A separate horizontal main grounding busbar shall be provided at either the top or the bottom of the MCC as specified in Article 2.01 of this Section and shall extend the full length of the MCC. The minimum size of the ground bar shall be 2 inch x ¼ inch;
4. Vertical busbars extending the full height of each cubicle shall be provided for connecting functional units to the main phase bars;
5. A vertical ground bar shall be provided in each cable zone. The ground bar shall extend the full height of the cable zone;
6. A control power supply bus shall be provided at the top of the MCC and shall extend the full length of the MCC; and
7. Busbars shall comply with the requirements of relevant standards and the following:
   a. Main busbars shall be high conductivity hard drawn copper bars of rectangular cross-section;
   b. Neutral busbar cross-sectional area shall be at least one third the phase busbar cross-sectional area;
   c. Busbars shall be current rated as shown on the Contract Drawings and as specified in Article 2.01 of this Section;
   d. Busbars shall be color coded with the appropriate phase color at intervals not exceeding 3 feet 3 inches along their length. Color coding shall be a 1 inch minimum width insulated (no PVC allowed) sleeve or painted strip encircling each busbar;
   e. Busbar supports and bracing shall be suitable for the minimum short-time withstand current rating of the MCC specified in Article 2.01 of this Section and shall be fabricated from high di-electric strength, heat resistant, high impact strength, non-hygroscopic insulating material;
   f. Busbar ends shall be carefully prepared and protected prior to making of joints, to avoid possible oxidation and/or overheating; and
   g. Busbar joints shall be bolted and effectively tightened to recommended bolt torque. All nuts and bolts shall be zinc plated.

G. Functional Units
1. Functional units shall be of uniform width and depth with a combination of modular heights permitting interchange, and shall be in accordance with the following requirements:
   a. Functional units shall include equipment shown on the Contract Drawings. All equipment shall be in accordance with this Section. Equipment shall be arranged within functional units to permit easy access and removal of all components without interference to the structure, other components or cable entry;
   b. Functional unit power connection to main vertical busbars shall be via clamp or spring contact devices;

c. All functional units controlling an outgoing circuit shall include an on-load isolating switch or fuse-switch unit operable by a handle on the outside of the unit door. The switch handle shall include a mechanical door interlock to prevent the door being opened whilst the isolating switch is in the "ON" position. However, the interlock shall be able to be deliberately defeated by authorized persons for test purposes;
d. Motor starter functional units below 150kW shall be so arranged and of sufficient size to allow outgoing power cables to be terminated within the functional unit while maintaining at least the minimum bending radius of the cabling as recommended by the cable manufacturer;
e. Starter functional units for motors 150kW and above shall be provided with insulated stubs protruding into the vertical cable zone for connection of the power cables. Busbar stubs protruding into the cable zones shall be fitted with shrouds providing NEMA 1 protection;
f. The minimum size functional unit shall be suitable in size to accommodate a 11kW starter unit;
g. Control equipment other than indicating lights, push buttons, ammeters and selector switches shall not be mounted on the functional unit door;
h. All live parts above 50VAC which are accessible when the functional unit door is open shall be fully shrouded and segregated; and
i. Functional unit internal wiring and terminals shall be in accordance with this Section and the Contract Drawings.

H. Main Air Circuit Breakers
1. Where shown on the Contract Drawings, incoming and bus-tie circuit breakers shall be three phase withdrawable type air circuit breakers complying with relevant standards and the following requirements:
a. Circuit breakers shall be current rated as shown on the Contract Drawings. The current rating shall be for the specified ambient temperature taking into consideration additional temperature rises due to the enclosure mounting. Circuit breaker voltage and fault ratings shall be in accordance with Article 2.01 of this Section and the Contract Drawings;
b. Circuit breakers shall incorporate "Service", "Test" and "Isolated" positions;
c. Closing operations shall be by a manually charged, stored energy, spring closing mechanism with mechanical release;
d. Opening operations shall be by trip release mechanism. A manual mechanical trip facility shall also be provided;
e. Normally open and normally closed auxiliary contacts shall be provided as shown on the Contract Drawings;
f. Where shown on the Contract Drawings, key interlocking to prevent closing of both incoming supply circuit breakers when the bus-tie breaker is closed shall be provided;
g. Interlocks shall be provided to prevent the following:
1) Racking with the spring mechanism charged;
2) Door opening with the circuit breaker closed; and

3) Operation of the circuit breaker with the door open, except when in the test position;

h. All controls and indication for circuit breakers shall be mounted on the front panel;

i. Racking handles shall be supplied with each circuit breaker;

j. Incoming circuit breakers shall be provided with integral hand reset protection relays and associated current transformers for the following:

1) Overcurrent and ground fault protection with characteristics as specified in Article 2.01 of this Section; and

2) High set instantaneous protection for both overcurrent and ground fault with the settings as shown on the Contract Drawings.

k. Incoming circuit breakers shall be provided with a multifunctional metering unit with RS485 communications capability.

I. Isolating Fuse-Switch Units (CFS)

1. Isolating fuse-switches shall conform to relevant standards and the following requirements:

a. Isolating switches shall be of fault make, load break, heavy duty type capable of interrupting, without damage, a locked rotor current equal to seven times full load current of the respective motors;

b. Motor isolators shall be provided with auxiliary switches as specified on the Contract Drawings;

c. All isolating devices shall have their incoming line terminals shrouded to prevent accidental contact;

d. The isolator operating handle shall be fixed to or have positive action linkage with the isolating switch and shall indicate clearly whether the isolating switch is in the "ON" or "OFF" position with the functional cell door both open or closed;

e. Provision shall be made for padlocking the isolator operating handle in the "OFF" position by means of up to two padlocks;

f. A door interlock shall prevent opening of the functional unit door when the isolating switch is in the "ON" position; and

g. A neutral bar shall be provided at the top of the cable zone adjacent to each isolating fuse-switch combination unit for sub-feeder circuits.

J. Molded Case Circuit Breakers

1. Molded case circuit breakers shall be rated as shown on the Contract Drawings and shall comply with the following requirements:

a. Circuit breakers connected directly to the Main Busbars shall be of the High Interrupting Class; fault rated as specified in Article 2.01 of this Section and shall have thermal overload and magnetic short circuit protection. All other molded case circuit breakers shall be Industrial Class;

b. Circuit breakers shall be continuously rated as shown on the Contract Drawings for the relevant load under the design conditions specified in Article 2.01 of this Section;

c. Circuit breakers which are used for circuit isolation shall be provided with an operating handle with door interlock and interlock defeat, and with "ON/OFF" indication and padlocking facilities as specified for functional units and

d. The circuit breaker toggle shall be a "trip-free" mechanism and the "tripped" position of the toggle shall be distinct from its "ON" and "OFF" positions.

K. Fuses

1. All fuses used for protection of power and control circuits shall be M class unless otherwise specified on the Contract Drawings;
2. All fuses for short-circuit protection of motor circuits shall be rated as shown on the relevant Contract Drawings; and
3. Fuse holders shall be of the all insulated type with shrouded contacts.

L. Contactors

1. All contactors shall be of the molded block type construction and shall satisfy the following requirements:
   a. Utilization category shall be AC3 unless otherwise specified in Article 2.01 of this Section;
   b. Normally open and normally closed auxiliary contacts shall be provided as shown on the Contract Drawings;
   c. Closing coils shall be continuous rated and suitable for use on the control voltage specified in Article 2.01 of this Section;
   d. Pole faces in the laminated magnetic circuit shall be fitted with suitable shading rings to minimise in-service vibration and hum;
   e. Contactors shall be suitable for DOL starting of 3 phase, 480V motors and shall be adequately sized to suit the kilowatt rating of the motor. The minimum sized contactor shall be rated for 11kW duty;
   f. Main contacts shall be double break silver alloy or similar and shall be suitable for uninterrupted (continuous) duty. Mechanical endurance shall be at least 5 million no-load operations; and
   g. Contactors shall have type 2 coordination with their short circuit protective devices in accordance with IEC 947-4-1.

M. Current Transformers

1. Current transformers shall be fully encapsulated and shall comply with relevant standards and the following:
   a. Metering transformers shall have accuracy class and secondary output as specified in Article 2.01 of this Section;
   b. Protection transformers shall be selected to suit the appropriate protection relay and shall have current ratios as shown on the Contract Drawings.

N. Small Power Transformer

1. Dry-type step-down transformers shall be general purpose UL listed, and meet all applicable NEMA, ANSI and IEEE standards.

2. Step down transformers shall ratings as shown on the Contract Drawings.

O. Motor Overload Protection
   1. As specified in NFPA 130 7.3.4.1 "Thermal overload protective devices on motor control of fans used for emergency ventilation shall not be permitted".
   2. Other motors less than 75kW shall be provided with bi-metal thermal overload units. Other motors 75kW and above shall be provided with electronic programmable type overload protection relays. Separate thermistor relays shall be provided where shown on the Contract Drawings. For drives 75kW and above, the thermistor protection shall be an integral feature of the electronic overload relay. Motor thermal protection devices shall be in accordance with the following:
      a. Electronic overload relays shall be type Rl, triple pole, complying with relevant standards. The relays shall have one normally closed and one normally open contact and shall be supplied with a door mounted reset pushbutton wired into the relay;
      b. Thermal overload relays shall be type Ql, triple pole, bimetallic, ambient compensated type with single phasing protection complying with relevant standards. All relays shall include an adjustable calibrated current setting. Trip contacts shall operate with a positive snap action and the current path in the trip circuit shall not include pivots or sliding elements. The relays shall be fitted with one normally closed and one normally open contact and shall be supplied with a door mounted reset pushbutton; and
      c. Thermistor relays shall be constructed in accordance with relevant standards for positive temperature coefficient thermistors and shall be of the inherently non auto-resetting type, except in case of power failure, whereby the thermistor relay shall automatically reset to the available-to-run state. The relays shall be fitted with one normally closed and one normally open contact and shall be supplied with a door mounted reset pushbutton.

P. Ground Leakage Protection
   1. Ground leakage relays of the core balance type, together with the necessary relays and toroids shall be provided where shown on the Contract Drawings;
   2. Ground leakage equipment shall comply with relevant standards; and
   3. Ground leakage equipment shall be provided with externally located test, reset and indication facilities on the front of the functional unit door.

Q. Restricted Ground Fault Protection
   1. Restricted ground fault protection shall be provided for the main incoming circuit breakers and busducts where shown on the Contract Drawings and shall comprise a relay with variable settings as specified in Article 2.01 of this Section, and current transformers (CTs) as follows:
      a. One CT for mounting in the transformer cable box on the neutral busbar located adjacent to the transformer neutral connection;
      b. Three CT's on the load side of the main incoming circuit breaker; and

c. The restricted ground fault relays shall be located on or adjacent to the main incoming or bus-tie circuit breakers and shall have trip signals for external circuits brought out to separate clearly marked terminals.

R. Control Power Supplies

1. A control power supply shall be provided with each main bus of the MCC(s) in accordance with the ratings specified in Article 2.01 of this Section and the following:
   a. Each power supply shall be of the same make, type and size;
   b. The control power supply transformer(s) shall be double wound, dry type with a grounded metal screen between windings;
   c. Secondary circuits for all control transformers shall be provided with a fuse on the active lead and grounding of secondary circuits shall be via a ground link connected to the neutral side of the transformer;
   d. DC control supplies shall be in accordance with relevant standards; and
   e. Control power shall be distributed by bus in accordance with this Section. Terminals shall be provided at the top of each tier and separate supplies shall be taken into the individual functional units. The control power supply within functional units shall be separately protected by a fuse.

S. Motor Heater Supplies

1. Power supplies for motor anti-condensation heaters shall be available from the respective motor starter compartment in accordance with the following:
   a. Power supplies shall be provided as shown on the Contract Drawings;
   b. Power supplies shall be fed from the load side of the functional unit isolator, separately fused and switched by a normally closed contact of the motor contactor;
   c. The power supplies shall be wired to segregated and fully shrouded heater supply terminals; and
   d. A danger sign reading, "Motor Heater requires Isolation before Maintenance" shall be fitted within all relevant starter compartments.

T. Instruments and Control Devices

1. Instruments and control devices shall be provided as shown on the Contract Drawings and shall comply with the following requirements:
   a. Direct indicating instruments including voltmeters, ammeters and kW meters shall comply with relevant standards and the following requirements:
      1) Instruments shall be flush mounted, industrial grade;
      2) Instruments shall be accuracy Class 1.0 unless specified otherwise in – Article 2.01 of this Section or on the Contract Drawings;
      3) Instruments shall be generally of the moving iron type with taut band suspension. Moving coil movements shall be used for all instruments used in conjunction with signal transducers; and
      4) Where double scaling is required dials shall be reversible with one scale on each face.

b. Selector switches shall be provided for all ammeters and voltmeters for selection of phase-to-phase voltage and phase current. Ammeter switches shall include an "OFF" position.
c. All control devices including indicating lamps, push buttons and selector switches shall comply with relevant standards and the following requirements:
    1) All control devices shall be oil-tight and dust tight;
    2) All indicating lamps shall have a minimum rated life of 3,000 hours at rated voltage;
    3) All indicating lamps shall include a press-to-test function; and
    4) Selector switches shall be of the rotary cam operated type. Switchgear control selector switches shall be uniquely key lockable. "Trip/Close" and "Trip" switches shall be fitted with a spring return to the neutral position.
d. Current transformers shall be provided for all ammeters;
e. Transducers shall comply with relevant standards and the following requirements:
    1) Accuracy Class shall be 1.0 unless specified otherwise in Article 2.01 of this Section or on the Contract Drawings;
    2) Transducers shall be static, isolating type with 4-20mA current output; and
    3) Output signal and maximum load resistance shall be as specified in – Article 2.01 of this Section.

U. Control Relays
1. Control relays shall be of the industrial plug-in type complying with relevant standards and the following:
    a. Contacts shall be silver alloy type rated at 5 Amps AC15 minimum;
    b. Contacts shall make with a wiping, self-aligning motion without bounce; and
    c. Relay coils shall be continuously rated.

V. Time Delay Relays
1. Time delay relays shall be of the rapid reset, continuous rated solid-state electronic type and shall include the following:
    a. Calibrated time setting dial;
        1) Repeat accuracy to at least 1% of the pre-adjustment over the setting range;
        2) Timers having a time delay period greater than 60 seconds shall have an elapsed time pointer or counter;
    b. Contacts shall be silver alloy type rated at 5 Amps AC15 minimum;
    c. Contacts shall make with a wiping, self-aligning motion without bounce; and
    d. Relay coils shall be continuously rated.

W. Internal Wiring

1. The MCC(s) shall be completely factory wired in accordance with relevant standards and the following requirements:
   a. All wiring shall be carried out in flexible copper cables, 0.6/1 kV, V75 grade PVC and terminated with insulated compression type lugs or connectors;
   b. The minimum size of flexible cable shall be as follows:
      1) Control wiring - 16AWG (stranded)
      2) Protection - 14AWG (stranded)
      3) Metering - 14AWG (stranded)
2. Wire colors shall comply with the following requirements of NFPA 70 and NFPA 79
   a. All internal wiring shall be neatly arranged and wherever practicable shall be contained in capped plastic ducting. Elsewhere, groups of wires shall be strapped together with nylon or other strong plastic ties or spiral binding to form neat wire bundles;
   b. Where groups of wires are required to connect to devices mounted on doors or access panels, wire bundles shall be arranged such that opening and closing of the door is not impeded and at the same time flexing, of the wiring is minimized; and
   c. All wiring shall be identified at each end by fully interlocking Z-type numbered ferrules. All such identification shall be in accordance with Contract Drawings.

X. Terminals
1. DIN rail mounted molded terminal blocks shall be provided for termination of all control wiring. Terminals shall carry a numeric designation in accordance with the Contract Drawings and shall be segregated according to function and voltage;
2. Terminal groups for the termination of control wiring external to the MCC(s) shall be arranged vertically and located within the vertical cable zone adjacent to their respective functional units. The terminal groups shall be spaced to facilitate easy connection of wiring and cables. Spare space shall be available on each terminal rail to accommodate additional terminals including spare PLC inputs and outputs and spare space for unused PLC slots; and
3. A separate terminal shall be provided for the connection of each individual wire. Bridging links as supplied by the terminal manufacturer shall be used to interconnect 'common' terminals.

Y. Gland Plates
1. Undrilled brass gland plates of 1/8 inch minimum thickness shall be provided within cable zones and shall be of sufficient size to accommodate all glands necessary for the termination of all power and control cables at the MCC's;
2. External power and control cables will be supplied and fitted; and
3. Each gland plate shall be solidly bonded to the main ground bar by a separate grounding conductor.

Z. Busducts

1. Busducts shall comply with relevant standards and the following requirements:
    a. The busducts shall be 3 phase, 4 wire plus ground, insulated copper conductors rated in accordance with the Contract Drawings;
    b. Busducts shall be enclosed in a sheet steel enclosure adequately braced to withstand the short-time withstand current specified in Article 2.01 of this Section;
    c. Busducts shall a have minimum degree of protection NEMA 4 unless specified in Article 2.01 of this Section;
    d. Busducts shall be scaled around the busbars at both ends to prevent the ingress of dirt;
    e. All busduct covers and flanges shall incorporate neoprene gaskets;
    f. Busducts shall be designed for flatwise configuration with dimensions in accordance with the Contract Drawings;
    g. Busducts shall be supplied complete with flanged ends, elbows, wall penetration flanges and hanger brackets for the switchroom sections;
    h. Busducts shall be manufactured, matched and aligned with the MCC before shipment;
    i. Phase sequences in the busduct shall match phasing arrangements of the MCC and transformer terminal arrangement Shop Drawings;
    j. The external flanged ends shall be suitable for top entry transformer terminal boxes and shall match the transformer terminal spacings of 8 inches;
    k. Flexible connections between the busducts and the transformer bushings, plus all associated hardware, together with transformer busduct gasket and bolts, shall be provided. Arrangement of the flexible connections shall be subject to approval of the Engineer.
    l. Dimensional information permitting co-ordination of the busduct design with transformer design shall be supplied;
    m. Where busducts pass through any building aperture, the busbar chamber shall be adequately fire sealed; and
    n. The outdoor sections of the busducts shall be supplied with gabled suncovers, which shall be offset above the busduct to maintain ventilation.

AA. PLC/RTU Input/Output Cubicles (Refer Section 16742, "SCADA System" of the Contract Documents)

1. A double sided cubicle shall be installed at one end of each MCC and shall contain the PLC/RTU input and output units associated with the MCC starters. In one side of the cubicles shall be left empty for future PLC/RTU equipment;
2. All inputs/outputs from the PLC/RTU shall be wired to the terminals. Terminals shall be provided for all PLC/RTU cards including spare slots.
3. Primary and secondary PLC/RTU, I/Os, modems shall be installed in separate cubicles.

BB. Nameplates and Labels

1. All equipment shall be identified with nameplates and labels in accordance with the following:

a. All enclosures and equipment shall be identified with white laminated phenolic nameplates and labels engraved with black lettering and complying with the following:
   1) Lettering shall be of minimum size 1/5 inches;
   2) Labels shall be detachable and interchangeable;
   3) All external labels shall be attached by means of screws;
   4) Fixing holes shall be slotted to allow for expansion and contraction; and
   5) Minor labels, within MCC compartments only, may be affixed by an approved adhesive.

b. Push buttons and pilot lights shall be supplied with standard metal engraved labels;

c. Nameplates shall be supplied for identifying each MCC. Lettering shall be minimum size 1 3/16 inches high engraved black on a white background with an approved text;

d. All shrouds over live equipment and bolt-on covers which provide access to live equipment shall be fitted with red danger labels engraved with white lettering "DANGER XYZ VOLTS" (where XYZ = rated voltage as nominated in Article 2.01 of this Section); and

e. A label schedule and layout shall be supplied for approval by the Engineer.

CC. Painting and Corrosion Protection

1. The supplier's standard painting and corrosion protection system:
   a. Shall be subject to approval by the Engineer;
   b. Full details of the proposed painting and corrosion protection system shall be as specified in Article 2.01 of this Section; and
   c. The color of the final surface coat shall be as specified in Article 2.01 of this Section.
2. The equipment shall be delivered with a minimum sample of 1 Gallon of the final surface paint in a sealed container. The container shall be labeled with sufficient information to permit re-ordering.

DD. Cables and Wiring

1. All cables for tunnel fire life safety systems shall comply with Section 16120 "Low Voltage Power Cables" for power cables and Section 16702 "Copper Outside Plant" for control and instrument cables, of the Contract Documents.
2. All cables for tunnel fire life safety systems shall comply with the requirements of NEC and NFPA 130 sections 6.3.3.2.2 through 6.3.3.2.9.

ARTICLE 3 EXECUTION

3.01 COORDINATION AND DISCRIMINATION

A. Contractor shall carry out a short circuit coordination study necessary to determine the correct selection and setting of protective devices for discrimination.

B. Contractor shall select and configure circuit breakers to allow for total discrimination between cascaded circuit breakers upstream and downstream.

C. Contractor shall configure adjustable trip circuit breakers to avoid false tripping of breakers during motor start up.

D. The Contractor shall coordinate the study with other Authority Contracts.

3.02 FIELD WIRING

A. The wiring between the input/output cubicles and the MCC starters shall be single core panel wiring in accordance with this Section. This wiring shall be terminated directly onto the marshalling terminals of the input/output cubicles.

3.03 TESTING

A. Type Testing
   1. Type test certificates from a recognized testing agency shall be provided to substantiate that the equipment, which is identical in essential details to that being supplied, has passed all necessary type tests. Type testing shall have been carried out in accordance with relevant standards including internal arcing tests.

B. Routine Testing
   1. Routine tests to relevant standards shall be carried out on the complete MCC, fully assembled in its final configuration, prior to dispatch and shall include, but not limited to, the following:
      a. Insulation resistance tests;
      b. Mechanical operating tests;
      c. Ductor test of each busbar bolted joint;
      d. Primary injection testing of all protection relays and current transformers;
      e. Check of protective circuits;
      f. Testing of all control and interlock circuits to ensure satisfactory operation;
      g. Check of all PLC inputs and outputs;
      h. Check of wiring and terminations; and
      i. Check of nameplates and labels.

3.04 PACKAGING AND SHIPMENT TO WORKSITE

A. The equipment, as far as practicable, shall be fully tested and assembled ready for shipment.

B. The equipment shall be adequately packaged for transporting to the Worksite.

C. Provisions shall be provided for off loading the equipment by overhead crane or fork truck.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16891.001 – Gateway Station Low Voltage Switchboards and Motor Control Centers shall be measured as a lump sum unit, complete in place.

B. Item 16891.002 – North Side Station Low Voltage Switchboards and Motor Control Centers shall be measured as a lump sum unit, complete in place.

C. Item 16891.003 – Gateway Station PLC/RTU System for Tunnel Services Equipment shall be measured as a lump sum unit, complete in place.

D. Item 16891.004 – North Side Station PLC/RTU System for Tunnel Services Equipment shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16891.001 – Gateway Station Low Voltage Switchboards and Motor Control Centers will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

B. Item 16891.002 – North Side Station Low Voltage Switchboards and Motor Control Centers will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

C. Item 16891.003 – Gateway Station PLC/RTU System for Tunnel Services Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

D. Item 16891.004 – North Side Station PLC/RTU System for Tunnel Services Equipment will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 16892

TUNNEL SERVICES UNINTERRUPTIBLE POWER SUPPLY

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for tunnel services uninterruptible power supply, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design, manufacture, furnish, install, and testing of the new uninterruptible power supply for tunnel services and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the uninterruptible power supply for tunnel services systems portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 15400, "Tunnel Services Scope of Work"

B. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

C. Section 16111, "Conduit"

D. Section 16120, "Low Voltage Power Cables"

E. Section 16702, "Copper Outside Plant"

F. Section 16742, "SCADA System"

G. Section 16889, "Tunnel Services Electrical Testing and Commissioning"

H. Section 16890, "Tunnel Services Electrical Requirements of Mechanical Equipment"

I. Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center"

J. Section 16894, "Tunnel Emergency Rail Lighting and Lighting Receptacles"

1.03 REFERENCE STANDARDS

A. ANSI

B. IEC

C. NEMA

D. NEC

E. NFPA

F. UL

1.04 SUBMITTALS

A. All submittals shall be sealed by a Professional Engineer.

B. Product Data and specifications on specified product;

C. Shop Drawings on specified product;

D. Monitoring interface communications protocol;

E. Documented functional test of the UPS module and battery system, including a battery discharge test.

ARTICLE 2 PRODUCTS

2.01 APPLICATION SPECIFIC REQUIREMENTS

Table 16892-1

ITEM	DESCRIPTION	UNIT	DATA
1	UPS Supply Rated Capacity	VA	As indicated on Single Line.
2	Mains Supply Voltage	VAC	As indicated on Single Line
3	Mains Supply Frequency	Hz	60
4	Dry Type Transformer	VAC	480 delta to 208 Y/120
5	Backup Time	Minutes	90
6	Operating Ambient Temperature	°F	104.
7	Minimum Operating Temperature	°F	32
8	Operating Relative Humidity	%	95.

2.02 UNITERRUPTIBLE POWER SUPPLY SYSTEM REQUIREMENTS

A. The UPS shall consist of standard equipment and shall meet specified capacity requirements.

B. Components shall be capable of withstanding the thermal and dynamic stresses resulting from internal and external short circuits and circuit switching operation.

C. Components shall be moisture and fungus proof and non-flammable wherever practicable. Capacitor electrolytes shall be non-toxic and totally free from polychlorinated biphenyls (PCBs).

D. Each UPS and battery rack shall be located inside a room with maximum ambient air temperature 104°F and a relative humidity not exceeding 95% non-condensing.

E. The static type UPS shall consist of the following components;
1. 6 pulse rectifier/charger
2. Static inverter
3. Internal automatic bypass
4. Microprocessor controlled logic and control panel with status indicators
5. Digital metering display
6. RS 232 interface port
7. Voltage free contacts for UPS status monitoring
8. UPS cabinet NEMA 3
9. Input and battery circuit breaker
10. Sealed maintenance free batteries
11. Battery cabinet
12. DC isolator

F. Tunnel Centralized Emergency Lighting Supply UPS for Emergency Lighting shall be list to UL924, UL924A and UL1778 latest reversion Standards

2.03 UNITERRUPTIBLE POWER SUPPLY LOAD RATING

A. UPS shall be rated to supply loads specified in Article 2.01 of this Section above a power factor of 0.9 lagging. The UPS shall be capable of starting up the connected load solely on the supply from the inverter. This is to allow for peak inrush currents associated with the switching of certain types of equipment including transformers, lamps, etc. from cold start.

2.04 UNITERRUPTIBLE POWER SUPPLY DESIGN LIFE

A. The minimum design life of the UPS equipment shall be 20 years from the date of installation. The batteries shall have a minimum design life of 10 years.

2.05 UPS SYSTEM INPUT PARAMETERS

A. The UPS module shall have a minimum input power factor of 0.9 lagging at full load and nominal input voltage and frequency.

B. The UPS module input current total harmonic distortion (THD) shall be no greater than 10% at full load and nominal input voltage and frequency.

C. The magnetizing inrush current of the UPS module shall be limited to no more than 800% of the module's full load rectifier input current.

2.06 UPS SYSTEM OUTPUT PARAMETERS

A. The UPS module shall have a fault clearing capacity of 200% of rated current for 10 cycles.

B. The UPS module shall have a make before break static switch transfer completed in less than 2 msec, with a maximum crest factor of 3:1.

C. The UPS shall be capable of supplying full rated power into a linear and non-linear load.

D. The UPS shall be protected against the following:
1. Overcurrent
2. Overvoltage
3. Overheating

2.07 UPS STATIC BYPASS SWITCH

A. The UPS module shall contain a fully rated, high speed solid state transfer device.

B. The UPS module shall initiate an automatic uninterrupted transfer to bypass for the following conditions:
1. Output overload period expired
2. Critical bus voltage out of limits
3. Over temperature period expired

C. Uninterrupted manual transfers shall be initiated from the UPS control panel.

D. The UPS module shall be capable of performing an automatic uninterrupted retransfer whenever the inverter is able to assume the load.

E. The UPS module shall inhibit automatic uninterrupted retransfers for the following conditions:
1. When transfer to bypass is activated manually.
2. UPS module failure.

F. All static bypass switch transfers and retransfers shall be inhibited for the following conditions:
1. Bypass voltage out of limits (+/- 10% of nominal).
2. Bypass frequency out of limits (+/- 0.5 Hz).
3. Bypass out of synchronization.

2.08 UPS BATTERIES

A. The battery type shall be heavy duty maintenance-free vent regulated sealed, suitable to the heavy discharge requirements of a UPS system.

B. All necessary battery mounting frames to accommodate the batteries shall be provided.

C. The batteries shall have a minimum life expectancy of 10 years.

D. The final minimum discharge cell voltage at full UPS load shall be limited to 1.66 V.

E. Nominal battery float voltage shall be 2.25 V per cell.

F. The battery shall have adequate capacity to allow the UPS module to operate at full load 0.9 power factor for the minimum period specified in Article 2.01 of this Section.

G. The battery charging current shall be limited to prevent battery overcharging.

H. The battery shall be recharged to 90% of capacity within 10 times the actual discharge time.

I. The batteries shall be insulated from ground and each supply conductor shall be protected at its source.

J. The batteries shall be string connected for back-up due to battery failure.

2.09 CONTROL FUNCTIONALITY

A. The UPS module shall have full automatic control through the use of microprocessor controlled logic.

B. Start up and transfer functions of the UPS module shall be an automatic function. The UPS module shall include the following status indicators:
1. System Normal (green)
2. Alarm (red)
3. Low Battery (red)
4. Battery Discharge (red)
5. Output Overload (red)
6. Sync. Loss (red)
7. AC Input Failure (red)
8. Overtemperature (red)
9. Shutdown Imminent (red)
10. On Bypass (red)
11. Inverter Failure (red)
12. Battery Fault (red)

C. The UPS module shall have alarm contact for any abnormal condition detected. The UPS shall have the capability of monitoring this alarm externally.

D. The UPS module shall have a digital meter panel capable of providing the following information:
   1. AC input voltage
   2. AC input current
   3. AC input frequency
   4. DC battery voltage
   5. DC battery current
   6. AC inverter output voltage
   7. AC inverter output current
   8. AC inverter frequency
   9. AC connected load current

E. The following control facilities shall be provided on the front panel:
   1. Rectifier ON/OFF control switch
   2. Output voltage adjustment
   3. Current limit adjustment
   4. Inverter ON/OFF control switch
   5. Load transfer control switch
   6. Battery isolating switch

2.10 MONITORING INTERFACES

A. Alarm contacts for the UPS shall be wired out to a terminal block to provide normally open and normally closed volt free contacts for remote monitoring.

B. In addition an RS-232 port shall be provided to allow communication of alarms to an alarm monitoring system. Details of the protocol used and message set shall be provided to facilitate alarm handling in the alarm monitoring system.

2.11 COOLING

A. The UPS shall be provided with cooling adequate to ensure trouble free operation when the UPS is operating at full load at an ambient temperature as specified in Article 2.01 of this Section.

2.12 SWITCHGEAR

A. It shall be a requirement that any circuit breakers or contactors within the UPS shall fully discriminate with the required circuit breakers.

B. The UPS design will allow for discrimination both upstream and downstream, of the incoming and outgoing circuit breakers for the UPS.

2.13 NOISE LIMIT

A. The sound pressure level measured at 6 feet from the UPS unit, at any position, shall not exceed 60 dB (A) at any load between zero and the rated output of the unit.

2.14 UNITERRUPTIBLE POWER SUPPLY MECHANICAL DESIGN CRITERIA

A. The rectifier, inverter and static switch shall be installed in one freestanding cabinet. Each cabinet shall be designed for front access only and be suitable for operation and maintenance with its rear panel against a wall and with similar units located immediately on both sides.

B. The enclosure shall provide a degree a protection of not less than NEMA 1. The unit shall be capable of operating continuously, delivering its rated output with natural air ventilation.

C. Removable gland plate for top cable entry shall be provided for incoming and outgoing cable and located to allow ample space for cable terminations. Suitable partitions between individual items shall be provided where necessary to allow adjustment and inspection to be carried out safely. All busbars shall be insulated.

D. All major assemblies shall be modular and replaceable from the front or top of the cubicle.

E. The UPS shall be designed with dual forced air cooling.

F. The UPS and battery cubicle shall have non-removable warning plates indicating that hazardous AC and DC voltages are present.

G. Rating plate(s) shall be permanently attached to the front of the cubicle.

H. Sufficient room shall be provided for cable entry and termination within the cubicle.

2.15 WIRING AND TERMINATIONS FOR UNITERRUPTIBLE POWER SUPPLY

A. All internal wiring shall be single core, insulated and have stranded copper conductors. All wiring shall be properly marked in accordance with the manufacturer's Working Drawings. Wiring between terminals shall be continuous and without joints. Wires shall be held into position by means of suitable cable fixing materials. Wiring between fixed portions and hinged doors shall be mechanically protected and without any tensions on the wiring when the doors are opened.

B. Terminals shall be provided for all external connections. External connections shall not be made directly to component terminals. Terminals shall be of rail mounted type and have screw connectors suitable for a minimum of 14AWG conductors. A maximum of two conductors shall be allowed to be terminated in each terminal. Insulating shields shall be used to separate terminals belonging to different circuits.

C. Additional load terminals shall be provided to facilitate connection of a separate incoming supply to the static bypass switch.

2.16 UNITERRUPTIBLE POWER SUPPLY MARKING CRITERIA

A. Nameplates shall be permanent, corrosion resistant and made of stainless steel plate or laminated plastic with engraved or stamped inscriptions and fixed in position with stainless steel 316 or nickel plated brass screws. The nameplate shall be in English, with the following information;
1. Name of manufacturer
2. Year of manufacture
3. Type and serial number of the unit
4. Nominal input current, voltage and frequency
5. Nominal output current, voltage and frequency
6. Battery nominal voltage and ampere-hour rating
7. Signs for batteries as per the relevant standards

B. Terminals of input and output supply cables shall be clearly and uniquely marked to indicate the nominal system voltage and the phase/polarity of the supply.

C. Rail mounted terminals or equipment and components shall be identifiable by numerical or alphabetical markings in accordance with the manufacturer's Working Drawings.

2.17 UNITERRUPTIBLE POWER SUPPLY GROUNDING CRITERIA

A. A ground rail, with a suitable number of grounding bolts and screws shall be provided in a position close to the external cable glands to facilitate termination of cable ground braids or armoring. Individual connections for all ground wires shall be provided.

B. A threaded brass ground stud of not less than 5/16 inch diameter, with nuts and spring washers, shall be provided within the enclosure and between the enclosure and the ground rail / ground stud shall be such as to maintain effective continuity of protective circuits.

C. Ground bonding conductors shall be utilized between enclosures and doors and where required to achieve effective protection.

ARTICLE 3 EXECUTION

A. Contractor shall supply and install all equipment necessary for the MCC Control Supply Distribution UPS to function properly, including but not limited to racks, mounting panels, mounting rails, hardware, terminal blocks, wires, cables and connectors.

B. Contractor shall supply and install all equipment necessary for the Tunnel Centralized Emergency Lighting Supply UPS to function properly, including but not limited to racks, mounting panels, mounting rails, hardware, terminal blocks, wires, cables and connectors.

C. Contractor shall install the UPS and as shown on the Contract Drawings.

D. UPS for Control Supply Distribution and Tunnel Centralized Emergency Lighting Supply shall be separate as indicated on the Contract Drawings.

E. The MCC Control Supply Distribution UPS and Tunnel Centralized Emergency Lighting Supply UPS shall be installed in the MCC rooms as indicated on the Contract Drawings.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16892.001 – MCC Control Supply Distribution Uninterruptible Power Supply Unit shall be measured as a lump sum unit, complete in place.

B. Item 16892.002 – Tunnel Centralized Emergency Lighting Supply Uninterruptible Power Supply unit shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16892.001 – MCC Control Supply Distribution Uninterruptible Power Supply will be paid at the lump sum price and shall include the cost of all work specified in this Section.

B. Item 16892.002 – Tunnel Centralized Emergency Lighting Supply Uninterruptible Power Supply will be paid at the lump sum price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16893

TUNNEL SERVICES POWER FACTOR CORRECTION

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for tunnel services power factor correction, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design, manufacture, furnish, install, and testing of power factor correction and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the automatic power factor correction system for tunnel services systems portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 15400, "Tunnel Services Scope of Work"

B. Section 15445, "Tunnel Mechanical Drainage Systems"

C. Section 15887, "Tunnel Ventilation and Balancing Dampers"

D. Section 15889, "Tunnel Ventilation Fans"

E. Section 15890, "Tunnel Ventilation Jet Fans"

F. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

G. Section 16111, "Conduit"

H. Section 16120, "Low Voltage Power Cables"

I. Section 16702, "Copper Outside Plant"

J. Section 16742, "SCADA System"

K. Section 16889, "Tunnel Services Electrical Testing and Commissioning"

L. Section 16890, "Tunnel Services Electrical Requirements of Mechanical Equipment"

M. Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center"

N. Section 16892, "Tunnel Services Uninterruptible Power Supply"

O. Section 16894, "Tunnel Emergency Rail Lighting and Lighting Receptacles"

P. Section 16895, "Tunnel Services Low Voltage AC Variable Speed Drive"

1.03 REFERENCE STANDARDS

A. ANSI

B. IEC

C. NEMA

D. NEC

E. NFPA

F. UL

1.04 SUBMITTALS

A. All submittals shall be sealed by a Professional Engineer.

B. Type test certificates from a recognized testing authority.

C. Product Data sheets showing voltage, ratings and size of switching and overcurrent protective devices, short circuit ratings, dimensions, and enclosure details.

D. Shop Drawings indicating front and side views of enclosures with overall dimensions. Include conduit entrance locations and requirements; nameplate legends; electrical characteristics including voltage, trip ratings; all termination numbers and identification of purpose.

E. Label schedule.

ARTICLE 2 PRODUCTS

2.01 APPLICATION SPECIFIC REQUIREMENTS

ITEM	DESCRIPTION	UNIT	DATA
1	Supply Voltage	VAC	480
2	Supply Frequency	Hz	60

3	Control Voltage	VAC	120
4	Power Factor Correction Unit Rating	kVAR	As Indicated on Single Line Diagram
5	Step Size	kVAR	25
6	Fault Rating	kA	65
7	Ambient Operating Temperature	°F	104
8	Minimum Operating Temperature	°F	32
9	Operating Relative Humidity	%	95

2.02 OPERATING CONDITIONS

A. Ratings
1. All equipment and materials shall be suitable for operation under the specified general service conditions as specified in Article 2.01 of this Section.
2. All equipment and materials shall be rated for continuous full load operation under any combination of the Design Environmental conditions specified in Article 2.01 of this Section.

B. Power System
1. The equipment shall be designed and manufactured for normal operation on the power supply system as specified in Article 2.01 of this Section.

C. Equipment Protection
1. All equipment shall have a minimum degree of protection of NEMA 1 unless otherwise specified in Article 2.01 of this Section.
2. All enclosures and assemblies shall be vermin proof.

2.03 POWER FACTOR CORRECTION EQUIPMENT

1. The power factor correction equipment shall be housed in flush fronted, totally enclosed free standing dead front type of enclosures incorporating switchfuse units, reactive relays, control relays, contactors and capacitor banks. The equipment shall be suitable for continuous operation and comply with relevant standards and regulations. The service voltage shall be 277/480v, 3 phase, 4 wire 60Hz unless specified otherwise in Article 2.01 of this Section. The equipment shall be able to interrupt supply at fault conditions as specified in Article 2.01 of this Section.

2. The system shall be suitable for fully automatic power factor correction operation through the switching of a static capacitor bank in KVAR steps as defined in Article 2.01 of this Section
3. Each KVAR step shall be switched on via a contactor rated for switching of capacitive loads. The switching of the capacitor banks shall be controlled by a reactive relay. The capacitor banks shall be sized to provide a corrected power factor of 0.95 under full load conditions. The control circuit shall prohibit over correction of the power factor.
4. The power factor correction system shall include a serial data communications interface for monitoring and diagnostic data transfer to the local SCADA system. In addition to this, the system shall include digital I/O diagnostic fault alarms, and analogue (4-20mA) signals for the remote transmission of power factor values.

B. Power Factor Correction Miscellaneous Equipment
1. A suitable rated main ground, copper bar shall be run the full length at the base of the enclosure. All cable sheaths, metal conduits and separate cubicles shall be bonded to the ground bar.
2. The power factor correction equipment shall be complete with all operating handles and any special tools. A complete set of drawings shall be installed within a spare compartment of the enclosure and a label fitted to indicate where the drawings are kept.
3. All small wiring cables within each switchboard shall be color coded throughout their length and marked with ferrules of an approved type at each end for identification.
4. All small wiring cables within the enclosure shall be neatly laced and cleated to the panel structure of each switchboard. Where wiring passes through a hole in the metalwork, suitable grommets shall be provided. Through wiring shall be terminated on terminal blocks in each cubicle.
5. All small wiring associated with remote control and indication circuits shall be segregated from the power wiring circuits and shall be suitably screened either by the use of screened cable or conduit or trunking installed within the cubicles.

C. Circuits and Labels
1. The circuit classification shall be as shown on the main distribution single line diagram. A label schedule and layout shall be supplied for approval by the Engineer.

D. Finish
1. The finish of the power factor correction enclosure shall be NEMA 1, finished to the Manufacturer's standard and of a color to be agreed with the Engineer.

E. Isolating Fuse-Switch Units (CFS)
1. Isolating fuse-switches shall conform to relevant standards and the following requirements:

a. Isolating switches shall be of fault make, load break, heavy duty type capable of interrupting, without damage, the full load current of the capacitors;
b. All isolating devices shall have their incoming line terminals shrouded to prevent accidental contact;
c. The isolator operating handle shall be fixed to or have positive action linkage with the isolating switch and shall indicate clearly whether the isolating switch is in the "ON" or "OFF" position with the cubicle door both open or closed;
d. Provision shall be made for padlocking the isolator operating handle in the "OFF" position by means of up to two padlocks;
e. A door interlock shall prevent opening of the cubicle door when the isolating switch is in the "ON" position.

F. Fuses
1. All fuses used for protection of power and control circuits shall be M class unless otherwise specified on the Contract Drawings;
2. All fuses for short-circuit protection of capacitors shall be rated as shown on the relevant Contract Drawings; and
3. Fuse holders shall be of the all insulated type with shrouded contacts.

G. Contactors
1. All contactors shall be of the molded block type construction and shall satisfy the following requirements:
   a. Utilization category shall be AC3 unless otherwise specified Article 2.01 of this Section;
   b. Normally open and normally closed auxiliary contacts shall be provided as shown on the Contract Drawings;
   c. Closing coils shall be continuous rated and suitable for use on the control voltage specified in Article 2.01 of this Section;
   d. Pole faces in the laminated magnetic circuit shall be fitted with suitable shading rings to minimise in-service vibration and hum;
   e. Contactors shall be suitable for switching of capacitive loads and shall be adequately sized to suit the kVAR rating as defined in Article 2.01 of this Section and the Contract Drawings.
   f. Main contacts shall be double break silver alloy or similar and shall be suitable for uninterrupted (continuous) duty. Mechanical endurance shall be at least 5 million no-load operations.

H. Current Transformers
1. Current transformers shall be fully encapsulated and shall comply with relevant standards and the following:
   a. Metering transformers shall have accuracy class and secondary output as specified in Article 2.01 of this Section;
   b. Protection transformers shall be selected to suit the appropriate protection relay and shall have current ratios as shown on the Contract Drawings.

I. Instruments and Control Devices
   1. Instruments and control devices shall be provided as shown on the Contract Drawings and shall comply with the following requirements:
      a. Direct indicating instruments including voltmeters, ammeters and kW meters shall comply with relevant standards and the following requirements:
         1) Instruments shall be flush mounted, industrial grade;
         2) Instruments shall be accuracy Class 1.0 unless specified otherwise in Article 2.01 of this Section and on the Contract Drawings;
         3) Instruments shall be generally of the moving iron type with taut band suspension. Moving coil movements shall be used for all instruments used in conjunction with signal transducers; and
         4) Where double scaling is required dials shall be reversible with one scale on each face.
      b. Selector switches shall be provided for all ammeters and voltmeters for selection of phase-to-phase voltage and phase current. Ammeter switches shall include an "OFF" position.
      c. All control devices including indicating lamps, push buttons and selector switches shall comply with relevant standards and the following requirements:
         1) All control devices shall be oil-tight and dust tight;
         2) All indicating lamps shall have a minimum rated life of 3,000 hours at rated voltage;
         3) All indicating lamps shall include a press-to-test function; and
         4) Selector switches shall be of the rotary cam operated type. Switchgear control selector switches shall be uniquely key lockable. "Trip/Close" and "Trip" switches shall be fitted with a spring return to the neutral position.
      d. Current transformers shall be provided for all ammeters.
      e. Transducers shall comply with relevant standards and the following requirements:
         1) Accuracy Class shall be 1.0 unless specified otherwise in Article 2.01 of this Section or on the Contract Drawings;
         2) Transducers shall be static, isolating type with 4-20mA current output.

J. Control Relays
   1. Control relays shall be of the industrial plug-in type complying with relevant standards and the following:
      a. Contacts shall be silver alloy type rated at 5 Amps AC15 minimum;
      b. Contacts shall make with a wiping, self-aligning motion without bounce; and
      c. Relay coils shall be continuously rated.

K. Internal Wiring
   1. The power factor correction equipment shall be completely factory wired in accordance with relevant standards and the following requirements:

a. All wiring shall be carried out in flexible copper cables, 600V, and terminated with insulated compression type lugs or connectors;
b. The minimum size of flexible cable shall be as follows:
    1) Control wiring - 16AWG (stranded)
    2) Protection - 14AWG (stranded)
    3) Metering - 14AWG (stranded)
c. Wire colors shall comply with the following requirements of NFPA 70 and NFPA 79
d. All internal wiring shall be neatly arranged and wherever practicable shall be contained in capped plastic ducting. Elsewhere, groups of wires shall be strapped together with nylon or other strong plastic ties or spiral binding to form neat wire bundles;
e. Where groups of wires are required to connect to devices mounted on doors or access panels, wire bundles shall be arranged such that opening and closing of the door is not impeded and at the same time flexing of the wiring is minimized; and
f. All wiring shall be identified at each end by fully interlocking Z-type numbered ferrules. All such identification shall be in accordance with the Contract Drawings.

L. Terminals
1. DIN rail mounted molded terminal blocks shall be provided for termination of all control wiring. Terminals shall carry a numeric designation in accordance with the Contract Drawings and shall be segregated according to function and voltage;
2. Terminal groups for the termination of control wiring external to the enclosure shall be arranged vertically and located within the vertical cable zone adjacent to their respective functional units. The terminal groups shall be spaced to facilitate easy connection of wiring and cables. Spare space shall be available on each terminal rail to accommodate additional terminals.
3. A separate terminal shall be provided for the connection of each individual wire. Bridging links as supplied by the terminal manufacturer shall be used to interconnect 'common' terminals.

M. Gland Plates
1. Undrilled brass gland plates of 1/8 inch minimum thickness shall be provided within cable zones and shall be of sufficient size to accommodate all glands necessary for the termination of all power and control cables at the power factor correction equipment;
2. External power and control cables will be supplied and fitted; and
3. Each gland plate shall be solidly bonded to the main ground bar by a separate grounding conductor.

N. Nameplates and Labels
1. All equipment shall be identified with nameplates and labels in accordance with the following:

2. All enclosures and equipment shall be identified with white laminated phenolic nameplates and labels engraved with black lettering and complying with the following:
    a. Lettering shall be of minimum size 13/64 inches;
    b. Labels shall be detachable and interchangeable;
    c. All external labels shall be attached by means of screws;
    d. Fixing holes shall be slotted to allow for expansion and contraction; and
    e. Minor labels within the enclosure only, may be affixed by an approved adhesive.
3. Push buttons and pilot lights shall be supplied with standard metal engraved labels;
4. Nameplates shall be supplied for identifying each enclosure. Lettering shall be minimum size 1 3/16 inches high engraved black on a white background with an approved text;
5. All shrouds over live equipment and bolt-on covers which provide access to live equipment shall be fitted with red danger labels engraved with white lettering "DANGER XYZ VOLTS" (where XYZ = rated voltage as nominated in Article 2.01 of this Section); and
6. A label schedule and layout shall be supplied for approval by the Engineer.

O. Painting and Corrosion Protection
1. The Contractor's standard painting and corrosion protection system:
    a. Shall be subject to approval by the Engineer; and
    b. The color of the final surface coat shall be subject to approval by the Engineer.
2. The equipment shall be delivered with a minimum sample of 1 Gallon of the final surface paint in a sealed container. The container shall be labeled with sufficient information to permit re-ordering.

ARTICLE 3 EXECUTION

3.01 TESTING

A. Installation
1. Install as per manufacturer's instructions.
2. Install required safety labels.

B. Type Testing
1. Type test certificates from a recognized testing authority shall be provided to substantiate that the equipment which is identical in essential details to that being supplied has passed all necessary type tests. Type testing shall have been carried out in accordance with relevant standards including internal arcing tests.

C. Routine Testing

1. Routine tests to relevant standards shall be carried out on the complete power factor correction system, fully assembled in its final configuration, prior to dispatch and shall include the following:
   a. Insulation resistance tests;
   b. Mechanical operating tests;
   c. Ductor test of each busbar bolted joint;
   d. Primary injection testing of all protection relays and current transformers;
   e. Check of protective circuits;
   f. Testing of all control and interlock circuits to ensure satisfactory operation;
   g. Check of all control system interfaces;
   h. Check of wiring and terminations; and
   i. Check of nameplates and labels.

3.02 PACKAGING AND SHIPMENT TO SITE

A. The equipment, as far as practicable, shall be fully tested and assembled ready for shipment.

B. The equipment shall be adequately packaged for transporting to site.

C. Provisions shall be provided for off loading the equipment by overhead crane or fork truck.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16893.001 – Tunnel Services Power Factor Correction shall be measured as an each unit, complete in place.

4.02 PAYMENT

A. Item 16893.001 – Tunnel Services Power Factor Correction will be paid at the unit price and shall include the cost of all work specified in this Section.

END OF SECTION

SECTION 16894

TUNNEL EMERGENCY RAIL LIGHTING AND LIGHTING RECEPTACLES

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for rail tunnel lighting and lighting receptacles, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design, manufacture, furnish, install, and testing of the new rail tunnel emergency lighting and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel emergency rail lighting and lighting receptacles portion of the Work. The Contractor shall be responsible to provide a completed design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 15400, “Tunnel Services Scope of Work”

B. Section 16111, “Conduit”

C. Section 16120, “Low Voltage Power Cables”

D. Section 16702, “Copper Outside Plant”

E. Section 16889, “Tunnel Services Electrical Testing and Commissioning”

F. Section 16890, “Tunnel Services Electrical Requirements of Mechanical Equipment”

G. Section 16891, “Tunnel Services Low Voltage Switchboard and Motor Control Center”

H. Section 16892, “Tunnel Services Uninterruptible Power Supply”

1.03 REFERENCE STANDARDS

A. ANSI

B. IEC

C. NEMA

D. NEC

E. NFPA

F. UL

1.04 SUBMITTALS

A. All submittals shall be sealed by a Professional Engineer.

B. Product Data and specifications on luminaries and accessories, and receptacles;

C. Shop Drawings on luminaries and accessories, and receptacles;

ARTICLE 2 PRODUCTS

2.01 APPLICATION SPECIFIC REQUIREMENTS

Table 16894-1

ITEM	DESCRIPTION	UNITS	DATA
1	Supply Voltage (Single Phase)	VAC	277
2	Supply Frequency	Hz	60
3	Average Maintained Light Level	Lux (Min)	2.7
4	Light Uniformity	Max:Min	10:1
5	Operating Ambient Temperature	°F	140
6	Minimum Operating Temperature	°F	32
7	Relative Humidity (non condensing)	%	95
8	Degree of Protection	NEMA	4X

2.02 OPERATING CONDITIONS

A. Ratings
1. All equipment and materials shall be suitable for operation under the specified general service conditions as specified in Article 2.01 of this Section.
2. All equipment and materials shall be rated for continuous full load operation under any combination of the design environmental conditions specified in Article 2.01 of this Section.

B. Power System
1. The equipment shall be designed and manufactured for normal operation on the power supply system as specified in Article 2.01 of this Section.

2.03 CONSTRUCTION

A. All luminaries shall be constructed from aluminum with a minimum thickness of 3/32 inch and be finished with a powder coating.

B. The enclosure shall have a minimum degree of protection of NEMA 4X unless otherwise specified in Article 2.01 of this Section. Gaskets shall be temperature resistant synthetic rubber and resistant to the atmosphere in the rail tunnel.

C. All tunnel luminare components shall be of low smoke and halogen free manufacture.

D. All lighting power circuit cables shall be fire resistant and of low smoke and halogen free manufacture and be installed in steel conduit.

E. All enclosures and assemblies shall be vermin proof.

F. Duplex Receptacle
   1. Duplex Receptacle shall be weather proof with heavy duty surface mount cast device box with cover.

2.04 LIGHTING TECHNICAL REQUIREMENTS

A. General
   1. Luminare mounting and positioning including maximum and minimum height requirements shall comply with the relevant Contract Drawings.

B. UPS Emergency Lighting
   1. Emergency lights shall be supplied from a dedicated UPS unit. UPS units shall automatically switch to battery backup in the event of a power outage.
   2. In the event of a power outage emergency lighting shall be maintained for a minimum period of 2 hours.
   3. Minimum emergency lighting levels on egress walkways shall be 2.7 lux minimum in accordance with NFPA 130.

C. Duplex Receptacle
   1. Duplex receptacle shall be 120VAC, 20A, 2 pole 3 wires, NEMA WD 6 5-20R with integral ground fault circuit interrupter.

ARTICLE 3 EXECUTION

3.01 LUMINAIRES

A. Contractor shall furnish and install all equipment necessary for the tunnel emergency lighting to function properly, including but not limited to luminaries, mountings brackets, light sources and fixings in accordance with the Contract Drawings.

3.02 DUPLEX RECEPTACLES

A. Contractor shall furnish and install all equipment necessary for the tunnel receptacles to function properly, including but not limited to duplex receptacles, weather proof heavy duty surface mount device box in accordance with the Contract Drawings.

3.03 TESTING

A. Tests to relevant standards shall be carried out on the complete lighting system, fully assembled in its final configuration:
   1. Insulation resistance tests;
   2. Ground continuity tests;
   3. Check of protective circuits;
   4. Operational test of all luminaries;
   5. Emergency lighting levels;
   6. Check of wiring and terminations; and
   7. Battery operated emergency system discharge test to establish the capacity of the batteries.

B. Tests to relevant standards shall be carried out on the complete duplex receptacles, fully assembled in its final configuration:
   1. Insulation resistance tests;
   2. Ground continuity tests;
   3. Check of GFCI protective circuits;
   4. Check of wiring and terminations.

3.04 PACKAGING AND SHIPMENT TO WORKSITE

A. The equipment, as far as practicable, shall be fully tested and assembled ready for shipment.

B. The equipment shall be adequately packaged for transporting to the Worksite.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16894.001 – Rail Tunnel Lighting System shall be measured as a lump sum unit, complete in place.

B. Item 16894.002 – Rail Tunnel Lighting Receptacles shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16894.001 – Rail Tunnel Lighting System will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

B. Item 16894.002 – Rail Tunnel Lighting Receptacles will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

END OF SECTION

SECTION 16895

TUNNEL SERVICES LOW VOLTAGE AC VARIABLE SPEED DRIVE

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment and incidentals necessary for low voltage AC variable speed drive controllers for tunnel services systems, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. Design, manufacture, furnish, install, and testing of the low voltage AC variable speed drive for tunnel services systems and other equipment associated with the system.

C. The Contract Documents provide the performance parameters and Design Criteria to complete the tunnel services low voltage AC variable speed drive portion of the work. The Contractor shall be responsible to provide a completed design for this portion of the work.

1.02 RELATED SECTIONS

A. Section 15400, "Tunnel Services Scope of Work"

B. Section 15889, "Tunnel Ventilation Fans"

C. Section 15890, "Tunnel Ventilation Jet Fans"

D. Section 15891, "Tunnel Services Mechanical Testing and Commissioning"

E. Section 16111, "Conduit"

F. Section 16120, "Low Voltage Power Cables"

G. Section 16702, "Copper Outside Plant"

H. Section 16742, "SCADA System"

I. Section 16889, "Tunnel Services Electrical Testing and Commissioning"

J. Section 16890, "Tunnel Services Electrical Requirements of Mechanical Equipment"

K. Section 16891, "Tunnel Services Low Voltage Switchboard and Motor Control Center"

L. Section 16893, "Tunnel Services Power Factor Correction"

1.03 REFERENCE STANDARDS

A. ANSI

B. IEC

C. IEEE

D. NEC

E. NEMA

F. NFPA

G. UL

1.04 SUBMITTALS

A. All submittals shall be sealed by a Professional Engineer.

B. Shop Drawings shall include circuit, connection and instrument loop diagrams which clearly identify all cables, terminations and connections and indicate accurately the numbers of cables, wires, terminals and cable cores marked on the installed plant. Shop Drawings indicating front and side views of enclosures with overall dimensions, including conduit entrance locations and requirements; nameplate legends; electrical characteristics.

C. Test certificate shall include equipment type test certificates where applicable.

D. Characteristic graphs of drive motor speed/torque/starting current and driven load torque on starting when run-up exceeds 8 seconds.

E. Technical specification and datasheets.

F. Documentation of offered design showing proven service.

ARTICLE 2 PRODUCTS

2.01 APPLICATION SPECIFIC REQUIREMENTS

Table 16895-1

ITEM	DESCRIPTION	UNIT	DATA
1	Supply Voltage Three Phase	VAC	480
2	Supply Voltage Motors Three Phase (Ventilation	VAC	480

	Fans, Jet Fans)		
3	Supply Frequency	Hz	60
4	Operating Ambient Temperature	°F	104
5	Minimum Operating Temperature	°F	32
6	Control Voltage	VAC	120

2.02 GENERAL

A. Should the Contractor propose any deviations from the specified requirements, such variations shall be submitted in writing to the Engineer for approval.

B. Ratings
1. All equipment and materials supplied by the Contractor shall be suitable for operation under the general service conditions as specified in Article 2.01 of this Section.
2. The Variable Speed Drive (VSD) controller components shall be capable of carrying continuously its assigned full load current at the ambient temperature as specified in Article 2.01 of this Section and rated voltage without exceeding the permissible maximum temperatures of the components parts.
3. Only service proven designs shall be offered. When a design has not been proven in service for at least five (5) years, quotations shall indicate which parts do not meet this requirement and the extent of experience with these parts.

C. Equipment Protection
1. All equipment shall have a minimum degree of protection of NEMA 12, unless otherwise specified in this Section.
2. All enclosures shall be vermin proof.

D. All electronic components, circuiting and Printed Circuit Boards (PCBs) shall be coated with fungistatic lacquer to prevent damage or failure due to moisture or fungus growth.

E. All VSD cabinets shall be made up of a framework of folded sheet steel and/or structural sections with additional supporting members provided where necessary for heavier components. All steelwork for electrical enclosures shall be free of rust, scale, burrs and sharp edges.

F. Eyebolts shall be provided so that no distortion or fatigue will result from lifting. It shall be possible to remove all lifting accessories without needing access to any internal section of the panel.

G. Direct air cooling for the VSD cubicles is preferred. Cooling fans and filters shall be provided.

H. Each VSD cabinet shall be fully shop assembled including wiring such that on site it will only be necessary to set each cabinet and connect outgoing circuits.

I. All equipment necessary for setting and connection on site shall be provided, and specified in the quotation.

2.03 TECHNICAL

A. Variable Speed Drive (VSD) Controller
1. The VSDs shall be of variable voltage variable frequency (VVVF) type utilizing the latest proven, digital variable speed drive technology. Preference shall be given to systems where the output voltage waveform is sinusoidal at all frequencies; to enable full utilisation of the rated motor power at rated frequency.
2. The kVA rating shall be of sufficient capacity to ensure continuous trouble free operation at continuous motor speed of the associated motor/load rating for duty type, starts per hour and an ambient environment as specified in the Article 2.01 of this Section and the Contract Drawings.
3. Preference shall be given to systems that can operate for the load types specified without the need for tacho-generator speed feedback.
4. Where the VSD requires additional functions such as dynamic braking capability and active front end units these will be specified in the Article 2.01 of this Section.

B. Harmonics, EMC and Power Factor
1. The variable speed drive shall be designed and adjusted to generate the minimum level of current harmonics consistent with the converter size, and pulse number. Standards IEEE 519 shall be used as a guide to indicate the expected level of harmonics.
2. Any limitations on performance or output rating of the motor load due to harmonics shall be described in technical data sheet.
3. Radio frequency interference emissions from the VSD controller shall be within the limits set out in IEEE 519.
4. The power factor (pu) for the load application over the entire speed range shall be detailed in technical data sheet.
5. Details of harmonic currents generated and tolerated by the drive must be provided. Preference will be given to VSDs with low generation of harmonic distortions onto the supply side and load side.
6. The Contractor shall complete technical data sheet giving full particulars on magnitudes of torque pulsations, which may result in undesirable vibration and noise. Special reference is to be made on the interaction between the fundamental and the fifth and seventh harmonics resulting in a sixth harmonic.

C. Internal Wiring and Termination

1. All internal wiring of the VSD cabinet shall be completely factory wired to terminal blocks.
2. Wiring to braking resistors and other heat emitting devices shall have fire resistant insulation.
3. No mid run connectors or soldered joints shall be permitted. The wiring shall be formed in a neat and systematic manner, fixed securely without strain by cleats of the compression type, and supported clear of the panels and without crossovers. Bushes shall be provided where necessary to prevent cable chafing.
4. Each control/metering/protection wire shall be identified at either end by full circle type self interlocking ferrules. Clip-on types shall not be used. Wire numbers shall be nominated by the Manufacturer.
5. All wire terminations at the equipment itself and terminal blocks, shall be by means of pre-insulated terminals and pins as required.
6. Terminal blocks shall have pairs of terminals for incoming and outgoing conductors and not more than two conductors shall be connected to any one block. They shall be mounted to enable ferrule numbers to be read without difficulty.
7. All outgoing cable cores shall have individual terminals.
8. For internal connections between modules and/or PCB's, plug connectors with retaining clips or screws are preferred to PCB edge connectors. Where edge connectors are used, the connecting leaves shall be sprung to ensure positive contacts, and the PCB's shall be held in place by mechanical means other than the connector itself. In both plug connectors and edge connectors, the contact surfaces shall be gold plated, and the connectors shall be polarised to prevent insertion of an incorrectly oriented plug or PCB.

2.04 ISOLATING DEVICES

A. Isolators are to be fitted so as to enable maintenance to be carried out on the VVVF drive electronics. Isolators shall have facility for padlocking and tagging and be mounted at the front of the VSD Cabinet.

B. Diagnostic systems to aid fault finding shall be provided.

C. Adjustable maximum and minimum speed limit settings shall be provided.

D. The controller shall stop supply to the motor and de-energise a trip relay in the event of:
   1. Motor overload Single Phase
   2. Heat-sink over temperature
   3. Loss of phase in AC supply
   4. Overcurrent
   5. Motor stall
   6. Voltage Transients
   7. Over- and Under-Voltage

8. Short Circuits
9. Ground Faults
10. Overload
11. VVVF Output Open Circuit
12. Single Phasing

E. All analogue input circuits, and all two-wire transmitter type analogue output circuits shall be protected within the controller against reverse polarity connection.

F. All analogue output circuits of locally powered equipment shall be protected within the controller such that short-circuits or open-circuit connection of the output, while the controller is powered on, shall not cause damage to the controller. Analogue outputs shall be insulated from earth.

ARTICLE 3 EXECUTION

3.01 INSTALLATION OF EQUIPMENT

A. All equipment shall be installed in readily accessible positions.

B. The Variable Speed Drive (VSD) controllers will be installed in areas and under conditions as detailed in Article 2.01 of this Section and the Contract Drawings.

C. All fastenings shall be cadmium plated, zinc plated or galvanized. Spring and flat washers shall be provided under nuts or bolt heads where necessary. Other fastenings shall be securely locked. Each bolt or stud shall be shortest standard length, which will show at least one full thread beyond its nut after assembly. Studs shall be screwed home at least 1 ¼ diameters.

D. All equipment shall be installed according to the Manufacturer's instructions in addition to the requirements stated herein.

E. All equipment shall be installed so that accuracy and reliability shall not be impaired due to vibration, pulsation, temperature, or contamination.

F. Ramp time for VSD controllers shall comply with NFPA 130.

3.02 CABLING

A. All cabling shall comply with NEC standards and the following requirements.

B. Cables requiring additional support or protection shall be enclosed in galvanized steel screwed conduit. PVC conduit shall not be used.

C. Except where glands are screwed into threaded metal entries of equipment or fitted to brass gland plates, they shall be fitted with brass ground tags and brass lock nuts. Ground tags shall be bonded to the equipment ground bar.

D. Each cable shall be identified at each end with a cable marker and each control cable core shall be identified at each end using cable core markers. Cable and core markers shall read left to right or top to bottom. Cable cores shall be terminated using pre-insulated pin or spade type crimp lugs.

3.03 PAINTING AND CORROSION PROTECTION

A. The painting and corrosion protection system shall be the Contractor's standard unless specified otherwise in the Related Sections.

B. The Contractor's standard for painting and corrosion protection shall be subject to approval by the Engineer.

C. The Contractor shall provide full details of the proposed painting and corrosion protection system.

D. Final color shall be as approved by the Engineer.

3.04 LABELLING AND MARKING

A. All equipment shall be provided with approved nameplates and information plates permanently secured to equipment in a readily visible area. These shall be stainless steel engraved plates or laminated plastic labels with black lettering on a white background. Lettering shall be 5/16 inch high minimum.

B. Labels and nameplates shall be screw fixed with stainless steel screws. Adhesive fixing shall not be used. Label fixing holes shall be slotted to allow for expansion. Labels larger than 6 ½ x 1 inch shall have a minimum of 4 fixing screws.

C. Labels shall be fixed in such a manner that the integrity of the enclosure classification is maintained.

D. All cables, wires, terminals and control and instrument cable cores shall be clearly labeled in accordance with the Contract Drawings to enable easy identification with the circuit connection and instrument loop diagrams.

E. All relays shall be identified identically and may be abbreviated as shown on the Contract Drawings.

F. Fuse labels shall show the type and size of each fuse. Labels for similar functions shall be of uniform size and interchangeable.

G. All components shall be labeled from the schematic Contract Drawings, indicating where necessary their functions and "ON" and "OFF" positions.

H. External and internal labels shall be provided to identify equipment that is accessible externally and internally.

3.05 TESTING

A. Electrical and instrument equipment supplied by the Contractor shall be routine tested at the manufacturer's facilities in accordance with the applicable Standards and to the approval of the Engineer. Tests shall include, but not be restricted to the following:
   1. Insulation resistance test.
   2. Point-to-point wire check.
   3. Test of individual control and instrumentation devices.
   4. Functional and operational check.

B. Tests to be carried out shall be as detailed as follows:
   1. Routine Tests
      a. Two copies of test certificates, graphs, etc., giving details and results of all tests carried out shall be submitted by the Contractor within 48 hours of the tests.
      b. Each variable speed drive system shall be fully calibrated by the Contractor prior to delivery to the Worksite.
      c. Equipment to be calibrated shall include but is not necessarily limited to the following:
         1) Converter/DC link/inverter and motor protection relays
         2) 4-20mA input signal converter/isolator
         3) Drive internal control loops for stable operation of connected loads detailed in this Section.

3.06 PREPARATION FOR SHIPMENT

A. All equipment shall be suitably protected to prevent damage during transport, storage, loading and unloading.

B. Equipment subject to damage due to vibration such as alarm annunciators, PLC cards, plug-in relays, instrument devices and the like shall be removed and separately packed in clearly marked containers.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16895.001 – Gateway Station Low Voltage AC Variable Speed Drive shall be measured as a lump sum unit, complete in place.

B. Item 16895.002 – North Side Station Low Voltage AC Variable Speed Drive shall be measured as a lump sum unit, complete in place.

4.02 PAYMENT

A. Item 16895.001 – Gateway Station Low Voltage AC Variable Speed Drive will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

B. Item 16895.002 – North Side Station Low Voltage AC Variable Speed Drive will be paid at the lump sum price and shall include the cost of all related work specified in this Section

END OF SECTION

SECTION 16901

COMMUNICATION SYSTEM INSPECTION AND TEST

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for communication system inspection and test, in accordance with the contract documents.

B. The Work of this Section includes, but is not limited to, the following activities:

1. Through testing and inspection Contractor shall verify that the Communication System meets Contract Specifications and all technical and performance requirements. Contractor shall test and inspect all items of hardware and software that it supplies, and furnish test results to the Engineer.

2. Tests and inspections shall be conducted according to procedures submitted by Contractor and approved by the Engineer. Suppliers' existing inspection and factory acceptance test (FAT) procedures may be utilized upon the Engineer's approval.

3. Contractor shall furnish all labor and materials necessary to perform tests, record data, and prepare reports.

4. Changes required to bring the system into compliance shall be at no additional cost to Authority, including costs for additional testing.

5. Upon completion of each test, all test equipment and temporary facilities shall be removed and the system restored to full operational status.

6. Contractor shall coordinate all communications system involving the Operations Control Center with the PAAC OCC operations and maintenance personnel.

1.02 RELATED SECTIONS

A. Section 01300, "Submittals."

B. Section 01777, "Construction Certification Program"

C. Section 16305, "Traction Power Substation SCADA System."

D. Section 16700, "Communications."

E. Section 16701, "Fiber Optic Outside Plant."

F. Section 16702, "Copper Outside Plant."

G. Section 16703, "Carrier Transmission System (CTS)."

H. Section 16705, "Communications System Power Supply."

I. Section 16721, "Telephone System."

J. Section 16722, "Radio System."

K. Section 16741, "Variable Message Sign/PA System."

L. Section 16742, "SCADA System."

M. Section 16750, "Digital Video System."

N. Section 16950, "OCC Upgrade"

1.03 REFERENCE STANDARDS

A. EIA Standard 490, "Standard Test Methods of Measurement for Audio Amplifiers."

B. TIA/EIA Standard 455 Series, "Fiber Optic Test Procedures, 526 "Standard Test Procedures for Fiber Optic Systems," and 603, "Land Mobile FM or PM Communications Equipment Measurement and Performance Standards."

C. TIA/EIA Standard 603.

D. Military Standard MIL-STD 461E.

E. Military Standard MIL-STD 810.

F. ANSI Standard S1.4.

1.04 SUBMITTALS

A. Inspection and Test Plan.

B. Factory Inspection and Test Procedures.

C. Field Inspection and Test Procedures.

D. Test Reports.

E. Test Setup Block Diagrams: Contractor shall submit block diagrams depicting test setup for each test, test equipment to be used, procedures, and method for recording data in all cases except where tests are to be performed in full accordance with published standards.

1.05 QUALITY ASSURANCE

A. Test Equipment and Calibration:

1. Contractor shall supply all test equipment required for factory and field testing.
2. Each piece of test equipment shall have its own permanently affixed identification number and shall be calibrated, adjusted and maintained at prescribed intervals, or prior to use, against certified equipment having known valid relationships to nationally recognized standards. Calibration shall be traceable to the National Institute of Standards and Technology (NIST).
3. The method and interval of calibration for each item shall be defined, based on type of equipment, stability, characteristics, required accuracy, intended use and other conditions affecting measurement control.
4. When measuring and test equipment are found to be out of calibration, the Engineer will conduct and document an evaluation of the validity of previous inspection and test results to determine the acceptability of items previously inspected and tested. If it is determined that the testing and inspection is invalid, a retest shall be conducted with properly certified test equipment and resubmitted for approval. Any additional testing shall be performed at Contractor's expense.
5. Out-of-calibration tools and equipment shall be tagged and not used until they have been re-calibrated and verified.
6. If any tools or equipment are consistently found to be out of calibration, as determined by the Engineer, they shall be repaired or replaced by Contractor.
7. A calibration shall be performed when inaccuracy is suspected.
8. All calibrations/certifications shall be recorded and become part of the quality assurance records.

PART 2 PRODUCTS

2.01 INSPECTION AND TEST PLAN

A. Contractor shall submit an Inspection and Test Plan for the Communication System to the Engineer for approval. The purpose of this plan shall be to:

1. Identify all of the inspections and tests to be performed.
2. Ensure that testing is in compliance with the overall Quality Assurance Program.
3. Achieve mutual understanding between Contractor and the Engineer on the range, depth, and other aspects of tests to be conducted.

B. The Inspection and Test Plan shall contain the following as a minimum:

1. Flow diagram showing the logical sequence of inspections and tests starting with qualification and factory assembly and concluding with system demonstration.
2. List of factory and manufacturer's recommended field test and inspection procedures, proposed submittal schedule, and proposed test schedule.

3. Outline and format of procedures and test data sheets for each type of test.
4. Requirements (if any) for Authority personnel.
5. Recommendations for witnessing by the Engineer.
6. Organization chart and description of Contractor's factory and field test organizations.
7. Diagram showing the flow of quality assurance and test data and its use within Contractor's Engineering and Quality Assurance organizations.
8. A list of all test equipment to be used in testing and calibration of the Communications System. The list shall include manufacturer and model number of each piece of test equipment and shall include date of calibration/certification, which shall be within 60 days prior to use.
9. Proposed test schedule indicating tests that must be conducted during peak hours and tests that could interfere with Authority's revenue service.

2.02 TEST PROCEDURES

A. Contractor shall submit all test procedures to the Engineer for approval at least 60 days before the scheduled test. No test procedures will be approved by the Engineer prior to approval of Contractor's Inspection and Test Plan.

B. Test procedures shall include, as a minimum, the following information:
   1. Objective and scope.
   2. Test setup.
   3. Test prerequisites.
   4. Test equipment to be used.
   5. Personnel required for the test.
   6. Estimated duration of the test.
   7. Pass/fail criteria.
   8. Samples of data sheets.

C. Procedures shall include all inspections, tests and documentation required by the Federal Communications Commission (FCC) and other regulatory agencies as appropriate.

D. Procedures shall include electromagnetic interference compatibility testing and integrated system testing.

E. No material or test equipment will be furnished by Authority for any testing or inspection. Requests for Authority operating personnel shall be submitted to the Engineer no later than 30 days before any testing is to be performed.

F. Supplier's existing test and inspection procedures may be utilized upon the Engineer's approval.

2.03 INSPECTION AND TEST REPORTS

A. Contractor, Subcontractors, and Suppliers shall submit to the Engineer signed inspection and/or test reports for every inspection and/or test performed no later than 10 days after completion.

B. Test reports shall contain, as a minimum, the following information:
   1. All data obtained during tests.
   2. Analysis of the data.
   3. Conclusions relating to the pass/fail criteria outlined in the test procedure.
   4. Discrepancies found and corrective action taken.
   5. Date of test.
   6. Signature of person conducting the test.
   7. Space for signature of witness.
   8. Specific test equipment used by name, type, serial number, and calibration details.
   9. Tested equipment item by serial number.
   10. Statement of remediation done to pass tests, retest criteria, and retest results. Test equipment of the same model and, if at all possible, the same serial number shall be used during retesting to ensure consistency. Changes made by Contractor in order to pass tests shall be at no additional cost to Authority.

C. Inspection reports shall contain, as a minimum, the following information:
   1. Complete description of facilities inspected.
   2. Complete description of observations.
   3. Discrepancies found and corrective action taken.
   4. Suggested actions, including but not limited to leased facilities ready for disconnection.
   5. Date of inspection.
   6. Signature of person conducting inspection.
   7. Space for signature of witness.

D. All factory and field inspection and test reports shall be documented on approved forms and submitted as project record. Factory inspection and test reports shall include, as a minimum, the following information:
   1. Manufacturer's certification that all cable and equipment meet specifications
   2. Specific factory test data results for RF testing on each BDA
   3. RF Budget Link and Fiber Optic Link data for Uplink and Downlink communications paths.
   4. Coverage Diagrams for LRV communications on the track and ROW. Complete portable radios coverage for the portable, at the hip level for on the LRV, outside the LRV and the ROW.
   5. Fiber optic cable Budget Line Diagram to include; connector, splice, individual span, and overall link for each fiber in each cable at 1310 nm.

2.04 FACTORY INSPECTIONS AND TESTS

A. STATISTICAL SAMPLING PLANS

1. Sampling plans may be used when tests are destructive, or when quality trend data, inherent characteristics of the product, or the non-critical application of the product indicate that a reduction in testing or inspection can be achieved without jeopardizing quality.
2. Contractor shall provide details on any sampling plans and submit the proposed sampling plan to the Engineer for approval prior to its use.
3. Any sampling plan used shall provide valid confidence and quality levels, as solely determined by the Engineer.

B. Contractor shall inspect and test each item to be provided under the Contract. The following inspections and tests shall be included:

1. Receiving inspection of raw materials or component parts at the factory.
   a. These inspection measures shall be used to preclude the use of incorrect or deficient products and to ensure that only products which are acceptable and in compliance with the Contract Documents are used and installed.
   b. All product certifications and Test Reports used as the basis for acceptance by Contractor shall be preserved.
2. In process inspections of production operations.
3. Factory qualifications testing, if applicable, as described in Article 2.05.
4. First article inspection test, if applicable, as described in Article 2.06.
5. Environmental testing, if applicable, as described in Article 2.07.
6. Factory acceptance tests, as described in Article 2.08.

C. General Requirements for Factory Inspections and Tests

1. Design tests: All subsystems, equipment, and components shall be tested at the factory on the first assembled equipment or system component to demonstrate compliance with specifications and/or industry standards.
2. Production tests: All systems, subsystems, and equipment shall be 100 percent factory inspected and tested to verify the quality and correctness of the manufacturing and assembly process.
3. The Engineer shall have the right to witness inspections or tests in Contractor's, Subcontractor's, or Suppliers' plants.
4. Contractor shall obtain the Engineer's approval of test results prior to making any shipment from its or its Suppliers' plants.
5. When approved by the Engineer, Suppliers' existing factory test procedures may be used.

D. Rack Wiring

1. All factory-installed rack wiring shall be tested before shipment.
2. Contractor shall perform point-to-point tests to verify the continuity and connection of each conductor.

E. Operational Testing

1. All equipment shall be operationally tested as a complete functional assembly prior to shipment.
2. Contractor shall test each function by simulating operating conditions.

F. Notification of Testing
1. In order to have the opportunity to witness testing, the Engineer shall be notified in writing a minimum of 2 weeks in advance of each test.
2. When tests are to be conducted continuously as a production-line routine, inform Engineer in writing at least 2 weeks in advance of the date of testing and the expected duration.

2.05 FACTORY QUALIFICATION TESTING

A. Qualification testing is required for new or modified components, systems, or equipment to verify that environmental and design requirements of the Contract are met.

B. Qualification testing may not be required for service-proven components, systems, or equipment based upon service records or previous qualification test records approved by the Engineer.

C. Qualification testing shall include environmental testing (temperature, humidity, vibration, etc.) as well as testing under normal and abnormal conditions.

2.06 FIRST ARTICLE INSPECTION TEST (FAIT)

A. Contractor shall perform a comprehensive FAIT on the first production item of any component or system that requires qualification testing.

B. FAIT shall be required even for service-proven equipment if the equipment has been modified.

C. FAIT shall include all interfaces to assure the complete and proper operation of the equipment.

D. FAIT shall require approval of the Engineer before additional systems are manufactured or installed.

2.07 ENVIRONMENTAL TESTING

A. All equipment shall be proven to operate properly over the temperature, humidity, and mechanical vibration and shock range defined in these specifications.

B. Environmental testing shall be in conformance with MIL-STD 810.

C. Service-proven equipment may not require environmental testing, but shall require evidence of proper performance in previous tests or similar operating environment, subject to Engineer approval.

2.08 FACTORY ACCEPTANCE TESTS

A. Prior to shipments, Contractor shall inspect all products to be delivered for installation into the Work or otherwise delivered to Authority to assure completion and conformance to the Contract Documents.

B. The inspections and preparation for shipment shall be verified by Contractor's quality control personnel. Engineer's approval shall be required before any shipment is made.

PART 3 EXECUTION

3.01 FIELD INCOMING INSPECTIONS AND TESTS

A. Contractor shall perform receiving inspection at the worksite for incoming products.
   1. Inspection shall preclude the use of incorrect or deficient products and ensure that only products which are acceptable and in compliance with the Contract Documents are used and installed.
   2. All product certifications and Test Reports used as the basis for acceptance by Contractor shall be preserved.

B. Contractor shall maintain a receiving inspection log for all items received at the worksite. Contractor shall submit the content of the log for the Engineer's approval.

3.02 FIELD INSPECTIONS AND TESTS

A. Contractor shall verify the quality of the installation by visual inspection and by tests of continuity, insulation resistance, resistance of ground connections, circuit breakdown, and other tests as required.

B. All tests required shall be performed to ensure the proper operation of all communication equipment and to prove the adequacy and acceptability of the total installation.

C. In the case of testing on operational portions of Authority's LRT system, Contractor shall return the system to operational status after testing.

D. Tests to be performed shall cause each system and subsystem to be sequenced through all required operations and include simulated conditions to prove the installation is in compliance with requirements.

E. Contractor shall obtain recommended field inspections and tests from all Suppliers for all equipment to be used in this Contract. These manufacturers' recommended field inspections and tests shall be contained in the Inspection and Test Plan.

F. Procedures for all tests shall be submitted for approval to the Engineer at least 60 days before the scheduled test.

G. The Engineer shall have the right to witness all field inspections and tests. The Engineer shall be notified in writing a minimum of 2 weeks in advance of each inspection or test.

H. Test Reports from Contractor and Suppliers shall be submitted within 10 days after performing tests.

I. Test Reports shall include any pass/fail history along with any corrective action taken to bring test into compliance, including recommended changes and retesting.

J. Contractor shall make every effort not to interfere with existing Authority systems during tests and inspections. Operational tests shall be performed during off-peak hours to the extent possible. If interference with existing Authority systems is unavoidable, arrangements must be made with Authority a minimum of 2 weeks in advance of the test.

3.03 FIELD QUALIFICATION TESTING

A. Field qualification testing shall be required for new or modified components, systems, or equipment to verify that environmental and design requirements of the Contract are met.

B. A comprehensive field qualification test shall be performed on the installed and integrated system and shall include all communication subsystems and interfaces. Field qualification testing shall demonstrate that the Communications System meets all Contract requirements including proper operation of all interfaces.

3.04 LRVS FOR TESTING

A. Authority will provide LRVs and crews to support the testing program. These shall be scheduled 30 days in advance.

3.05 FIBER OPTIC CABLE INSPECTIONS AND TESTS

A. Testing of fiber optic outside plant shall be in conformance with TIA/EIA Standard 455, Fiber Optic Test Procedures.

B. Factory Inspections and Tests
   1. Contractor shall ensure that each finished and installed fiber optic cable segment is traceable to the test date on file for each step in the manufacturing process.

2. Physical tests shall be made on samples selected at random at the place of production. Each test sample shall be taken from the accessible end of different reels. Each reel selected and the corresponding sample shall be identified. The number and lengths of samples shall be as specified for the individual test.
3. Optical tests shall be made on the entire length of each continuous fiber provided within each fiber optic cable. Each test shall be completed during manufacture as required, and again prior to shipping, after the cable is secured to the reel in final shipping packaged form.
4. All optical fibers shall be 100 percent attenuation tested at the factory for compliance with performance specifications described herein. The attenuation of each fiber shall be provided in a report provided with each cable reel.
5. The manufacturer shall provide, at the point of production, apparatus and labor for making any or all of the following tests under the supervision of the Engineer, to include, but not be limited to tensile strength, impact resistance (crushing and flexing), optical attenuation, optical spectral dispersion, and optical time domain reflectometry (OTDR).

C. Field Inspections and Tests
1. All fibers shall be 100 percent attenuation tested in the field before pulling the fiber optic cable in place to assure that no damage was incurred in shipment.
2. Upon completion of installation and termination of fiber optic cable, a visual inspection shall be made of all portions of the installation, recording all defects noted.
3. Upon completion of installation and termination of fiber optic cable, all fibers within each cable shall be tested as terminated on each fiber distribution panel.
4. Contractor shall notify the Engineer in writing at least 2 weeks in advance of testing so that the Engineer may be present for the tests.
5. Tests shall include but not be limited to the following:
   a. Cable length.
   b. Propagation delay.
   c. Optical loss.
   d. Point discontinuities.
   e. Optical spectral dispersion.
   f. OTDR.
6. All OTDR records and all other graphical test records shall be labeled and identified. The output shall be either photographic or computer printed/plotted.
7. Tests shall be conducted for both directions of transmission. All OTDR tests shall be made with an OTDR approved by the Engineer.

D. OTDR (Optical Time Domain Reflectometer), where used, shall meet the following requirements:
   a. Light source and detector: specific unit for each applicable wavelength
   b. Fiber type: 50/125 μm and 60/125 μm multi-mode, 9/125 μm single-mode fiber.
   c. Minimum Event dead zone: 0.5m at 850nm, 1m at 1300nm and 1550nm

d. Miniumum attenuation dead zone: 4.5m at 850nm, 8m at 1300nm and 1550nm.
e. Fiber length: minimum 3km at 850nm, 60km at 1300nm and 1550nm
f. Dynamic range: typical 15dB at 850nm, 24dB at 1300nm and 1550nm
g. Distance accuracy: 1.1m
h. Reporting: include reporting software and interface to a personal computer.

E. Optical Power (Loss) meter, where used, shall meet the following requirements:
a. Light source and detector: specific unit for each applicable wavelength
b. Fiber type: 50/125 μm and 60/125 μm multi-mode, 9/125 μm single-mode fiber.
c. Measurement range 0 to -52dBm at 850nm, 0 to -60dBm at 1300nm and 1550nm.

F. All test tools must have been calibrated by the tool manufacturer or a testing entity not directly affiliated with the Contractor and acceptable by the Authority. The calibration validity time must include the dates the testing is performed, and the calibration must be traceable to the National Bureau of Standards.

G. Conduct OTDR and optical power measurements, after installation of the fibers, based on EIA/TIA-455-59, EIA/TIA-455-60, EIA/TIA-455-61, and EIA/TIA-455-34, and submit related reports to the Authority, for:
1. each spliced optical fiber
2. each optical fiber section longer than 200 feet.

H. An optical fiber is considered acceptable if all of the following requirements are met:
1. Individual splice loss is less than 0.03dB per splice for single-mode fiber, and less than 0.02dB per splice for multi-mode fiber.
2. Connector loss is less than 0.75 dB per mated connector pair. Where the installed FO connector assembly terminates onto a connector at a FO device, and the said mating device connector is not separable from the device, then the insertion loss of the single installed FO connector assembly shall be less than 0.35dB.
3. Connector return loss (connector reflectance loss) is less than -55dB per mated connector pair.
4. Optical power loss introduced by unexpected loss events, such as those caused by micro-bending, pinching and sharp bends in fiber, is less than 0.5dB per cause, and the total loss introduced by such causes, combined, is less than 1dB. All power losses not attributable to planned connectors and splices are considered unexpected loss events.

I. Identified causes of excessive power losses, such as bad splices, may be corrected where feasible. If the excessive losses cannot be improved to acceptable levels after three attempts, the related fiber is considered not usable.

J. Submit test reports on all required optical fibers. OTDR tests shall include a graphical plot of the measurements, and distances and signal level at the detected loss and reflective events.

3.06 COPPER CABLE INSPECTIONS AND TESTS

A. Factory Inspections and Tests
   1. Tests shall include, but not be limited to:
      a. Tensile strength.
      b. Impact resistance, crushing and flexing.
      c. Attenuation.
      d. Mutual capacitance.
      e. Insulation resistance.
      f. Conductor resistance.
      g. Conductor imbalance.
      h. Crosstalk.
      i. High voltage.
      j. Shield continuity.
   2. All communication cable, coaxial cable, and patch cords shall be tested with a Time Domain Reflectometer. The results shall be documented and submitted as project record.

B. Field Inspections and Tests
   1. Installed Field Tests: Testing of installed outside plant copper communications cable shall be performed before and after installation, and after complete termination of the cable.
   2. Testing shall be performed on the copper conductors, as terminated on the Main Distributions Frames (MDFs).
   3. All test results shall be recorded on PAAC approved test forms.
   4. Tests shall include, but not be limited to, the following:
      a. Attenuation at 1000 Hz, 150 kHz, and 772 kHz, between terminations.
      b. Conductor to conductor resistance.
      c. Insulation resistance.
         1) Prior to the test, disconnect power sources, direct connection to ground circuits, and any equipment that may be damaged by the voltages of the test instrument unless connection incorporates an isolation link.
         2) Connection to ground for the test shall be the most convenient previously verified low resistance connection to ground available.
         3) Test all wire and cable installed at the job site for insulation resistance between the conductor and ground, using a direct resistance reading instrument having a self-contained or generating test voltage of 500 to 1000 VDC.
         4) Minimum insulation resistance to ground for circuits shall be 100 megohms. Wires and cable shall be replaced when insulation resistances

are below these values. Actual resistance readings shall be recorded on test forms and submitted as project documentation.

   d. Time Domain Reflectometer (TDR) Test, conducted for both directions of transmission records.

5. All TDR records and all other graphical test records shall be labeled and identified. The output shall be either photographic or computer printed/plotted.
6. Tests shall be conducted for both directions of transmission. All OTDR tests shall be made with an OTDR approved by the Engineer.

3.07 GROUND RESISTANCE TEST

A. Contractor shall test communication equipment room ground buses to ensure the resistance between each bus and the single point ground source is not greater than 5 ohms.

B. All connections to the ground bus shall be tested to verify proper and adequate connections.

C. Contractor shall submit proposed test method and test equipment to be used for ground resistance test.

3.08 CARRIER TRANSMISSION SYSTEM INSPECTIONS AND TESTS

A. System Level Factory Test
   1. A System Level Test of the CTS shall be performed by Contractor. A sufficient number of each component of the CTS shall be included in the test to demonstrate all interfaces between components and proper operation of components.
   2. The System Level Test shall include the following at a minimum:
      a. One Head-end SONET Multiplexers.
      b. One Remote SONET Multiplexer.
      c. Two T1 Intelligent Multiplexers (Channel Banks).
   3. Inspection and Test Plan shall include a complete description of the System Level Test.

B. Field Inspection and Test. The CTS shall be tested as a system upon completion of installation. Tests shall include but not be limited to demonstrating and testing the following:
   1. Each equipped DS-1 shall be tested end to end between DSX patch panels.
   2. Each equipped channel shall be tested end to end with sufficient test equipment to test all functionality of each channel.
   3. Full functionality of the DACS. This shall included but not be limited to the following:
      a. Redundancy.
      b. Memory backup.
      c. Test Access.

4. Full functionality of the NMS. This shall include but not be limited to the following:
   a. Communications with every SONET multiplexer.
   b. Communications with the DACS.
   c. Communications with every T1 multiplexer (channel bank).
   d. Display and logging of all CTS alarms and faults.
   e. Communications of alarms and faults to the OCC Computer System.
   f. Alarm Interface Card (relay contact output).
   g. Real time inventory access.
5. Automatic Protection Switching of the SONET. Various types of failures shall be simulated, including fiber optic cable failure and SONET multiplexer failure, and resulting switching shall be measured.
6. Automatic Protection Switching of DS-1 systems.
7. Optical Redundancy of Optical Interface Card.
8. Protection of common units, cards and components.
9. System timing and synchronization.
10. DS-1 and DS-0 allocation according to plan.
11. Channel type allocation according to plan (4W E&M, data, etc.)
12. Front panel display alarms, audible annunciation of alarms, operation of CID.
13. OAM&P, local and remote access.
14. Access and password protection.
15. Software versions.

3.09 COMMUNICATION SYSTEM POWER SUPPLY INSPECTIONS AND TESTS

A. Field Inspections and Tests
   1. Upon completion of installation of CSPS, the CSPS shall be tested as two separate power backup systems (48VDC & UPS), before being used to power the communications subsystems. CSPS system test shall be conducted with a test load that is approximately equal to the anticipated actual load.
   2. CSPS system test shall include but not be limited to the following:
      a. Proper operation under normal conditions.
      b. Simulation of a commercial power failure.
      c. Return of commercial power after failure.
      d. Proper operation with batteries disconnected (only for UPS testing).
      e. The following shall be recorded for each of the above conditions:
         1) Audible noise.
         2) Voltage regulation over load range.
         3) Dynamic response to step change from 20 percent to 100 percent of the full rated load.
      f. Float and equalize voltage range.
      g. High voltage shutdown.
      h. Load sharing.
      i. Alarm indications and contact.
      j. Harmonic distortion.

k. Battery capacity and recharge time.

3.10 TELEPHONE SYSTEM INSPECTIONS AND TESTS

A. Field Inspections and Tests
   1. Following completion of the installation of the new PBX system and all telephones at the NSC sites, Contractor shall inspect all equipment and wiring to verify that all mechanical connections are made and properly secured, and all hardware is installed in its proper location and is properly terminated.
   2. Testing shall be accomplished from the wiring frame in the site communication room as well as testing from any local termination in the vicinity of an instrument. Testing shall include but not be limited to the following:
      a. Conductor and shield continuity from each telephone location to protector block on MDF.
      b. Isolation verification of all installation wiring.
   3. Upon completion of installation and integration with the NSC CTS and Authority phone system, end to end tests shall be conducted for every phone installed under this contract. Telephones shall be tested for full functionality.
   4. Comprehensive test plans and functional requirements for the PBX system are identified in Section 16721 "Telephone System".

3.11 LEAKY COAXIAL AND RF CABLE INSPECTIONS AND TESTS

A. Samples
   1. Provide samples of the proposed leaky coaxial feeder cable for use in the tunnel and stations. The cable samples shall become the property of Authority.
   2. Provide actual or mockup samples of each type of RF connector, antennae, coaxial cable, splitters, terminations and other accessories or ancillary items that related to the NSC radio system.
   3. Provide samples of actual self-locking hangers for the tunnel cables appropriately sized for the leaky coaxial cable and the fiber optic cable with the required separation between the two cables.

B. Certification
   1. Provide specific manufacturer certification for the leaky feeder cable in tunnels and RF distribution cable in subway stations shall be required to demonstrate the compliance with the fire retardant specifications.
   2. Provide Manufacturer Certification that the leaky feeder cable, including the flexible cable and jumpers, and the station RF distribution cable outer jacket shall be designed and use material suitable for underground tunnel applications, and be specifically rated to be fire retardant, contain no halogens and include in the construction a barrier type to prevent molten dielectric material from dripping in a melt down situation.

C. Tests

1. Leaky feeder cable in tunnels: After field installation of the RF connectors and prior to the hookup of the BDA equipment, the cables shall be tested for DC integrity and appropriate frequency sweep tests.
2. RF distribution cables in the NSC stations: After field installation of the RF connectors and prior to the hookup of the other equipment, the cables shall be tested for DC integrity performance at the appropriate frequencies.

3.12 RADIO SYSTEM INSPECTIONS AND TESTS

A. Testing of the radio system shall be in conformance with TIA/EIA Standard 603, Land Mobile FM or PM Communications Equipment Measurement and Performance Standards and shall include:
   1. Test Reports for the existing conditions of the radiating coaxial cable systems, due before CDR.
   2. Qualitative intermodulation and signal strength test plans.
   3. Quantitative signal strength test plans.
   4. Talk-in and Talk-out Radio System propagation and interference simulations and studies for all sites to verify the conceptual design.

B. Preliminary Tests
   1. Contractor shall submit to the Engineer for approval field test plan before beginning any tests. Contractor shall procure or lease any required test equipment, subject to the approval of the Engineer. Contractor shall also present all test results to the Engineer in report form. All test results are the property of Authority.
   2. The testing Contractor shall perform shall include but not be limited to insertion loss tests and field strength tests for each existing segment of radiating coaxial cable under known input power and frequency.

C. Field Inspections and Tests shall include but not be limited to the following:
   1. Transmitter spurious and harmonic outputs.
   2. Transmitter modulation.
   3. Transmitter audio frequency response.
   4. Transmitter audio distortion.
   5. Transmitter frequency modulation noise.
   6. Transmitter audio sensitivity.
   7. Transmitter output power.
   8. Receiver sensitivity, EIA SINAD.
   9. Receiver selectivity, EIA SINAD.
   10. Receiver audio output level.
   11. Receiver audio distortion.
   12. Receiver modulation acceptance.
   13. Receiver intermodulation EIA SINAD.
   14. Antenna and antenna feed system reflected power and SWR.

D. Upon completion of installation of all base stations, quantitative field RF coverage tests shall be performed as specified in Section 16722, "Radio System."

1. LRV Coverage Test: The tests shall be conducted on the ROW using an omni-directional 0 dB gain antenna mounted on the top of an LRV and connected to either an RF field strength meter or a spectrum analyzer, subject to the approval of the Engineer. Either measurement device shall have an NTSB traceable calibration certificate. The measurements shall be conducted using a continuous wave transmitted signal without audio. The measurement bandwidth shall be that of a single audio channel and the configuration of the measurement device shall be subject to the approval of the Engineer. Contractor shall measure talk-in and talk-out success rates by attempting voice and data communications links at 150 m (500 ft) intervals along the entire LRV ROW. Contractor shall attempt no less than 100 voice communication events at different locations to determine this success rate for hand-held portables.
2. Portable Coverage Test. Utilize the same measurement device as used in the LRV Coverage Test but use a device-mounted omni-directional 0dB gain antenna. Contractor shall measure talk-in and talk-out success rates by attempting voice and data communications links at 150 m (500 ft) intervals along the entire LRV ROW at an elevation that simulates portable use. Measurements shall also be made on all station platforms, mezzanines, escalators, hallways or staircases. Contractor shall attempt no less than 100 voice communication events at different locations to determine this success rate for handheld portables.
3. Vehicle Mounted Radio Coverage Test. Utilize the same measurement device as used in the LRV Coverage Test but use a device-mounted omni-directional 0Db gain antenna. Contractor shall measure talk-in and talk-out success rates by attempting voice and data communications links at street level within 150 m (500 ft) of the station entrances at Gateway Center, North Side and Allegheny Stations. Contractor shall attempt no less than 40 voice communication events at different locations to determine this success rate for vehicle mounted mobiles.

E. An integrated system field test shall be performed by the Contractor after all site tests are completed. Test shall include but not be limited to the following:

1. OCC control of the radio system.
2. Pitt Tower remote workstation control of the radio system.
3. South Hills Junction remote workstation control of the radio system.
4. Voting/Comparator system
5. Simulcasting to determine that the RF, Audio and Phase are within acceptable tolerances.
6. LRV to OCC data communications.

3.13 VARIABLE MESSAGE SIGN/PA INSPECTIONS AND TESTS

A. Testing of PA amplifiers shall be in conformance with EIA Standard 490.

B. Field Inspection and Tests

1. Contractor shall test the VMS/PA equipment in each NSC station once installation is complete and the Engineer has approved the inspection certification. System testing shall address at minimum:
   a. Functional testing of each equipment item installed.
   b. Each individual speaker output shall be tested by measuring the sound pressure level generated by the speaker. Contractor shall verify that the speaker meets 104 dBa at 3.3 ft on centerline axis with the speaker adjusted for 4 watt input power. The equipment used to test and document the sound pressure level shall be an industry recognized, ANSI S1.4 compliant, Sound Pressure Level meter, and audio spectrum analyzer for white noise generation.
   c. Balancing and adjusting speaker levels throughout the system to demonstrate an average sound pressure level of 6 dBa ±2 dBa above ambient noise levels, at ear level [4.9 ft above floor level], throughout the station platform area.
   d. Proper indication of the audio announcement level, as monitored by the IQ-PIP-USP2 module.
   e. Distortion check between each adjacent pair of speakers to demonstrate speaker polarization is correct.
   f. Message quality at four locations in each speaker chain, using inputs from each of the available sources of announcements.
   g. Demonstration that audio level at ear level shall not exceed 115 dBa at any point in the station with the system control settings at operational maximum output.
   h. Demonstration of amplifier priority input functions. Contractor shall demonstrate that inputs of higher priority, as shown in Table 16741-1, Section 16741, "Variable Message Sign/PA System" automatically take precedence and completely mute all other inputs.
   i. Demonstration of all system control functions available at the OCC.

C. Integration Testing
   1. Integration testing of the complete VMS/PA System shall follow completion of installation and system testing work, including station and OCC based system tests. Integration testing shall consist of exercising the overall VMS/PA System from the OCC to verify all interlocks, panel-lamp indications, priority definitions, and a sample of distortion readings at various stations to check the entire system, including all interface levels to and from the carrier system. Levels and distortion readings shall be taken at random locations defined by the Engineer.
   2. Contractor shall test the equipment after installation to determine if it operates properly when each station is selected from the operator's workstations in the OCC. Contractor shall demonstrate that stations may be selected individually or in groups. The VMS/PA System shall respond to each of the selections by commanding the audio matrix switch to connect to the selected station(s). The VMS/PA System shall broadcast live audio announcements when the push-to-talk button on the microphone station is depressed. After the live audio announcement is made, Contractor shall demonstrate that the connection is properly closed by

commands to the audio matrix switch. In addition, Contractor shall demonstrate the successful audio/visual message and schedule downloading to each VMS/PA station controller. Contractor shall demonstrate that each VMS/PA station controller receives and stores the message and schedule files assigned to it according to the database kept at the VMS/PA head-end server in the OCC.

3. Contractor shall demonstrate that any live audio announcement made by VMS/PA operators at Pitt Tower has priority over any initiated from the OCC. Contractor shall demonstrate that all live audio announcements made from Pitt Tower or the OCC automatically mute any pre-recorded messages playing at a station.
4. Contractor shall demonstrate that the background music originating at Pitt Tower can be heard at the new NSC stations.

3.14 SCADA INSPECTIONS AND TESTS

A. Integration testing of the complete SCADA system shall follow completion of all work regarding the SCADA system, including system testing at all NSC stations and at the OCC. Integration testing shall consist of exercising the overall SCADA system from the OCC and locally to verify its operation.

B. Field Inspection and Tests
   1. Testing shall include but not be limited to the following:
      a. Communications equipment room (CER) equipment, environmental and intrusion alarms.
      b. Contractor shall coordinate with the OCC for testing the portion of the SCADA System associated with the Substation Control and Alarm System (SACS).
      c. Contractor shall coordinate with the OCC for testing the SCADA System as it relates to the tunnel ventilation system known as the Remote Indication and Control System (RICS).
      d. RTUs system testing shall confirm proper operation of all control, indication, and analog data points, in accordance with the approved test plan.

3.15 DIGITAL VIDEO SYSTEM INSPECTIONS AND TESTS

A. System Level Factory Test
   1. A System Level Factory Test of the Digital Video System shall be performed by the Contractor. A sufficient number of components shall be included in the test to demonstrate that the IP video cameras can be viewed and recorded on the Video Management System equipment to be installed in the Pitt Tower control center.
   2. The System Level Factory Test shall include the following components as a minimum:
      a. Two IP Video PTZ Dome Cameras
      b. Two IP Video Fixed Dome Cameras
      c. Two Gigabit Ethernet Switches & fiber cable to form a ring
      d. One Video Management System Server
      e. One Video Management System Client Workstation & Monitor

f. Two 19" LCD Monitors
g. One Network Video Recorder
h. Two Ethernet LAN Switches

3. The goal of this test is to verify that all communications interfaces perform properly and to demonstrate that the Video Management System software can perform the following basic functions over the Gigabit Ethernet Ring:
   a. Monitor the IP Video cameras
   b. Control the PTZ cameras
   c. Display live video images in single & multi-screen format
   d. Record IP video in MPEG4 format at 8 frames/sec
   e. Verify disc storage requirements for one camera at 4CIF for one day
   f. Retrieve video while recording
   g. Assign video to an LCD Monitor
4. Contractor shall provide a System Level Factory Test Plan along with a configuration diagram showing how the components listed above will be configured for this test.

B. Field Inspection and Test. The Digital Video System shall be tested as a fully integrated system upon the successful installation and stand alone testing of all components. Integration testing shall consist of exercising the overall Digital Video System from Pitt Tower to verify its operation. Testing shall assure that any and all CCTV cameras installed as part of the Project can be selected, displayed and retrieved from the Network Video Recorder (NVR) on any of the Operator Workstations and Video Wall monitors at Pitt Tower.

1. Field Integration testing on the video system shall include the following:
   a. Comprehensive System Integration tests of the integrated system, after satisfactory completion of all individual assembled sub-systems. The intent of this test is to demonstrate and certify the communication performance and interactions between key system components over communication media used in the project.
   b. Field Integration Test shall include all components at Pitt Tower, the three NSC stations, and the OCC as specified in Section 16750 "Digital Video System"
   c. Demonstrate the following aspects for each CCTV camera:
      1) Verify that a video image from each CCTV camera is received and displayed properly. Also verify for each camera that the video image is visible with the following lighting levels at the camera site:
         a) Minimum lighting level as specified for monochrome video.
         b) Minimum lighting level as specified for color video.
      2) Using the PTZ controller verify that each CCTV camera with PTZ functions respond properly for the following commands:
         a) Pan changes.
         b) Tilt changes.
         c) Zoom changes.

d) Preset changes, for all required preset positions
e) Tour mode activated.

d. The following aspects shall be tested for the Video Management system, at a user workstation:
   1) Verify that the Video Management System can generate the following video patterns on one display:
      a) Live video image from any digital camera
      b) Playback of recorded video images from any camera in the system
      c) Display live and recorded video images on same screen.
      d) Display full-screen, 4, 7, 9, 10, 13 or 16 camera combinations of any cameras on the system.
   2) Verify that the Video Management System responds as specified to the following conditions:
      a) "Loss of image" detection and alarming
      b) Restoration of power after power down: automatic resumption of video recording and other configured operations.
      c) System freeze-up: automatic reboot of the system.
      d) Sensor alarm input: automatically issue PTZ command for related camera to move to the related camera preset position.
      e) Generate an audible alarm at an operator workstation at Pitt Tower when the Portal Surveillance System detects an intruder. Verify one second response time.
      f) Arrange for tests to demonstrate setting, changing and storing PTZ presets.
      g) Arrange for tests to demonstrate the scheduling features of different scanning pattern of detection coverage (sets of PTZ presets) for each camera.

3.16 INTERFACE TESTING

A. Contractor shall conduct interface testing to demonstrate that all interfaces are functioning seamlessly.

PART 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement shall be made for the work of this Section.

4.02 PAYMENT

A. No separate payment will be made for the work of this Section. Payment for the work shall be included in the payment for related portions of the Work.

END OF SECTION

SECTION 16950

OPERATIONS CONTROL CENTER (OCC) SYSTEM UPGRADE

ARTICLE 1 GENERAL

1.01 SUMMARY

A. The work of this Section includes, but is not limited to, providing all labor, materials, tools, equipment, and incidentals necessary for the Operations Control Center (OCC) System upgrade, in accordance with the Contract Documents.

B. The work of this Section includes, but is not limited to, the following activities:
   1. OCC System upgrade includes, but is not limited to: the design, construction, delivery, installation, testing, placing into revenue operations, and warranty for the upgraded OCC System.
   2. OCC Site Survey includes, but is not limited to: survey and documentation of the existing OCC System, Voice Communications System (VCS), Private Automatic Branch Exchange (PABX), Closed Circuit Television (CCTV) Video Management System, and Variable Message Sign/ Public Address (VMS/PA) System.
   3. Update of OCC System Overview Display includes, but is not limited to: the design of the graphical depiction of the North Shore Connector (NSC) track layout and the Supervisory Control and Data Acquisition (SCADA) monitor/control points, modification of the overview display screen layout to create space for the NSC portion of the track diagram, and updating the OCC System configuration data to implement the necessary overview display modifications.
   4. Update of OCC System Console User Display includes, but is not limited to: the design of the graphical depiction of the NSC track layout and the SCADA monitor/control points and updating the OCC System configuration data to implement the necessary console display modifications.
   5. Update of OCC System External Interfaces includes, but is not limited to: the installation of cable and all necessary equipment such as new terminal servers, modem splitters, modems, and distribution frames to provide additional RS-232C physical connections between the OCC System and the NSC Carrier Transmission System (CTS) to support the new code system interfaces to NSC field units, updating the OCC System configuration data to implement the new code system interfaces, and testing the new code system interfaces.
   6. Update of VCS includes, but is not limited to: the installation of new line cards, installation of cable to provide additional physical connections between the VCS and the NSC CTS to support the new Public Address (PA), PABX, and Radio System interfaces, updating the configuration data to assign new NSC voice circuits to the VCS communication circuit groups, and updating the VCS display on the OCC System consoles.

7. Update of CCTV Video Management System includes, but is not limited to: updating the CCTV Video Management System console displays to depict the seven (7) new NSC cameras, which will be connected to the existing Pitt Tower Video Matrix Switch, as icons on the existing or new maps, and assigning any new maps to the appropriate users to allow them access to those seven (7) new NSC cameras upon logon.
8. Update of VMS/PA System includes, but is not limited to: updating the VMS/PA server configuration to communicate to the new VMS/PA Station Controllers deployed at NSC stations via the existing Ethernet interface connecting the VMS/PA server to the existing CTS Ethernet Switch.

C. The Contract Documents provide the performance parameters and design criteria to complete the OCC System Upgrade portion of the Work. The Contractor shall be responsible to provide a complete design for this portion of the Work.

1.02 RELATED SECTIONS

A. Section 16700, "Communications"

B. Section 16702, "Copper Outside Plant"

C. Section 16703, "Carrier Transmission System"

D. Section 16742, "SCADA System"

E. Section 16701, "Fiber Optic Outside Plant"

F. Section 16724, "Emergency Telephone System"

G. Section 16721, "Telephone System"

H. Section 16741, "Variable Message Sign/PA System"

I. Section 16750, "Closed Circuit Television (CCTV) System"

J. Section 13580, "Train To Wayside Communications (TWC)"

K. Section 13570, "Signal System Requirements"

L. Section 15400, "Tunnel Services Scope of Work"

M. Section 16305, "Traction Power Substation SCADA System"

N. Section 071777, "Construction Certification Program"

1.03 REFERENCE STANDARDS

A. ANSI.
   1. EIA RS-232-C Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange (ANSI/EIA/TIA-232-E-91)

B. ANSI/IEEE.
   1. ANSI/IEEE-2 National Electrical Safety Code.
   2. ANSI/IEEE-829-1998

C. IEEE
   1. IEEE 802.3 – Ethernet Standards

D. ISO
   1. Open Systems Interconnection OSI Model.
   2. ISO-9001.

E. UL.
   1. UL Standard 444 Communications Cables

F. Military Standards (MS).
   1. STD-781 – Reliability, Test Methods, Plans, and Environments for Engineering, Development, Qualification and Production.
   2. STD-217 – Reliability Prediction of Electronic Equipment.

1.04 SUBMITTALS

A. Submit product data sheet/manual for each product and major component specified.

B. Submit Shop Drawings for each component.

C. Submit hardware and software design plans, for approval by the Engineer.

D. Submit wiring diagrams, for approval by the Engineer.

E. Submit the Function Assignment Sheets, for approval by the Engineer.

F. Submit the Code Function Assignment Sheets, for approval by the Engineer.

G. Submit Product Certification: Signed by manufacturer of equipment certifying that products comply with the Contract Document requirements.

H. Submit test plans and procedures, for approval by the Engineer.

I. Submit test reports, for approval by the Engineer.

J. Submit reliability and performance reports, for approval by the Engineer.

K. Submit maintenance data for materials and products, and parts list which shall be included in Operating and Maintenance Manual.

L. Submit As-built Drawings and As-Configured data and documentation, for approval by the Engineer.

M. The Contractor's design drawings shall be sealed by a Professional Engineer registered in the State of Pennsylvania.

1.05 DEFINITIONS

A. Assignment: A combination of territories, code channels, and code lines that are initialized and controlled by a specific position.

B. Code Channel: A code channel is the physical connection to any device. It carries the data for one or more code lines for the code system interface.

C. Code Function Assignment: Provides the necessary information to do the code system tabling. The devices listed on the Code Function Assignment Sheets shall match those on the Function Assignment Sheets.

D. Code Line: A code line is a logical connection. It is used to process I/O over a code channel to the field device. A code line allows one or more code stations to communicate with the office.

E. Code Station: An addressable location from a code line, which is used to interface the office to the field devices. The code station is used to maintain a list of control and indication slots. A list of code stations is maintained by a code line.

F. Control: Represents data that is sent from the central control center to the wayside location, typically for the purpose of requesting an action for the field device.

G. Control Point: A device that typically represents a railroad or transit station, but may be defined as any system or subsystem that owns and controls a group of devices.

H. Function Assignment: The picture of what a location should look like when drawn using the System Configuration Tool. The Function Assignment Sheet also identifies all of the various devices for a location.

I. Indication: Represents data that is received from the wayside location to the central control center, typically for the purpose of reporting a status of a field device.

J. Position: Defines a job description for an operator including the default territory assignments for the position.

K. Route: A list of switches that must be lined (and required positions) and signal lamps that must be cleared, to get from one signal lamp (the entrance) through another signal lamp (the exit) up to the next forward signal lamp.

L. Station: A Station is used to maintain information about a single node on the code line. Included in this information is the node address, and state data that is used to process the interaction between the OCC System and the field unit.

M. Task: An instance of a program being executed by the operating system. Also known as a process.

N. Territory: Describes the owner of control points. A territory is the smallest assignable group of dispatcher-controlled points.

1.06 PERFORMANCE REQUIREMENTS

A. The work performed on the OCC System by the Contractor to upgrade the OCC System shall not result in the OCC System having lower reliability compared to the existing OCC System.
   1. The Contractor shall estimate and document the end-to-end reliability of both the existing and new connections between field Remote Terminal Units (RTUs) and the OCC System servers using the reliability models provided in MIL-STD-217 with approval by the Engineer. The estimated average reliability of the new connections shall not be lower than the estimated average reliability of existing connections.
   2. The Contractor shall estimate and document the reliability of both the existing and upgraded OCC System servers using the reliability models provided in MIL-STD-217 with approval by the Engineer. The estimated reliability of the upgraded OCC System server shall not be lower than the estimated reliability of the existing OCC System server.
   3. The Contractor shall estimate and document the end-to-end reliability of both the existing and new voice circuits, that support Pubic Address (PA), Radio, Telephone, and Emergency Telephone functions, and which terminate on the Penta PCx Voice Matrix Switch using the reliability models provided in MIL-STD-217 with approval by the Engineer. The estimated average reliability of the new voice circuits shall not be lower than the estimated average reliability of existing voice circuits.
   4. The Contractor shall estimate and document the reliability of both the existing and upgraded Penta PCx Voice Matrix Switch using the reliability models provided in MIL-STD-217 with approval by the Engineer. The estimated reliability of the upgraded Penta PCx Voice Matrix Switch shall not be lower than the estimated reliability of the existing Penta PCx Voice Matrix Switch.

B. The work performed on the OCC System by the Contractor to upgrade the OCC System shall not result in the OCC System having lower performance (e.g., longer reporting indication times, slower response times, slower command execution times) compared to the existing OCC System.

1. The Contractor shall document the existing OCC System performance with approval by the Engineer, prior to making any modifications to the OCC System configuration. During testing, the Contractor shall demonstrate to the Engineer that the upgraded OCC System has not degraded the performance of the OCC System.

1.07 OCC SYSTEM TRAIN CONTROL AND SCADA REQUIREMENTS

A. This Section provides a description of the existing hardware and software components of the OCC System that support train to wayside communications (TWC), train signaling, and SCADA monitoring and control functions. The existing OCC System was designed and installed by Union Switch & Signal Inc., (US&S). The base US&S control system software was used as the foundation for the OCC System. This Section also includes those requirements related to the hardware and software upgrade of the OCC System to support the NSC.

B. The existing OCC System hardware consists of consoles, servers, projection overview display subsystem equipment, Ethernet Network equipment, and Communications subsystem equipment. Refer to Drawing CC0010 in the Hardware Detailed Design Drawings for the Stage II Light Rail Transit System as part of Contract LRS-98-05-R that is included in the "also" plans for the NSC-009, for a general overview of the existing OCC.

C. Consoles
   1. The upgraded OCC System shall not require any new consoles to support the NSC. Control and monitoring of trains and SCADA input/output shall be from the existing consoles.

D. The existing OCC System consists of the following types of servers.
   1. System Servers
   2. Communications Servers
   3. Training Server
   4. Relational Database Servers
   5. Overview Server

E. The existing OCC System was designed to have enough spare capacity to support the NSC. Therefore the servers listed above in ARTICLE 1.07D should be capable of supporting the additional processing and storage requirements associated with the NSC. However, the Contractor shall analyze the existing server capacity to determine whether enough capacity is available to support the NSC at the time of execution of the OCC System upgrade. If additional capacity is required to support the NSC, the Contractor shall design, install, and configure the additional server hardware to support the NSC.

F. Projection overview display subsystem
   1. The existing overview display subsystem contains all of the necessary components to support the overview display. The existing overview display is a series of screens which are capable of displaying train control diagrams, SCADA diagrams and CCTV images.
   2. The existing overview display system hardware consists of an overview server, rear projectors and projection screens.
   3. All new graphics associated with the NSC (e.g., NSC track alignment) shall be designed by the Contractor such that it can fit on the existing overview display screens. Additional overview display screens shall not be required to support the NSC.

G. Ethernet network
   1. The existing OCC System supports a redundant, or dual rail, Ethernet network. Each OCC System computer and many of the network attached peripherals are attached to both networks.
      a. The upgraded OCC System shall not require any additional Ethernet switches to support the NSC.

H. Communications subsystem
   1. The existing communications subsystem is the point of concentration for all external interfaces which are directly managed by OCC System software. The existing communications subsystem configuration consists of two (2) communications servers, two (2) sets of terminal servers and one (1) set of modem splitters. The terminal servers are used in conjunction with the modem splitters to provide redundant paths, over the two OCC System Ethernet networks, to each of the external (serial) interfaces. One set of terminal servers is attached to one of the OCC System Ethernet networks. The other set of terminal servers is attached to the other OCC System Ethernet network.
   2. The upgraded OCC System shall support additional serial connections to connect the OCC System to the new TWC, train signaling, and SCADA field units deployed along the NSC.
   3. The Contractor shall determine whether the number of spare ports on the existing Terminal Servers, the number of spare modem splitters, the number of spare modems, and the number of spare ports on existing distribution frames available at the time of execution of the OCC System upgrade are sufficient to support all the additional serial connections. If not, then the Contractor shall design, install, and configure the new additional Terminal Servers, modem splitters, modems, distribution frames and wiring to support the additional serial connections. If new Terminal Servers are required, then the Contractor shall design, install, and configure the new Ethernet connections required between the new Terminal Servers and the spare ports on existing Ethernet switches that are part of the OCC System dual rail Ethernet network.

I. The existing OCC System software architecture consists of a set of inter-operating processes called tasks. Each task performs one or more of the functions of the system.

Tasks inter-operate by exchanging messages on the message bus, and need not be running on the same computer system provided that such separate computers are connected by a network.

1. The existing OCC System software processes (tasks) utilize the data stored within the system configuration database in performing their various functions. System configuration database files are generated by the System Configuration Tool (SCT) and contain static data regarding the configuration of certain aspects of the system (e.g., track configurations, graphic display descriptions). For example, to add a new channel that should be managed by an existing interface task, the new channel must be added to the assignment definitions, associated with the interface task, stored in the system configuration database.
2. The SCT permits the off-line modifications of the configuration database files via a graphical user interface. The SCT provides the ability to configure certain aspects of the OCC System without the need to make source code modifications. The tool is intended to be used by system maintenance personnel throughout the life of the OCC System. The Contractor shall use the SCT to make most of the necessary changes to the system configuration database files to perform the upgrade to the OCC System. Other tools that can be used to modify configurable data are; Form – a form based user interface, Flat File – files modified and created through the use of a commercial text editor, and Xdesigner – a COTS tool used to define layouts of user interface forms.
3. The Contractor shall be responsible for ensuring that he/she are adequately trained, to the satisfaction of the Engineer, to make modifications to the OCC System using the custom US&S software configuration tools described above. Satisfactory training shall be considered the receipt of a formal training certificate from US&S confirming the completion of the necessary training courses, or proof of successful usage of these tools on past projects for other transit agencies.
4. The following external interface tasks are supported on the existing OCC System to interface with TWC, train signaling, and SCADA field units:
    a. H&K (Hanning & Kahl) TWC Interface Task – responsible for retrieving indications from the H&K HCS-R Unit.
    b. US&S Microlok Genisys Protocol Interface Task – responsible for retrieving indications from the US&S Microlok II units and transmitting controls to the US&S Microlok II units for delivery to the field.
    c. GE Fanuc Series 90 PLC Remote Terminal Unit Interface Task – responsible for retrieving indications from the GE Fanuc Series 90 PLC or GE Fanuc Versamax Micro Units and transmitting controls to the GE Fanuc Series 90 PLC or GE Fanuc Versamax Micro Units for delivery to the field.

J. The OCC System shall be upgraded to allow the Authority operators from the existing consoles at the OCC to monitor and control the following subsystems along the NSC:
1. TWC - including train location, train identification, and routes
2. Train Signaling including the strobe lights
3. SCADA
    a. Tunnel Ventilation

b. Traction Power
c. Ticket Vending Machine Alarms
d. Station Communications Alarms

K. The Authority operators shall be able to issue individual controls and view indications associated with new devices deployed along the NSC that are part of the subsystems listed above in exactly the same way as the OCC System controls and monitors existing devices.

L. In addition to operations available from the existing consoles, the existing OCC System provides large screen system-wide graphic overview displays that can be viewed by the Authority operators. These overview displays shall be upgraded to represent the expanded track diagram to show the rail alignment along the NSC in a semi-geographical orientation, showing train locations and SCADA and Signal System device conditions.
1. No additional rear projectors or overview display screens shall be installed to support the NSC.
2. The rail alignment along the NSC shall be displayed on the existing overview display screens.
3. Contract Drawing CM-104 illustrates the layout of existing overview display screens.
4. The existing overview graphics display selector provides the capability to select any of the graphics diagrams available from the OCC software system and display them on the overview display. The Contractor shall ensure that any new NSC graphics diagrams added to the OCC System as part of this contract are capable of being selected and displayed on the overview display.

M. The upgraded OCC System shall utilize new instances of the following existing external interface tasks to support data exchange between the OCC System and new field devices supported on the NSC.
1. H&K TWC Interface Task
2. US&S Microlok Genisys Protocol Interface Task
3. GE Fanuc RTU Interface Task

N. H&K TWC Interface Task
1. The NSC track alignment will be equipped with Hanning & Kahl Communication System Route Equipment (Hanning & Kahl Communication System Type-R (HCS-R)) to provide train-to-wayside communications (TWC). It will be designed to provide the OCC System with train identification, location, and route information.
   a. The HCS-R Units are part of the Signal System and specified in Section 13570.
   b. See Contract Drawings CM011, CM012, and CM013 for number of TWC HCS-R Units required along the NSC.
2. The OCC System shall be upgraded to interface with each HCS-R Unit deployed along the NSC.

3. New instances of the existing H&K TWC Interface tasks running on the existing communications servers shall be used to support the communications between the OCC System and HCS-R units deployed along the NSC. No modifications to the core system software shall be required to interface the OCC System to the new NSC HCS-R Units. Only configuration database changes (e.g., creation of new instances of the H&K TWC Interface task, creation of new code channels, code lines, code stations, control/indication slots and bits) shall be required.
4. The existing H&K TWC Interface task supports external communications with the HCS-R Unit using the H&K Train-to-Wayside Communications (TWC) protocol. This protocol and relevant HCS-R Unit behavior are defined in the following vendor documentation, which will be provided to the Contractor after award of contract:
   a. Hanning & Kahl Technical Proposal, Port Authority of Allegheny County (PAAC) Train-to-Wayside Communication (TWC): Hanning & Kahl Communication System (HCS-R), Revision 0.4, 3/18/2002
5. The new H&K TWC Interface code channels and code lines that allow the OCC System to communicate with HCS-R Units along the NSC shall be configured to operate and function as the existing H&K TWC Interface code channels and code lines.
   a. The Contractor shall update the configuration database files to ensure that the configuration parameters (e.g., primary and secondary code channels, codelines, polling cycles, station addresses, message time-outs) associated with the new H&K TWC Interface code channels and code lines are consistent with the existing H&K Interface code channels and code lines.
   b. The Contractor shall be provided the configuration details of the existing code channels and code lines after award of contract.

O. US&S Microlok Genisys Protocol Interface Task
1. The NSC Signal System will be equipped with US&S Microlok II units.
   a. The US&S Microlok II units are part of the Signal System and specified in Section 13570.
   b. See Contract Drawings CM012, CM013, and CM014 for number of Signaling US&S Microlok II units required along the NSC.
2. The OCC System shall be upgraded to interface with each US&S Microlok II Unit deployed along the NSC.
3. New instances of the existing US&S Genisys Interface tasks running on the existing communications servers shall be used to support the communications between the OCC System and new US&S Microlok II Units deployed along the NSC. No modifications to the core system software shall be required to interface the OCC System to the new NSC Signaling System equipment. Only configuration database changes (e.g., creation of new instances of the US&S Genisys Interface task, creation of new code channels, code lines, code stations, control/indication slots and bits) shall be required.
4. The existing US&S Genisys Interface task supports external communications with the US&S Microlok II units using the US&S Genisys protocol.

a. The US&S Genisys protocol is described in Union Switch & Signal service manual 6300A, Genisys Non-Vital Logic Emulator and Microlok Plus Vital + Non-Vital Control Package (Non-Vital Section), which will be provided to the Contractor after award of contract.

5. The new US&S Microlok Genisys Protocol Interface code channels and code lines that allow the OCCS to communicate with US&S Microlok II units along the NSC shall be configured to operate and function as the existing US&S Microlok Genisys Protocol Interface code channels and code lines.
   a. The Contractor shall update the configuration database files to ensure that the configuration parameters (e.g., primary and secondary code channels, codelines, polling cycles, station addresses, message time-outs) associated with the new US&S Microlok Genisys Protocol Interface code channels and code lines are consistent with the existing US&S Microlok Genisys Protocol Interface code channels and code lines.
   b. The Contractor shall be provided the configuration details of the existing code channels and code lines after award of contract.

P. GE Fanuc RTU Interface Task
1. The SCADA System used to monitor and control Tunnel Ventilation, Traction Power, Ticket Vending Machine Alarms, and Station Communications Alarms will be equipped with GE Fanuc Versamax Micro Units.
   a. The GE Fanuc Versamax Micro Units are part of the SCADA System and are specified in Section 16742.
   b. See Contract Drawings CM011, CM012, and CM013 for number of GE Fanuc Versamax Micro Units (SCADA Remote Terminal Units (RTU)) required along the NSC.
2. The OCC System shall be upgraded to interface with each GE Fanuc Versamax Micro Unit deployed along the NSC.
3. New instances of the existing GE Fanuc RTU Interface tasks running on the existing communications servers shall be used to support the communications between the OCC System and GE Fanuc Versamax Micro Units deployed along the NSC for all SCADA subsystems. The tunnel ventilation subsystem, for redundancy purposes, requires a separate GE Fanuc RTU interface task for each RTU. No modifications to the core system software shall be required to interface to new GE Fanuc Versamax Micro Units. Only configuration database changes (e.g., creation of new instances of the GE Fanuc RTU Interface task, creation of new code channels, code lines, code stations, control/indication slots and bits) shall be required.
4. The existing and new GE Fanuc RTU interface tasks shall support external communications with the GE Fanuc Series VersaMax Micro Units using the GE Remote Terminal Unit (RTU) protocol.
   a. The RTU protocol is described in the GE Fanuc Automation Series 90 PLC Serial Communications User's Manual, GFK-0582D, November 2000, which will be provided to the Contractor after award of contract.

5. The new GE Fanuc RTU Interface code channels and code lines that allow the OCC System to communicate with GE Fanuc Versamax Micro Units along the NSC shall be configured to operate and function as the existing GE Fanuc RTU Interface code channels and code lines.
   a. The Contractor shall update the configuration database files to ensure that the configuration parameters (e.g., primary and secondary code channels, code lines, polling cycles, station addresses, message time-outs) associated with the new GE Fanuc RTU Interface code channels and code lines are consistent with the existing GE Fanuc RTU Interface code channels and code lines in both redundant and non-redundant scenarios.
   b. The Contractor shall be provided the configuration details of the existing code channels and code lines after award of contract.

Q. Monitoring and Control of Strobe Lights
   1. The existing OCC System does not support monitoring or control of strobe lights. The NSC strobe lights deployed along the NSC, which are part of the Signal System and specified in Section 13570, shall be controlled from the US&S Microlok II units.
   2. The following control and monitoring functions of the strobe light subsystem deployed along the NSC shall be provided:
      a. The OCC System console display shall be updated to represent the strobe lights and strobe light zones along the NSC, showing strobe light conditions. The graphical icons representing the strobe lights shall be located on the display such that their position along the track alignment graphic corresponds to their position in the field.
      b. The specific design of the graphical icon shall be submitted by the Contractor for approval.
      c. An authorized user at an OCC System console shall be capable of turning on and off strobe lights within a strobe light zone via the consoles graphical user interface. The OCC System shall receive an indication that contactor is open or closed.
      d. The graphical representation of the strobe light shall be color driven. Green shall indicate operational, and red not operational.

R. The existing OCC System has the capability of displaying alarms generated from field devices, alarms associated with code channels, and alarms associated with code lines, on the console screens.
   1. The upgraded OCC System shall be capable of displaying on the console screens the same alarm types as the existing OCC System, associated with new field devices, new instances of interface tasks, new code channels, and new code lines.
   2. The alarms associated with new field devices, new instances of interface tasks, new code channels, and new code lines, shall be displayed on the console screens in the exact same way as the existing OCC System displays these types of alarms.

1.08 VOICE COMMUNICATIONS SYSTEM REQUIREMENTS

A. This Section provides a description of the existing hardware and software components of the VCS. This Section also includes those requirements related to the hardware and software upgrade of the VCS to support the NSC.

B. The existing VCS is a Penta Corporation PCx Communications Control System. All radio, telephone, and public address channels are managed by this subsystem.

C. The existing VCS hardware consists of a Penta PCx Voice Matrix Switch and two (2) redundant Penta Master Computers.
   1. The Penta Master Computers are connected to the OCCS Ethernet network to communicate with the OCC software system to receive user status and territory assignment information.
   2. The Penta PCx Voice Matrix Switch supports three (3) audio connections and a serial connection to each console.
   3. The Penta PCx Voice Matrix Switch supports a serial connection to each Penta Master Computer.
   4. The Penta PCx Voice Matrix Switch supports audio connections to the existing CTS and existing PABX to interface to all voice circuits.
   5. The Penta PCx Voice Matrix Switch is a non-blocking switch that can control up to 512 lines and consoles.

D. The existing VCS software components consist of a Penta Corporation PCx Communications Control System Graphical User Interface (GUI), a PCx Master Computer Edit application, and the OCCS software system Penta PCx Interface task.
   1. The Penta Corporation PCx Communications Control System GUI is used to provide a graphical user interface for all console based radio, telephone and public address communications.
   2. The PCx system contains a Master Computer Edit application which is used to configure the system for operation.
   3. The Penta PCx Interface task is responsible for the interface between the OCCS and the Penta Corporation PCx Communications Control System.

E. The existing VCS shall be upgraded to allow Authority operators from the existing consoles at the OCC to access and control new voice circuits, which are associated with telephones, emergency telephones, the public address system, and the radio system deployed along the NSC, via the existing Penta Corporation PCx VCS GUI.

F. The following systems will be upgraded to support new voice circuits to support NSC communications:
   1. Telephone system (including Emergency Telephones) – see Section 16721 and 16724 for further details.
   2. Radio system – see Section 16700 for further details.
   3. VMS/PA system – see Section 16741 for further details.

G. VCS to NSC CTS Interface

1. Interfaces supporting PA circuits
   a. The Contractor shall design and install 2 or 4-wire audio circuits between the existing Penta PCx Voice Matrix Switch and NSC CTS in support of the new PA circuits for "live" announcements to the NSC stations. Refer to Drawing CM044 for the number of new audio circuits required to be terminated on the VCS to transmit "live" PA announcements.
2. Interfaces supporting Radio circuits
   a. Receive audio from the new base stations located at Allegheny Station will be voted at the existing radio system voter/comparator equipment, which is part of the Radio System and specified within Section 16700. The voted audio is transmitted to the existing Penta PCx Voice Matrix Switch via existing audio circuits. New audio circuits shall not be required between the existing Penta PCx Voice Matrix Switch and the radio system voter/comparator equipment.
   b. The Contractor shall design and install new 4-wire audio circuits between the existing Penta PCx Voice Matrix Switch and the NSC CTS to support the transmit audio from the existing Penta PCx Voice Matrix Switch to the new base stations located at Allegheny Station. DTMF tones shall be used to support signaling between the existing Penta PCx VCS and the new base stations. Refer to Drawing CM044 for the number of new audio circuits required to be terminated on the VCS to support the transmit audio to the new base stations.

H. VCS to New PABX Interface

1. The existing interface supports fifteen (15) analog trunk circuits interconnecting the VCS to the existing PABX, where 6 of the 15 analog trunk circuits are allocated solely for emergency telephone calls and the remaining 9 analog trunk circuits are hunt group. The existing PABX at the OCC will be replaced (see Section 16721) with a new redundant head-end PABX. The Contractor shall terminate the existing fifteen (15) analog trunk circuits on the new PABX.
2. The determination of whether the existing fifteen (15) analog trunk circuits between the Penta PCx Voice Matrix Switch and the new PABX is capable of supporting the additional telephone circuits supported along the NSC shall be the responsibility of the Contractor. If the Contractor determines that additional trunk capacity is required, then the Contractor shall design and install the new analog trunk circuits between the Penta PCx Voice Matrix Switch and the new PABX.

I. VCS to OCC System Interface

1. The existing OCC System supports the following external interfaces to support data and audio exchange between the OCC System and the Penta VCS.
   a. Penta PCx Interface Task
   b. Caller ID Task
   c. Console to VCS Interface
2. Penta PCx Interface Task
   a. The existing Penta PCx Interface Task extends the OCC System logon/logoff implementation to the Penta PCx VCS by translating internal OCC System

logon/logoff-related events into relevant PCx command messages. The command messages are used to set appropriate permissions to allow a given Console the ability to access specific Penta PCx capabilities. Permissions are granted to a Console during a user logon in the form of an associated Penta PCx logon with access to one or more of the 32 communication circuit groups supported by the Penta PCx. The current permissions are reflected in the Penta PCx GUI window that is permanently open on a Console. This effectively extends the OCC System logon security implementation to the Penta PCx GUI.

b. The Contractor shall assign new NSC voice circuits to one or more of the 32 Penta PCx communications circuit groups using the Penta PCx Master Computer Edit application.

c. Within the existing OCC System, users logon to a given Console with a desired user title which is implemented as a Position definition. Each Position definition may be assigned one or more Territory definitions. Each Territory definition may include an access definition to one or more Penta PCx communication circuit groups.

d. The Contractor shall structure Position and Territory definitions to allow the appropriate operators access to the NSC voice circuits. The Territory definition that includes the NSC stations shall include an access definition that includes at least those Penta PCx communication circuit groups associated with the NSC voice circuits.

3. Caller ID Task

a. The Caller ID Task within the OCC System receives the caller ID information from the Whozz Calling 4/8 Caller ID device, manufactured by Zeus Phonstuff, that taps into the analog trunk circuits, allocated to emergency calls, between the VCS and PABX and connects to the Penta Master Computers via a serial connection. The Penta Master Computers pass the received Caller ID data to the OCC System Caller ID Task via the OCC System Ethernet network. The Caller ID Task is responsible for interpreting the received caller ID information and highlighting the associated telephone icon on the track diagram. The existing 6 analog trunk circuits are sufficient to support the additional emergency telephones along the NSC and as a result additional Caller ID devices are not required.

b. The Contractor shall add the new emergency telephone icons that graphically depict new NSC emergency telephones onto the track diagram.

c. The Contractor shall update the OCC System configuration database files to associate Caller ID data to each new NSC emergency telephone.

4. Console to VCS Interface

a. There are three (3) existing audio connections and one (1) existing serial connection to each of the consoles. The three (3) audio connections are for receive, transmit and monitor. The serial connection is used for certain control functions.

b. Update of this interface to support the NSC is not required.

J. An existing semi-custom Windows-based GUI is integrated into the OCC System console to provide authorized Authority personnel with the ability to monitor and access the various circuits managed by the Penta PCx VCS.
   1. The same controls available to the user for existing circuits managed by the VCS shall also be available for all new circuits managed by the upgraded VCS and associated with the NSC.

K. Existing Radio controls include:
   1. Connect
      a. The user shall be able to connect to a NSC radio circuit by clicking on the electronic cell representing the NSC radio circuit.
   2. Transmit
      a. The user shall be able to transmit over a connected NSC radio circuit by activating the Push To Talk (PTT) functions and speaking into an available audio device. The PTT function can be activated via the PTT status bar or via one of the PTT hardware switches.
   3. Instant Transmit
      a. The user shall be able to transmit over a NSC radio circuit without connecting to the circuit. This operation is known as instant transmit.
   4. Monitor
      a. The user shall be able to monitor one or more NSC radio circuits.
   5. Mute
      a. The user shall be able to mute monitored NSC radio circuits.
   6. Patch
      a. The user shall be able to create a conference consisting of one or more NSC radio circuits. The user shall be able to include the local workstation's radio in the conference as well.
   7. Supervisory Control
      a. An authorized user shall be able to take control of a NSC radio circuit in use by another user.
   8. Supervisory Monitor
      a. An authorized user shall be able to monitor a NSC radio circuit in use by another user.
   9. Test Tone
      a. The user shall be able to generate a 1000 Hz tone over a given NSC radio circuit.

L. Existing Telephone controls include:
   1. Selecting a NSC telephone circuit
      a. The user shall be able to select a NSC telephone circuit from the frequently dialed phone circuit area of the main VCS form.
   2. Incoming Call List
      a. If an electronic cell has been associated with the NSC telephone circuit of an incoming call, the display characteristics of the cell shall reflect the circuit's call status.

M. Existing PA controls include:
   1. Station Select
      a. The VCS GUI shall be upgraded to allow the user to select one or more NSC stations for the purpose of issuing a free form PA announcement. The user shall be able to select the station(s) from an electronic cell or from a list.
   2. Monitor Volume
      a. The VCS GUI shall support a Volume Unit (VU) indicator representing a tone level for a given NSC circuit. VU indicators shall only be provided for PA circuits.

N. The VCS GUI shall be upgraded to include electronic cells representing NSC circuits and functions.
   1. Electronic cells shall be used to represent NSC radio, telephone, and PA circuits.
   2. Electronic cells representing NSC circuits shall provide circuit identification and status information. This function is available for existing electronic cells.
   3. Electronic cells representing NSC circuits shall provide circuit connect and disconnect functions. This function is available for existing electronic cells.
   4. Electronic cells shall be used to activate, de-activate, and navigate to other VCS functions. This function is available for existing electronic cells.
   5. If there are more electronic cells than can be displayed at any given time, the GUI shall support a mechanism by which the user can view multiple pages of cells. This function is available for existing electronic cells.

O. The existing OCC System has the capability of displaying alarms generated by the Penta PCx Voice Matrix Switch line cards, on the console screens.
   1. The upgraded OCC System shall be capable of displaying on the console screens the same alarm types as the existing OCC System, associated with any new line cards that the Contractor must install as part of this contract.
   2. The alarms associated with new Penta PCx Voice Matrix Switch line cards shall be displayed on the console screens in the exact same way as the existing OCC System displays these types of alarms.

1.09 PABX

A. The existing PABX located at the OCC is a Lucent (Avaya) Definity Prologic PABX.

B. The existing PABX shall be replaced with a new redundant headend PABX at the OCC to support the termination of the new telephone circuits associated with the NSC. See Sections 16721 and 16724 for further details on the types of telephones, number of circuits, and the new PABX.

1.10 CCTV VIDEO MANAGEMENT SYSTEM REQUIREMENTS

A. This Section provides a description of the existing hardware and software components of the CCTV Video Management System. This Section also includes those requirements related to the hardware and software upgrade of the CCTV Video Management System to support the NSC.

B. The existing CCTV Video Management System hardware consists of a Pelco System Video Matrix Switch, Video Multiplexers, Distribution Amplifiers, Digital Video Recorders, and CCTV server.
   1. The existing Video Matrix Switch at the OCC provides an interface to four video feeds from the Pitt Tower facility. These four existing video feeds interconnect the Video Matrix Switch at the OCC to the Video Matrix Switch at the Pitt Tower facility. An existing serial data connection between the existing Video Matrix Switches at the OCC and the Pitt Tower facility allow the Authority operators at the OCC to select a particular camera video feed that is terminated on the Video Matrix Switch at the Pitt Tower facility to be switched and transmitted to the OCC via one of the four video feeds that interconnect the two Video Matrix Switches.
   2. The OCC System shall have access to video feeds from the seven (7) new NSC CCTV cameras that are connected to the existing Video Matrix Switch at the Pitt Tower facility via the existing four video feeds. See Section 16750 for further details on the particular NSC CCTV cameras that are to be connected to the Pitt Tower Video Matrix Switch. No additional video feeds shall be required to be terminated on the existing Pelco Video Matrix Switch to support the NSC.
   3. The Authority operators shall have the ability to select a particular camera video feed, from any of the seven (7) new NSC CCTV cameras discussed above, to be transmitted to the OCC via the four existing video feeds that interconnect the two Video Matrix Switches.

C. The existing CCTV Video Management System software components consist of Cameleon's Commercial-Off-The-Shelf (COTS) client/server based software package and the OCC System software system Pelco Interface task.
   1. The Cameleon software package enables users to control certain cameras and map camera displays to local workstation monitors as well as overview displays. The Cameleon software package is based on a client/server software architecture. The client software resides on the consoles while the server software resides on the CCTV server.
   2. The Pelco Interface task is responsible for the interface between the OCC System and the Pelco System Video Matrix Switch.

D. The OCC System shall be upgraded to allow Authority operators from the existing consoles at the OCC to view video from new CCTV cameras deployed along the NSC.

E. The existing OCC System supports the display of CCTV camera images on the console and overview display using the existing Cameleon software package. The existing OCC System is provided four video feeds from the Pitt Tower facility. Additionally, there are cameras located at the Rail Operations Building. The existing OCC System can not control the existing Pitt tower cameras, but are able to control any existing Pan Tilt Zoom (PTZ) equipped cameras located at the Rail Operations Building.

1. The new NSC cameras, specified in Section 16750, will be connected to the Pitt Tower facility. The OCC System operator shall not be able to control any PTZ equipped cameras deployed along the NSC.

F. The existing OCC System supports the following external interfaces to support data and video exchange between the OCC System and CCTV Video Management System.
   1. Pelco Interface Task
   2. Console to VMS Interface
      a. One (1) existing composite video connection
      b. One (1) existing serial data connection (via CCTV server – console communicates with CCTV server over OCC Ethernet network)
      c. Update of this interface to support the NSC is not required.

G. Pelco Interface Task
   1. The existing Pelco Interface Task allows the existing OCC System to provide periodic time/date directives to the Pelco System 9760 Video Matrix Switch using the PEL protocol's Set Time and Date command message.
   2. Update of this interface task to support the NSC is not required.

H. CCTV Video Management System Display
   1. The existing CCTV Video Management System display is provided by the Cameleon Software. Cameleon provides the OCC System console a graphical interface to the Pelco Video Matrix Switch.
   2. The Contractor shall upgrade the CCTV Video Management System display such that each of the seven (7) new NSC cameras connected to the existing Video Matrix Switch at the Pitt Tower facility is displayed as an icon on the Cameleon map. The map and icons are configurable.
      a. The existing Cameleon softare allows more than one Pelco map to be configured, where the particular maps available to a user are based on the login id. The user can dynamically select the map to be viewed provided the user is authorized to view the selected map.
      b. The Contractor shall upgrade the CCTV Video Management System display software to ensure that authorized operators are allowed to view those maps showing the seven (7) new NSC cameras based on their login id.
   3. The existing Cameleon software provides the capability for a console user to select a CCTV image to be displayed on the console. The Contractor shall ensure that this capability is available for the seven (7) new NSC cameras connected to the existing Video Matrix Switch at the Pitt Tower facility.
   4. The existing Cameleon software provides the capability to display a selected CCTV image on the overview display wall. The Contractor shall ensure that this capability is available for the seven (7) new NSC cameras connected to the existing Video Matrix Switch at the Pitt Tower facility.

I. The existing OCC System has the capability of displaying alarms generated by CCTV cameras, on the console screens.
   1. The upgraded OCC System shall be capable of displaying on the console screens the same alarm types as the existing OCC System, associated with the seven (7) new NSC CCTV cameras connected to the existing Video Matrix Switch at the Pitt Tower facility.
   2. The alarms associated with these new cameras shall be displayed on the console screens in the exact same way as the existing OCC System displays these types of alarms.

1.11 VARIABLE MESSAGE SIGN (VMS)/PA SERVER REQUIREMENTS

A. This Section provides a description of the existing hardware and software components of the VMS/PA Server and Workstations located at the OCC. This Section also includes those requirements related to the hardware and software upgrade of the VMS/PA Server and Workstations to support the NSC.

B. The VMS/PA Server is the central point of the VMS/PA System, and allows the user to download recorded announcements to the VMS/PA station controllers at each station and control variable message signs via the VMS/PA station controllers at each station.

C. The VMS/PA Workstations connect to the VMS/PA server via an Ethernet network. New VMS/PA Workstations and servers are not required to support the NSC.

D. The existing VMS/PA Server supports an Ethernet interface to connect to the existing CTS Ethernet Switch. Recorded announcements and data to control variable message signs are transmitted to the appropriate VMS/PA station controllers via this Ethernet interface.
   1. The existing Ethernet interface shall be used to connect to the new VMS/PA station controllers deployed at the new NSC stations. The new VMS/PA station controllers are specified in Section 16741.
   2. The Contractor shall update the VMS/PA Server configuration (e.g., program the new IP/Ethernet addresses associated with the new VMS/PA station controllers) to allow the VMS/PA server located at the OCC to communicate to the new station controllers at the NSC stations.

ARTICLE 2 PRODUCTS

2.01 WIRE AND CABLE

A. Telephone Cable
   1. See Section 16702 "Copper Outside Plant" for specifications.

B. Data Cable, Extended Distance
   1. See Section 16742 "SCADA System" for specifications.

2.02 TERMINAL SERVERS

A. The Contractor shall utilize any spare ports available on the existing Terminal Servers to implement the OCC System upgrade. Based on the existing design for interconnecting the OCC System to the existing CTS, each physical RS-232C connection from the NSC CTS shall be split via a passive modem splitter to create two RS-232C connections that are terminated on different Terminal Servers for redundancy.
   1. Refer to Drawing CM-102 for the general connectivity design of OCC System and NSC CTS.
   2. Refer to Drawings CC321 thru CC328, CC330 thru CC333, CC340 thru CC345, and CC350 thru CC356 in the Hardware Detailed Design Drawings for the Stage II Light Rail Transit System as part of Contract LRS-98-05-R that are included in the "also" plans for the NSC-009 for the detailed wiring of existing circuits associated with code system interfaces to TWC, Signal, and SCADA field units. The Contractor shall utilize the wiring concept illustrated in these drawings to connect the OCC to the NSC CTS to support the new code system interfaces to TWC, Signal, and SCADA field units along the NSC.

B. The Contractor shall verify the number of spare ports on existing Terminal Servers during the OCC Site Survey. If the number of spare ports on existing Terminal Servers is not adequate to meet the requirements within this Section for the OCCS upgrade at the time of system installation, then the Contractor shall design, install and configure new Terminal Servers in primary/backup pairs to meet the physical connection requirements.

C. Terminal Servers shall be Lantronix EDS32PR 32 port Terminal Server, or approved equal.

D. The Contractor shall use the included Windows-based DeviceInstaller™ to manage the configuration of terminal servers.

2.03 MODEM SPLITTERS

A. The Contractor shall utilize any spare modem splitters to implement the OCC System upgrade. Based on the existing design for interconnecting the OCC System to the existing CTS, each physical RS-232C connection from the NSC CTS shall be split via a passive modem splitter to create two RS-232C connections that are terminated on different Terminal Servers for redundancy.
   1. Refer to OCC System Contract Drawing CM-102 for connectivity design of OCC System and NSC CTS.
   2. Refer to Drawings CC321 thru CC328, CC330 thru CC333, CC340 thru CC345, and CC350 thru CC356 in the Hardware Detailed Design Drawings for the Stage II Light Rail Transit System as part of Contract LRS-98-05-R that are included in the "also" plans for the NSC-009 for the detailed wiring of existing circuits associated with code system interfaces to TWC, Signal, and SCADA field units.

The Contractor shall utilize the wiring concept illustrated in these drawings to connect the OCC to the NSC CTS to support the new code system interfaces to TWC, Signal, and SCADA field units along the NSC.

B. The Contractor shall verify the number of spare modem splitters during the OCC Site Survey. If the number of spare modem splitters is not adequate to meet the requirements within this Section for the OCC System Upgrade at the time of system installation, then the Contractor shall install new modem splitters to meet the physical connection requirements.

C. Modem Splitters shall be BB Electronics Model 232MDS, or approved equal.

2.04 MODEMS

A. The Contractor shall utilize any spare modems to implement the OCC System upgrade. Based on the existing design for interconnecting the OCC System to the existing CTS, the RS-232C connections associated with the SCADA (including ventilation, traction power, station communications) TWC, and Train Signaling systems shall be connected to the NSC CTS via a modem.
   1. Refer to OCC System Contract Drawing CM-102 for connectivity design of OCC System and NSC CTS.
   2. Refer to Drawings CC321 thru CC328, CC330 thru CC333, CC340 thru CC345, and CC350 thru CC356 in the Hardware Detailed Design Drawings for the Stage II Light Rail Transit System as part of Contract LRS-98-05-R that are included in the "also" plans for the NSC-009 for the detailed wiring of existing circuits associated with code system interfaces to TWC, Signal, and SCADA field units. The Contractor shall utilize the wiring concept illustrated in these drawings to connect the OCC to the NSC CTS to support the new code system interfaces to TWC, Signal, and SCADA field units along the NSC.

B. The Contractor shall verify the number of spare modems during the OCC Site Survey. If the number of spare modems is not adequate to meet the requirements within this Section for the OCC System upgrade at the time of system installation, then the Contractor shall install new modems to meet the physical connection requirements.

C. Modems shall be Telenetics DSP9612RM Flash Poll Modem, or approved equal.

2.05 DISTRIBUTION FRAMES

A. The Contractor shall utilize any spare ports available on the existing Distribution Frames to implement the OCC System upgrade. Based on the existing design for interconnecting the OCC System to the existing CTS, Distribution Frames shall be used to provide terminations for wiring between the OCC System modems or modem splitters and the NSC CTS Channel Banks.
   1. Refer to Drawings CC321 thru CC328, CC330 thru CC333, CC340 thru CC345, and CC350 thru CC356 in the Hardware Detailed Design Drawings for the Stage

II Light Rail Transit System as part of Contract LRS-98-05-R that are included in the "also" plans for the NSC-009 for the detailed wiring of existing circuits associated with code system interfaces to TWC, Signal, and SCADA field units. The Contractor shall utilize the wiring concept illustrated in these drawings to connect the OCC to the NSC CTS to support the new code system interfaces to TWC, Signal, and SCADA field units along the NSC.

B. The Contractor shall verify the number of spare ports on existing Distribution Frames during the OCC Site Survey. If the number of spare ports on existing Distribution Frames is not adequate to meet the requirements within this Section for the OCC System upgrade at the time of system installation, then the Contractor shall design, install and configure new Distribution Frames to meet the physical connection requirements.

C. Distribution Frames shall be Avaya 1100GS3-24 24-port RJ45 to 110 Connector Block and Avaya 2500CAT5PS-24 24-port RJ45 to 25 Pair Connector Block, or approved equals.

2.06 PENTA PCX VOICE MATRIX LINE CARDS

A. The Contractor shall utilize spare ports on the Penta PCx Voice Matrix Switch to terminate the additional voice circuits associated with the NSC in support of the telephone, public address, and radio systems.

B. The Contractor shall verify the spare capacity on the existing Penta PCx Voice Matrix Switch during the OCC Site Survey. If the number of spare ports on existing line cards of the Penta PCx Voice Matrix Switch is not adequate to meet the requirements within this Section for the OCC System upgrade at the time of system installation, then the Contractor shall design, install and configure new line cards to meet the NSC voice circuit termination requirements.

C. Refer to Drawings CC330 thru CC333, and CC360 thru CC367 in the Hardware Detailed Design Drawings for the Stage II Light Rail Transit System as part of Contract LRS-98-05-R that are included in the "also" plans for the NSC-009 for the detailed wiring of existing voice circuits terminating on the Penta PCx Voice Matrix Switch. The Contractor shall utilize the wiring concept illustrated in these drawings to connect the OCC to the NSC CTS to support the new voice circuits along the NSC.

2.07 PABX

A. A new head-end redundant PABX with its own dedicated UPS will be installed at the OCC. See Sections 16721 and 16724 for further details on the PABX.

ARTICLE 3 EXECUTION

3.01 GENERAL

A. Contractor shall provide all equipment, hardware, accessories, terminations, cabinets, conduits, raceways, cable trays, and cables required for the installation of the OCC System upgrade.

B. Contractor shall install all system equipment in accordance with all Contract requirements, approved Shop Drawings and consistent with standard industry practices.

C. Equipment and material to be furnished and installed shall be approved prior to installation.

D. Contractor shall perform all work required to install the equipment, and for the installation of wire and cable.

E. Contractor shall submit detail and layout Shop Drawings of all equipment to be installed, prior to installation, for approval. Contractor shall install all equipment to provide easy accessibility for maintenance and testing, unless otherwise approved in writing.

F. All console and overview diagrams shall be presented to and approved by the Engineer.

G. Contractor shall provide all new mounting and fastening materials for equipment to be installed in the final layout. The exact location of equipment will be approved in the field by the Engineer and shall be in accordance with approved Shop Drawings.

H. Grounding and power shall be in accordance with the manufacturers' recommendations and the requirements of Section 16700, "Communications".

I. Contractor shall comply with testing requirements specified in Section 16901, "Communication System Inspection and Test", including:
   1. General Communications Testing
   2. Communications Cable Testing
   3. Communications Equipment and Subsystem Testing
   4. Factory, Pre-Installation, and Final Acceptance Testing

J. Installation of equipment, wire and cable, configuration of hardware, software and database files, and testing shall not interfere with the Authority's revenue operations and shall be coordinated with the Engineer prior to start.
   1. Uploading system configuration data that changes the existing operational configuration and testing of the re-configured system data shall be performed during the periods between 1AM and 4AM, leaving an hour to re-establish the system to its original configuration prior to beginning revenue operations at 5AM.

3.02 INTERCONNECTION OF OCCS WITH NSC CTS

A. The Contractor shall install the wire/cable and all necessary equipment to interconnect the OCC System with the NSC CTS based upon the interconnection design illustrated in OCC System Contract Drawing CM-102 and the approved connectivity and wiring diagrams/schedules submitted by the Contractor.
   1. Refer to Drawings CC0208 and CC0209 in the Hardware Detailed Design Drawings for the Stage II Light Rail Transit System as part of Contract LRS-98-05-R that are included in the "also" plans for the NSC-009 for the existing detailed wiring between the existing Terminal Servers and the OCC System Ethernet Switches.
   2. Refer to Drawings CC330 thru CC333, CC340 thru CC345, and CC350 thru CC356 in the Hardware Detailed Design Drawings for the Stage II Light Rail Transit System as part of Contract LRS-98-05-R that are included in the "also" plans for the NSC-009 for the detailed wiring of existing circuits associated with code system interfaces to TWC, Signal, and SCADA field units. The Contractor shall update these drawings and provide any additional drawings as necessary to document the detailed wiring of circuits associated with code system interfaces to TWC, Signal, and SCADA field units along the NSC.
   3. The Contractor shall utilize available spare equipment and ports to implement the OCC System upgrade.
      a. The Contractor shall perform a survey of the OCC to determine the number of spare equipment available to be used for the NSC after award of contract and at the time of installation. If the spare equipment is not adequate to support the NSC, then the Contractor shall be responsible for specifying, procuring, installing, and testing all new equipment required to support the NSC.

B. All wiring shall be installed as per the wire/cable installation requirements in Section 16700 "Communications".

C. New Terminal Servers, Modem Splitters, Modems, and Distribution Frames if required to be installed to support the OCC System upgrade requirements, shall be installed as per the equipment/subsystem installation requirements in Section 16700 "Communications".

D. The Contractor shall download the existing configuration file (ASCII) using the Windows-based DeviceInstaller™ to configure the additional ports on the existing Lantronix EDS32PR 32 port Terminal Servers that are necessary to support the new interfaces to NSC field equipment.

E. If the Contractor installs new Terminal Servers, then the Contractor shall configure the Lantronix EDS32PR 32 port Terminal Servers using the Windows-based DeviceInstaller™. Configuration information includes IP address, TCP connection, and port information to support the new interfaces to NSC field equipment.

F. If the Contractor installs new Terminal Servers, then the Contractor shall provision the IP address on the Ethernet Port of the Lantronix EDS43PR 32 port Terminal Server. The IP address shall follow the current IP address scheme used within the OCCS.

G. The Contractor shall verify proper installation during Site Acceptance Testing to ensure that the equipment has been properly installed and connected. Equipment will also be checked to ensure that it is of the appropriate model, and tagged and labeled correctly.

H. The Contractor will verify the installation of new and relocated equipment and cables to ensure adherence to the manufacturer's specifications, contract documents, engineering drawings, and local codes.

I. Testing will not interfere with the Authority's revenue operations and shall be coordinated with the Engineer prior to start.

3.03 INTERCONNECTION OF VCS WITH NSC CTS AND PABX

A. Refer to Drawing CM044 for the number of new audio circuits required to be terminated on the Penta PCx, interconnecting the Penta PCx to the NSC CTS, to support the NSC PA and radio systems.

B. The number of new analog trunk circuits required to be terminated on the Penta PCx, interconnecting the Penta PCx to the new PABX, to support the NSC telephone system must be determined by the Contractor.

C. Refer to Drawings CC330 thru CC333, and CC360 thru CC367 in the Hardware Detailed Design Drawings for the Stage II Light Rail Transit System as part of Contract LRS-98-05-R that are included in the "also" plans for the NSC-009 for the detailed wiring of existing voice circuits terminated on the Penta PCx Voice Matrix Switch. The Contractor shall update these drawings and provide any additional drawings as necessary to document the detailed wiring and termination of new voice circuits on the Penta PCx Voice Matrix Switch to support the NSC.

D. The Contractor shall utilize spare equipment and ports to terminate new voice circuits associated with the NSC in support of telephone, public address, and radio systems on the Penta PCx Voice Matrix Switch.

1. The Contractor shall perform a survey of the OCC to determine the spare capacity on the Penta PCx Voice Matrix Switch available to be used for the NSC after award of contract and at the time of installation. If the spare capacity is not adequate to support the NSC, then the Contractor shall be responsible for specifying, procuring, installing, and testing all new equipment required to support the NSC. For example, the Contractor shall determine whether the existing Penta PCx supports enough spare ports on existing line cards, whether new line cards must be added, and/or whether the system must be expanded to support the termination of new audio and trunk circuits in support of the NSC.

E. The Contractor shall perform all necessary work to terminate the required number of audio and trunk circuits to support the NSC on the Penta PCx.

F. The Contractor shall install the wire/cable to interconnect the Penta PCx with the NSC CTS and the new PABX based upon the interconnection design illustrated in Contract Drawings CM044 and CM051 and the approved connectivity and wiring diagrams/schedules submitted by the Contractor.

G. All wiring shall be installed as per the wire/cable installation requirements in Section 16700 "Communications".

H. The Contractor shall verify proper installation during Site Acceptance Testing to ensure that the equipment has been properly installed and connected. Equipment will also be checked to ensure that it is of the appropriate model, and tagged and labeled correctly.

I. The Contractor will verify the installation of new and relocated equipment and cables to ensure adherence to the manufacturer's specifications, contract documents, engineering drawings, and local codes.

J. Testing will not interfere with the Authority's revenue operations and shall be coordinated with the Engineer prior to start.

K. The existing Penta PCx is currently being updated to support the required signaling functions for interfacing with the existing radio system. These functions include the ability to select/disable the channel guard function, transmit function, repeat function, and a lockout function required to disable the Talk-Around base station when a LRT base station is transmitting on the same channel and vise-versa. This work is being performed by the existing Stage II LRT-006 Contractor. These functions are also required for interfacing with the new radio base stations at the Allegheny Station. The Contractor shall ensure that once the Penta PCx has been successfully updated by the LRT-006 Contractor that the interface between the Penta PCx and the new base stations at the Allegheny Station supports the same functions as the existing interfaces.

L. The Contractor shall perform updates to the Penta PCx from the System Administration console.
   1. The following maintenance functions can be performed from the System Administration console:
      a. Add, delete, and update the master electronic phone directory.
      b. Define radio and telephone circuits.
      c. Define call-in priorities.
      d. Perform system diagnostics.
      e. Distribute configuration changes.

3.04 UPDATE TRACK DIAGRAM

A. The specific layout of the overview specific Track Diagram shall be defined by the Contractor during the design phase of the project, submitted as part of the Function Assignment Sheet submittal, and shall be subject to approval by the Engineer. An overview of the existing layout of the overview display is provided in Contract Drawing CM-104.

B. The existing overview display will need to be modified to create space for the NSC portion of the track diagram. The Contractor shall modify the layout of the existing overview display using the existing Christie Digital Wall Manager software which provides the ability to move and/or resize the windows on the overview display.
   1. A potential solution to create space on the existing overview display that shall be considered by the Contractor is to reassign the top left screen, which is currently assigned to display a CCTV camera image, to display the NSC portion of the updated track diagram.

C. The Contractor shall update the OCC System configuration databases to make the necessary updates to the track diagram graphical display on both the consoles and the overview displays.

D. The updated track diagram shall represent the rail alignment along the NSC in a semi-geographical orientation, showing train locations and SCADA and Signal System device conditions.

E. The Contractor shall update the OCC System configuration databases to display and configure the new track sections, switches, signals, and other devices based upon the approved Function Assignment Sheets submitted by the Contractor.

F. The US&S System Configuration Tool (SCT) shall be used to perform the necessary updates.
   1. The SCT is a software tool that allows users to graphically and textually produce a functional layout of train control and SCADA systems.
   2. A summary of the SCT capabilities is shown below:
      a. Graphical layout of the following displays:
         1) Track Diagram
         2) System Summary
         3) Ventilation Displays
         4) Traction Power Displays
         5) Overview Displays
         6) Standard Table Displays
      b. Assignment of address and bits to devices (bit tabling)
      c. Creation of a device instance from predefined device types
      d. Creation of a graphical representation of a device
      e. Definition of locations (stations)
      f. Tabling of route priorities and preferred routes

g. Definition of static graphics "text" and other symbols
h. Creation of User Titles
i. Assignment of default territories
j. Territory creation
k. Definition of Fan Sequences
l. Definition of Light Rail Vehicle Ids
m. Definition of Alarms/Log Messages
n. Report of Alarm Configuration

G. Graphics colors are not configurable via the SCT. Graphics colors shall be configured via the X Windows Resource File method.

3.05 UPDATE OTHER DISPLAYS

A. Other displays to be updated:
1. System Summary Display
   a. The existing System Summary display provides an overview of all device subsystems at all locations on a single page and enables the user to view a collection of summary indicators and key indications for each location. A summary indicator is configurable and can summarize any number of indications. Each summary indicator represents a device subsystem at the location.
   b. The Contractor shall update the System Summary display to support the display of any new summary indicators associated with the NSC using the SCT. The new summary indicators shall be defined by the Contractor and approved by the Engineer.
2. Central Business District (CBD) Ventilation Display
   a. The existing CBD Ventilation Display provides a display that enables the user to monitor and control the ventilation devices for the CBD area.
   b. The existing display depicts the tunnel area, including zone boundaries and tunnel ventilation fans for the Gateway, Wood Street, Penn Park and Steel Plaza areas. In addition, the existing display depicts the status of the tracks and signals in the tunnel area, and shows the current location and identification of any vehicles that are on the track. Depending on the declutter level setting, the display may also show Traction power devices.
   c. The Contractor shall submit a design for updating the CBD ventilation display to show the tunnel area, zone boundaries, and tunnel ventilation fans for the NSC area, for approval by the Engineer. See Contract Drawings MC-400 and MC-401 for a preliminary assignment of ventilation zones.
   d. The display shall be updated using the SCT to show the tunnel area, zone boundaries, and tunnel ventilation fans for the NSC area as approved by the Engineer. In addition the display shall be updated to show the status of tracks and signals along the NSC tunnel area.
3. Traction Power Schematic Display

a. The existing OCC System supports a separate Traction Power Schematic display for each existing substation. The existing display shows a graphical representation of the traction power circuitry at the substation.
b. The existing display allows the user to monitor and control the traction power devices from this display.
c. The Contractor shall submit a design for the new Traction Power Schematic Displays for each new substation along the NSC for approval by the Engineer.
d. The OCC System shall be upgraded using the SCT to support new Traction Power Schematic Displays for each new substation along the NSC as approved by the Engineer. The new Traction Power Schematic Displays shall show a graphical representation of the traction power circuitry at the substation and enable the user to monitor and control the traction power devices from this display.

4. Standard Table Display
   a. The existing OCC System supports a separate Standard Table display for each location and subsystem. The existing Standard Table display provides a table oriented display that enables the user to monitor all status points and issue controls for a specific SCADA subsystem at a specific location.
   b. The Contractor shall submit a design for the new Standard Table Displays for each SCADA subsystem at each new NSC station for approval by the Engineer.
   c. The OCC System shall be upgrade using the SCT to support new Standard Table Displays for each SCADA subsystem at each new NSC station as approved by the Engineer. The new Standard Table Displays shall enable the user to monitor all status points and issue controls for the SCADA subsystem at the new NSC stations.

3.06 CODE SYSTEM INTERFACES TO NEW FIELD DEVICES

A. New field devices along the NSC shall be accommodated by modifying the OCC System configuration databases and tables through the utilization of the existing configuration tools.

B. The Contractor shall update the system configuration databases to configure the new code system interfaces (i.e., code channels, code lines, code stations) necessary to interface the OCC System with the NSC field devices.

C. The Contractor shall update the system configuration databases to configure the control and indication slots within each code station, and the control and indication bits within each slot. The configuration shall be based upon the approved Code Function Assignment Sheets submitted by the Contractor.

D. The existing US&S SCT Tool shall be used to perform the necessary updates.

E. The upgraded OCC System shall be capable of monitoring and controlling the ventilation system in the NSC tunnel. The Contractor shall configure a separate GE RTU Interface task for each ventilation system RTU. This helps isolate software failures induced by communicating to field units not related to tunnel ventilation and is consistent with the existing system configuration.

F. Ventilation Systems deployed within NSC tunnels, as existing Ventilation Systems, will be installed with redundant GE Fanuc VersaMax Micro PLCs in an active/standby pair to administer the same set of field controls and indications.
   1. Each unit will have an associated GE RTU Interface task.
   2. The Contractor shall configure the additional parameters in the OCC System configuration database to account for the active/standby status of the GE Fanuc VersaMax Micro PLCs.
   3. The Contractor shall utilize the same configuration method that is used for the existing Ventilation Systems and specified in the existing OCC System software documents.
   4. The Contractor shall be provided the existing OCC System software documents after award of contract.

G. The OCC System provides the capability to control ventilation devices either individually, or in pre-programmed sequences. The Contractor shall program sequences for control of new ventilation devices deployed along the NSC.
   1. The Contractor shall submit a proposed set of sequences for the control of new ventilation devices, for approval by the Engineer. Contract Drawings MC-402, MC-403, and MC-404 list a preliminary set of ventilation sequences, referred to as ventilation modes on the Contract Drawings. Each sequence identifies the specific tunnel ventilation fans to be operated, their direction of operation and flow rates.
   2. The system shall be initially configured with a set of sequences approved by the Engineer.
   3. The OCC System SCT shall be used by the Contractor to configure the fan sequences.

3.07 TESTING UPDATED DATABASES AND CODE SYSTEM INTERFACES

A. Testing shall not interfere with the Authority revenue operations and shall be coordinated with the Engineer prior to start.

B. The updated OCC System shall be tested through System Integration Testing, Performance Testing and Site Acceptance Testing to validate that the updated system meets the requirements within this specification.

C. The Contractor shall submit a Test Program Plan that shall follow ANSI/IEEE Std. 829-1998 for approval by the Engineer.

1. The testing covered by this Plan shall encompasses all hardware, software, user functions (controls), responses from field equipment (indications), error conditions, alarms, redundancy, and communication with external interfaces.

D. The Contractor shall submit Test Procedures, a document providing detailed instructions for the execution of one or more test cases, for approval by the Engineer.

E. After completion of each Testing Stage, the Contractor shall submit Test Records, which is a record of the test specification, and actual outcome for each test.

F. In testing external interfaces, the Contractor shall perform tests where each control and indication bit is sent/received to ensure that the bits are correctly mapped to their corresponding devices and to insure that every bit in the Code Function Assignment data sheets is correctly mapped in the OCC System.

G. In testing external interfaces, the Contractor shall perform tests where each control and indication condition is functionally tested and all the various operating and alarm sequences are executed. These tests shall verify that each individual control and indication bit operates properly and the far end device reacts accordingly.

H. External interface tests conducted within the Site Acceptance Testing phase shall be end-to-end, i.e., from the OCC workstation screen through the remote terminal units to the actual field devices for controls and from the actual field devices through the remote terminal units to the OCC workstation screens for the indications. If any alarms, indication bits or other abnormal status indication bits cannot be generated by the normal running field device, then the test engineer shall force the bit indications at the demarcation terminal block so that they may be verified at the OCC.

I. Functional testing shall be for 100% of system functions and points and shall be performed from the OCC System.

J. Pre-installation tests shall be performed using external simulators.

K. Post-installation tests shall be performed using actual field devices (e.g., TWC units, RTU/PLCs).

L. The Contractor must ensure that the original equipment configuration can be reverted to if necessary.

M. The existing OCC System makes use of the various system operation accounts that are used to run copies of the OCC System in various operational modes.
   1. One of the system operation accounts is the **occint** account, which hosts an integration test environment. This environment is used to test new software versions and database configurations. System functionality is, for the most part, identical to the production environment. However, certain interfaces may be simulated. When using this account, the OCC System functionality can be limited to what is required to perform the targeted testing.

N. The Contractor shall use the **occint** account to configure and test the upgraded OCC System. The **occint** account shall be configured to only have access to those terminal server ports allocated for communications to NSC field devices. Utilizing the **occint** account allows the Contractor to configure and test the updated system without polluting the live operational system since new data is added to a separate database file.

O. The Contractor shall also use the existing Training Console, which is a full functional workstation, to perform updates and testing of the OCC System.

3.08 UPDATE DISPLAY AND CONFIGURATION OF VOICE COMMUNICATION SYSTEM

A. The Contractor shall submit a plan for supporting the appropriate user logon permissions for access to NSC voice circuits. The plan shall include proposed assignments of new NSC voice circuits to Penta PCx communication circuit groups, new OCC System position and territory definitions that include an access definition to one or more Penta PCx communication circuit groups.

B. The Contractor shall update the Penta PCx configuration data and the OCC System configuration data to implement the plan for supporting the appropriate user logon permissions, as approved by the Engineer.

C. Penta provides a set of configuration tools that enable a user to edit the configuration data required for the PCx. The Contractor shall utilize these configuration tools to make the necessary Penta system configuration updates.

D. The Contractor shall submit a plan for updating the VCS console display to show all new electronic cells that represent NSC circuits and functions as specified in ARTICLE 1.08 of this Section, for approval by the Engineer.

E. The Contractor shall implement the plan for updating the VCS console display, as approved by the Engineer, by updating the configuration of the Penta system.

F. After updating the VCS, the Contractor shall test the updated system to ensure that all user logon permissions are functioning correctly and all required functions are operating correctly for the new electronic cells.
   1. Contractor shall submit a test plan, test procedures, and test records as part of executing the testing of the updated VCS.

3.09 UPDATE CCTV DISPLAY ON OCCS CONSOLE

A. The Contractor shall submit a plan for updating the CCTV Video Management System display on the OCC System console, for approval by the Engineer. The plan shall address the need or not for new maps to depict the seven (7) new NSC cameras that are connected to the existing Video Matrix Switch at the Pitt Tower facility. Any access control capabilities for allowing new maps to be available to particular users based on the login ID shall also be addressed in the plan.

B. The Contractor shall implement the plan for updating the CCTV Video Management System display, as approved by the Engineer.

C. After updating the CCTV Video Management System display, the Contractor shall test the updated system to ensure that the correct video stream is displayed when the user selects each of the new icons on the display representing the seven (7) new NSC cameras, and that any access control configurations have been successfully implemented.
   1. Contractor shall submit a test plan, test procedures, and test records as part of executing the testing of the updated CCTV Video Management System.

3.10 IP ADDRESSING

A. The Contractor shall ensure that any new IP network interfaces required to be installed as part of the OCC System upgrade conform to the existing IP addressing scheme used for the OCCS.

B. The Contractor shall be provided with the existing IP addressing scheme after award of contract.

3.11 OCC SYSTEM STAGING

A. The OCC System shall be staged to match the construction sequencing and subsequent operation at the conclusion of each stage. Each stage of the OCC System, defined herein, shall be placed into service to match the actual conditions at the time of the cutover.
   1. All testing, including pre-testing of the OCC System shall be performed at and for each stage as defined herein.
   2. Advanced work and testing for subsequent stages may be incorporated in prior stages, however, the implementation of the required stage shall not be delayed by such work, and the operation of the OCC System shall not be adversely affected in anyway, as a result of the advanced staging work.

B. As subsequent stages are brought into service, any functions or graphics provided in previous stages that are no longer required shall be removed from the OCC System via modifications to the configuration database files.

C. The NSC will be constructed and put into operation during Stage 2 of the two-stage sequence. Stage 1 installs a new turn back at the existing Wood Street Station, and removes the existing Gateway Station and existing Loop from operation. Construction of the NSC will proceed while train service utilizes Wood Street Station for turn-back. After completion of construction of the NSC the entire NSC will be put into operation during Stage 2.

D. Stage 1 – Wood Street Turn Back
   1. During this stage the existing loop will no longer be available and a new double crossover at Wood Street will be utilized to perform turn back operations.
   2. The OCC System shall be updated with new routes and new controls/indications for existing or new Wood Street signals.
   3. Track diagram and console displays shall be modified to remove non-functioning devices along the existing loop, ignore indications from non-functioning devices along the existing loop, depict the new double cross-over and any new signals at Wood Street.
   4. Existing fans in the existing loop shall be disconnected, except for fans EM-9 and EM-10, which will both remain in service. EM-9 and EM-10 are the fans located between Wood Street and Gateway stations.

E. Stage 2 – Final Stage
   1. Track diagram shall be modified to depict entire NSC rail alignment, new TWC, Signaling, and SCADA devices.
   2. OCC System shall be updated with new routes.
   3. OCC System shall be updated to interface to
      a. new HCS-R Units provided by the Signal System during this stage
      b. new US&S Microlok II Units provided by the Signal System during this stage
      c. new GE Fanuc Versamax Micro Units provided by the SCADA and Communications Systems during this stage
      d. new voice circuits provided by the Communications Systems during this stage
   4. OCC System shall be updated to display video from the seven (7) new cameras at the new Gateway, North Side Connector and Allegheny Stations that are connected to the existing Video Matrix Switch at the Pitt Tower facility.
   5. The OCC System shall be purged of all elements and functionality associated with systems and devices that are not part of the Final system configuration.

ARTICLE 4 MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Item 16950.001 – OCC Site Survey Work including documentation of existing hardware and system configuration and documentation of reliability and performance of existing systems shall be measured as a lump sum unit, complete in place.

B. Item 16950.002 – Upgrade of the OCC System, including design work, installation of circuits to connect existing spare equipment/ports, software configuration modifications, training, and testing, as described in this Section, during each stage to eventually support the final system configuration of the NSC shall be measured as a lump sum unit, complete in place. This item does not include the design, procurement, installation, and testing of additional hardware necessary to support the upgrade of the OCC System, which is addressed in Item 16950.006.

C. Item 16950.003 – Upgrade of the VCS, including design work, installation of circuits to connect existing spare equipment/ports, software configuration modifications, training, and testing, as described in this Section, during each stage to eventually support the final system configuration of the NSC shall be measured as a lump sum unit, complete in place. This item does not include the design, procurement, installation, and testing of additional hardware necessary to support the upgrade of the VCS, which is addressed in Item 16950.006.

D. Item 16950.004 – Upgrade of the CCTV Video Management System, including design work, software configuration modifications, training, and testing, as described in this Section, during each stage to eventually support the final system configuration of the NSC shall be measured as a lump sum unit, complete in place. This item does not include the design, procurement, installation, and testing of additional hardware necessary to support the upgrade of the CCTV Video Management System, which is addressed in Item 16950.006.

E. Item 16950.005 – Upgrade of the VMS/PA System, including design work, software configuration modifications, training, and testing, as described in this Section, during each stage to eventually support the final system configuration of the NSC shall be measured as a lump sum unit, complete in place. This item does not include the design, procurement, installation, and testing of additional hardware necessary to support the upgrade of the VMS/PA System, which is addressed in Item 16950.006.

F. Item 16950.006 – Design, Procurement, Installation, and Testing of Additional Hardware and Necessary Hardware Upgrades to OCCS Servers to support the upgrade of the OCC System and VCS shall be measured as directed by the Engineer.

4.02 PAYMENT

A. Item 16950.001 – OCC Site Survey Work including documentation of existing hardware and system configuration and documentation of reliability and performance of existing systems will be paid at the lump sum price and shall include the cost of all related work specified in this Section.

B. Item 16950.002 – Upgrade of the OCC System, including design work, installation of circuits to connect existing spare equipment/ports, software configuration modifications, training, and testing, as described in this Section, during each stage to eventually support the final system configuration of the NSC will be paid at the lump sum price and shall include the cost of all related work specified in this Section. This item does not include the design, procurement, installation, and testing of additional hardware necessary to support the upgrade of the OCC System, which is addressed in Item 16950.006.

C. Item 16950.003 – Upgrade of the VCS, including design work, installation of circuits to connect existing spare equipment/ports, software configuration modifications, training, and testing, as described in this Section, during each stage to eventually support the final system configuration of the NSC will be paid at the lump sum price and shall include the cost of all related work specified in this Section. This item does not include the design, procurement, installation, and testing of additional hardware necessary to support the upgrade of the VCS, which is addressed in Item 16950.006.

D. Item 16950.004 – Upgrade of the CCTV Video Management System, including design work, software configuration modifications, training, and testing, as described in this Section, during each stage to eventually support the final system configuration of the NSC will be paid at the lump sum price and shall include the cost of all related work specified in this Section. This item does not include the design, procurement, installation, and testing of additional hardware necessary to support the upgrade of the CCTV Video Management System, which is addressed in Item 16950.006.

E. Item 16950.005 – Upgrade of the VMS/PA System, including design work, software configuration modifications, training, and testing, as described in this Section, during each stage to eventually support the final system configuration of the NSC will be paid at the lump sum price and shall include the cost of all related work specified in this Section. This item does not include the design, procurement, installation, and testing of additional hardware necessary to support the upgrade of the VMS/PA System, which is addressed in Item 16950.006.

F. Item 16950.006 – Design, Procurement, Installation, and Testing of Additional Hardware and Necessary Hardware Upgrades to OCC System Servers to support the upgrade of the OCC System and VCS will be paid at the Predetermined Amount (PDA), and shall include the cost of all materials, equipment, service fees, and system maintenance contract fees.
   1. Payment shall be based on actual paid invoices for the purchase price of the hardware from the Supplier, as approved by the Engineer. Any hardware provided for any other purpose shall not be paid for by Authority.
   2. No Contractor markup, overhead or profit will be paid for the purchase of hardware.
   3. The following shall be submitted to the Engineer as applicable for each item for this portion of the Work:
      a. Supplier invoices with details breakdown of materials and costs.
      b. Certified proof of payment to Supplier by Contractor.

END OF SECTION