SECTION 23 52 33 - WATER-TUBE BOILERS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Packaged water-tube boilers.

1.02 REFERENCE STANDARDS

A. ASME BPVC - Boiler and Pressure Vessel Code; 2015.

B. ASME BPVC-VIII-1 - Boiler and Pressure Vessel Code, Section VIII, Division 1 - Rules for Construction of Pressure Vessels; 2015.

C. ASME CSD-1 - Controls and Safety Devices for Automatically Fired Boilers; 2021.

D. ASTM A106/A106M - Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service; 2015.

E. NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum); 2014.

F. NFPA 31 - Standard for the Installation of Oil Burning Equipment; 2016.

G. NFPA 54 - National Fuel Gas Code; 2015.

H. NFPA 70 - National Electrical Code; Most Recent Edition Adopted by Authority Having Jurisdiction, Including All Applicable Amendments and Supplements.

I. UL 726 - Oil-Fired Boiler Assemblies; Current Edition, Including All Revisions.

1.03 WORK INCLUDED

A. Provide a complete shop assembled packaged watertube boiler capable of firing natural gas and fuel oil and generating at least 80,000 lbs/hr of 125 psig saturated steam, each including the following:
   1. Boiler
   2. Boiler Accessories
   3. Controls
   4. Economizer
   5. Breeching
   6. Expansion Joints
   7. Piping
   8. Burner
   9. Burner Management System
   10. Combustion Air Fan
   11. Flue Gas Recirculation (FGR)
   12. Air Ducts and Draft Control
   13. Stack
   14. Structural Steel

B. Provide all labor, materials, equipment, etc. to design, fabricate, and deliver the equipment to perform as specified herein.

C. Provide shipment and insurance of the equipment Freight on Board (FOB) the Owner's facility located in Knoxville, Tennessee.

1.04 SUBMITTALS

A. Delivery schedule for all equipment and materials, including shop drawings for approval in number of days from date of contract award. Shop drawings shall be adequate for final design of structural, electrical, and mechanical systems. Shop drawings shall include those indicated herein, as well as foundation drawings, arrangement drawings, system schematics, electrical schematics, P&ID drawings and control interface drawings for connection to the existing plant control system.

B. Shop Drawings: Full shop drawing package shall be submitted within 4 weeks of the purchase order execution date. The drawings shall include the following:
   1. General arrangement plan and elevation drawings.
   2. Piping and Instrumentation Drawings (P&ID's) of all systems.
   3. Complete narrative description of the system components and operation.
   4. Forces, weights, and foundation loading drawings for foundation design.
   5. Dimensioned skid and equipment drawings with mounting details. Drawings shall indicate the size and locations of all mechanical and electrical connections as well as all required clearances. Include installation documents that indicate the lifted weights of component sections or pieces and the dimensions of the components or pieces to ensure openings into the space are adequate.
   6. All load and setting plans with structural support requirements
   7. Static and dynamic allowable loads for all piping and nozzles.
   8. Compressed air requirements
   9. Electrical power requirements
   10. Minimum and maximum natural gas supply pressure required.
   11. Minimum and maximum acceptable natural gas supply temperature.
   12. Minimum and maximum fuel oil supply pressure reqruied.
   13. Emissions and process guarantees
   14. A description of the proposed BMS control system including specific vendor hardware, software and network(s) proposed for use in project.
   15. Water trim components.
   16. Steam trim components.
   17. Natural gas and No.2 fuel oil train components.
   18. Wiring Diagrams: Detailed wiring for power and control connections. Differentiate between factory-installed and field-installed wiring, piping, valves, ductwork, and trim.
   19. Control panels, Programmable Logic Controllers, and associated feed water control, burner management, and combustion control logic.
   20. Allowable moments and forces for all piping connections.
   21. Access platforms, grating, ladders, and handrails.
   22. All instrumentation, trim, and valves.
   23. SAMA logic and descriptions for all boiler control functions. Logic must detail normal operating logic, interlock requirements between loops, failure modes such as loss of a measured variable signal and interlocks between the combustion controls and burner management. Required measurement ranges for variables necessary for control functions must be

provided. Limiting operating conditions or limits for trim functions such as oxygen trim shall be noted. Overall logic shall include the following at a minimum.

a. Fully metered cross-limited fuel/Air control loops for combustion control and boiler master.
b. Oxygen trim control.
c. Three (3) element feedwater control with single element selection.
d. Flue gas recirculation (FGR) damper control.

24. Bill of materials and manufacturer's data sheets, performance data, and specifications for all purchased components.
25. An electronic version of general arrangement plan and elevation drawings and Piping and Instrumentation Diagrams (PID) in AutoCad two dimensional format.
26. A three-dimensional model (3D) model of the system in AutoCad 3D format AND in Revit format.

C. Erection procedure for the boiler.

D. Project Schedule with delivery milestones from notice to proceed through delivery to the site.

E. Equipment size, configuration, total weight, and weight of individual components. Include general description of the style of the boiler proposed and materials of construction.

F. A list of any field welds that require ASME/ANSI boiler boundary code certification.

G. Location, name, address, company contact and phone number of the nearest factory authorized representative with trained personnel capable of providing engineering, start-up and commissioning support, in addition to parts and routine service.

H. The following shall be submitted for review prior to shipment:
1. A certificate of insurance which provides evidence of coverage for the contract value of the equipment and components during shipment from the Manufacturer's facility to the Owner's site.
2. Six (6) paper copies of operating and maintenance manuals compiled into 8.5" x 11" three (3) ring binders and a digital copy which, as a minimum, shall include the following:
   a. Written operating and maintenance procedures.
   b. Maintenance schedule
   c. Detailed list and product data sheets of all purchased components and parts.
   d. Field Wiring Diagrams
   e. Contact information for field service, parts, and factory service.
   f. Spare parts list for all wearing surfaces and component
   g. parts.
   h. Certified drawings of boilers, plus drawings of all other components on 11" x 17" sheets
3. All ASME documentation
4. An electronic version of all certified drawings in AutoCAD and PDF format.

5. An electronic version of the operating and maintenance manuals in searchable PDF format.
6. An electronic version of the results from all testing performed at the Manufacturer's facility in PDF format.
7. The final version of the 3D model of the system in AutoCad 3D format AND in Revit format.

I. Piping and instrumentation drawings with all terminal points clearly defined and items included in bidder's scope of work and supplied by the bidder clearly delineated.

J. Provide complete list of items that are furnished in package with the Manufacturer identified and listed for each item. Clearly indicate items shipped loosely that are to be installed by the installation contractor.

K. Provide the boiler's expected performance at varying firing rates for both natural gas and No. 2 fuel oil. At a minimum, these firing rates shall be 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20% and minimum fire. At a minimum, the submitted boiler's expected performance shall include the following:
   1. Gross output, MMBtu/h
   2. Fuel input (hhv), MMBtu/h
   3. Steam output at non-return valve
   4. Drum Operating Pressure (PSIG)
   5. Steam temperature (degrees F)
   6. Steam quality, ppm and %
   7. Operating pressure (PSIG) at non-return valve outlet
   8. Excess Air (%)
   9. Flue gas recirculation (%) (if required)
   10. Furnace exit temperature (degrees F)
   11. Flue gas temperature leaving boiler (degrees F)
   12. Surface blowdown (%)
   13. Gas flowrate leaving boiler (ACFM and lb/hr)
   14. Gas flowrate thru flue gas recirculation (ACFM and lb/hr) (if required)
   15. Gas flowrate leaving the stack (ACFM and lb/hr)
   16. CO2 emitted (PPM and lb/mmbtu)
   17. CO emitted (PPM and lb/mmbtu)
   18. NOx emitted (PPM and lb/mmbtu)
   19. O2 emitted (%)
   20. SO2 emitted (PPM and lb/mmbtu)
   21. VOC emmited (PPM and lb/mmbtu)
   22. Excess air
   23. Furnace pressure (in/WC)
   24. Draft loss total (in/WC)
   25. Forced draft fan static required (in/WC) (include boiler and assumptions for stack and breeching)
   26. Heat Losses (MMBtu/H)
   27. Radiation and Convection Losses (%)
   28. Total Losses (%)
   29. Combustion Efficiency (%)
   30. Thermal Efficiency (%)

L. Provide the recommended start up and testing procedure through full operating range.

M. Provide a detailed list of exceptions, alterations, or deviations from this specification section.

N. Manufacturer's Inspection Report: Submit authorized boiler inspection prior to shipment.

O. Manufacturer's Field Reports: Indicate that specified performance and efficiency has been met or exceeded; at minimum provide report of the following combustion tests: boiler firing rate, over fire draft, gas flow rate, heat input, burner manifold gas pressure, percent carbon monoxide (CO), percent oxygen (O), percent excess air, flue gas temperature at outlet, ambient temperature, net stack temperature, percent stack loss, percent combustion efficiency, and heat output.

P. ASME "A" Stamp Certification and Report: Submit "A" stamp certificate of authorization as required by authorities having jurisdiction, and document hydrostatic testing of piping external to boiler.

Q. The following shall be submitted for review and approval prior to start-up and commissioning.
   1. Boil-out Procedure - Provide a minimum of two (2) weeks prior to the scheduled boil out. Boiler manufacturer shall provide a boiler-out procedure, which shall included written step by step instructions for:
      a. Filling the boiler with water
      b. Chemical addition (type and concentration)
      c. Time/pressure steps
      d. Cool down
      e. Rinse out
   2. Startup Reports – Provide a minimum of three (3) weeks prior to start-up.
      a. Boiler manufacturer shall provide the startup and commissioning services for the entire package boiler assembly. Coverage of services shall be continuous, start to finish, without a lapse in services.
      b. Startup reports detailing all testing completed, testing results, and all field modifications or adjustments shall be delivered for Owner record's following a successful startup.
   3. Owner Training – Provide am minimum of two (2) weeks prior to the start of training.

1.05 SHIPPING REQUIREMENTS

A. Shipping F.O.B. to Knoxville, TN shall be included in the price of the boiler.

B. Boiler shall be shipped from the point of manufacturer to the project site via over the road trucking or via rail.

C. Boiler shall be delivered to the project site in new condition. Boiler will be inspected both inside and out by the Project Engineer or Owner’s Representive prior to rigging.

D. Boiler and/or burner shall be manufactured with lifting lugs for rigging and handling.

E. All openings shall be plugged or capped prior to shipment.

F. Boiler shall be shipped with the burner.

G. All shipped loose items shall be crated in a sturdy wood crate for shipping. All shipped loose materials shall be shipped with the boiler and arrive at the same time as the boiler.

H. The boiler manufacturer shall give an approximate delivery date and time at least 15 working days prior to anticipated delivery. A final appointment shall be made 24 hours prior to arriving onsite.

1.06 WARRANTY AND GUARANTEES

A. Manufacturer shall warrant that the equipment provided shall be free from defects in design, materials, and workmanship for a period of one (1) year starting from the date of Substantial Completion.

B. The boiler pressure vessel and burner proprietary parts shall be guaranteed for three (3) years from the date of Substantial Completion.

C. Manufacturer will repair or replace pressure vessel components, casing of boilers that fail, due to materials or workmanship within five years from date of Substantial Completion, pro rata.

D. Manufacturer shall guarantee that all equipment provided will operate in accordance with the specified requirements and shall fully guarantee that all products furnished shall meet the design conditions specified herein on a continuous basis, and the Manufacturer shall be solely responsible for the performance of the furnished equipment.

E. Manufacturer shall guarantee that emissions at the stack shall continuously be equal to or less than the emission rates specified herein when operating between 20% and 100% of rated capacity based on the higher heating value of the fuel.

F. Manufacturer shall guarantee that each boiler will produce a minimum of 80,000 lbs/hr of dry saturated steam at 125 psig at the outlet of the non-return valve when fired with natural gas and with No.2 fuel oil at the rated heat input.

G. Manufacturer shall guarantee that each boiler will have a total dissolved solids content in the steam from the drum of no more than 1 ppm with a boiler water total dissolved solids concentration of 2,000 ppm and that moisture of the steam will be no more that 0.5% under all operating conditions.

H. Have a minimum efficiency of 82 % when firing at rated capacity.

1.07 DESIGN CODES

A. American Society of Mechanical Engineers (ASME) Power Boiler Code

B. American Society of Mechanical Engineers (ASME) Power Piping Code B31.1

C. National Fire Protection Agency (NFPA) Codes

D. International Building Code – 2012 Edition

E. Occupational Safety and Health Administration (OSHA) Regulations

F. National Electrical Code (NEC)

G. American Institute of Steel Construction (AISC)

H. Code of Federal Regulations (CFR): 40 CFR Part 60 Subpart Dc

I. Code of Federal Regulations (CFR): 40 CFR Part 63 Subpart JJJJJ

1.08 WORK BY OTHERS

A. Compliance testing for emissions.

PART 2 PRODUCTS

2.01 GENERAL

A. It is not the intent of these specifications to completely specify all details of design and construction of the equipment; however, the equipment furnished and installed shall conform in all respects to the highest standards of engineering, design, and workmanship. The omission of detailed instructions does not relieve the Manufacturer from the responsibility of designing all components to be suitable for the intended use and in accordance with good engineering practice and specified codes and standards. The complete unit when delivered and installed shall demonstrate its capability of performing in continuous commercial operation up to the manufacturer's guarantee and in a manner acceptable to the Engineer and Owner.

B. Material not specified herein shall be of the best industrial quality. All materials shall be free from defects that might affect the serviceability of the finished product.

2.02 ACCEPTABLE MANUFACTURERS

A. Boiler Basis of Design: Cleaver-Brooks

B. Other Boiler Acceptable Manufacturers:
   1. Rentech Boilers
   2. Superior Boilers
   3. The Babcock and Wilcox Company.

C. Valves, Instrumentation and Control Devices provided by the boiler Manufacturer shall be manufactured by American companies unless a high quality component is not available from an American manufacturer. Acceptable brands are Clark-Reliance, Warrick, Yarway, Everlast, Edwards, Crane, Powell, Vogt, Kunkle, or approved equals.

D. Acceptable burner vendors: Cleaver Brooks, Coen Company, Faber Burner Company or Zeeco.

E. The burner shall be a standard product of the burner manufacturer specifically designed for the boiler.

F. The identification of any manufacturer or model number does not relieve the Manufacturer from complying with all of the specifications provided herein.

2.03 PERFORMANCE REQUIREMENTS

A. General:
1. The packaged boiler shall be constructed with a steam outlet nozzle and standard manufacturer's internals to support operation at the indicated pressure and temperature while providing the indicated guaranteed steam quality.
2. Specified steam flow rate shall be the total delivered steam flow rate downstream of the non-return valve. Non-impinging, controlled flame profile at all loads within the boiler control range. Flame control and profile shall be maintained when firing on natural gas or No. 2 fuel oil.
3. Smooth operation during increasing firing rate or decreasing firing rate with stable flame over the entire operating range of the boiler with a rate of change for steam demand of 20 percent Maximum Continuous Rating (MCR) per minute.
4. The package's equipment shall be designed for steady state stresses and seismic stresses for seismic as described in the International Building Code. Under these conditions, the boiler and associated equipment shall shut down safely without damage and be capable of safe and immediate restarting.
5. Boiler noise shall not exceed 85dbA as measured in accordance with American Boiler Manufactures Association (ABMA) testing guidelines.
6. The boiler will be installed on no less than a 4" concrete housekeeping pad (provided by the installing contractor), while access platforms and ladder supports will be installed on no less than a 1/2" grout bed.

B. Design Conditions
1. Maximum Rated Design Heat Input: 99,000,000 Btu/hr
2. Minimum Rated Design Capacity: 80,000 lbs/hr (higher capacity at less than the maximum rated heat input is desirable)
3. Minimum Boiler Design Pressure: 250 psig
4. Operating Pressure at Outlet of Steam Non-Return Valve: 125 psig
5. Operating Temperature: Saturated.
6. Economizer Minimum Design Pressure: 400 psig
7. Maximum Furnace Heat Release Rate: 75,000 BTU/ft^3 (using higher heating value and ABMA standards)
8. Fuels:
   a. Natural Gas – Pipeline Quality
   b. Fuel Oil – Specification #2
9. Drum Lower Safety Valve Set point: 150 psig
10. Drum Upper Safety Valve Set point: 155 psig
11. Maximum total dissolved solids in steam leaving drum with boiler water total dissolved solids concentration of 2,000 ppm: 1 ppm.

12. Maximum moisture in steam leaving the drum: 0.5%
13. Maximum Water-Side Pressure Drop Across Economizer: 10 psi.
14. Maximum Gas-Side Pressure Drop Across Economizer: 1.5 in. w.c.
15. Available Feedwater Temperature: 227 °F
16. Available Natural Gas Pressure: 30 psig
17. Available Fuel Oil Pressure: 125 psig
18. Available Instrument Air Pressure: 100 psig

C. Emissions
1. Stack emissions shall be controlled by a combination of low NOx burner and induced recirculation of flue gas. Submit complete predicted emissions for natural gas and No. 2 fuel oil thru all required firing rates.
2. The emissions shall not exceed the following emission rates when operating between 25% and 100% of rated capacity based on the higher heating value fuel input.
3. During Natural Gas Combustion:
   a. Nitrogen Oxides (NOx): 0.0364 lb/MMBtu
   b. Carbon Monoxide (CO): 0.0375 lb/MMBtu
   c. Sulfur Dioxide (SO2): 0.0006 lb/MMBtu
   d. Volatile Organic Compounds (VOC): 0.0055 lb/MMBtu
   e. Particulate Matter: 0.005 lb/MMBtu
4. During Fuel Oil Combustion (No. 2 fuel oil with 0.05% sulfur):
   a. Nitrogen Oxides (NOx): 0.1 lb/MMBtu
   b. Carbon Monoxide (CO): 0.04 lb/MMBtu
   c. Sulfur Dioxide (SO2): 0.051 lb/MMBtu
   d. Volatile Organic Compounds (VOC): 0.004 lb/MMBtu
   e. Particulate Matter: 0.04 lb/MMBtu

D. Site Conditions
1. Location: Knoxville, Tennessee
2. Elevation: 850 feet above MSL
3. Outdoor Ambient Temperature: -5°F to 110°F (Combustion air from outdoors
4. Outdoor maximum Relative Humidity: 98%
5. Combustion Air Design for Guarantees: 80 F / 50% RH
6. Boiler Environment (building interior): 60 to 110 F
7. Wind Speed/Exposure: 90 mph (3 second gust), Exposure B
8. Seismic: $S_S = 0.58$ $S_1 = 0.146$

E. Forced Draft Fan:
1. Combustion Air Design for Guarantees: 80 F / 50% RH
2. Sound Level: Noise levels shall not exceed 85dBA at normal, full operating conditions at a distance of 3’-0”. Provide sound attenuating device on forced draft fan intake ductwork (upstream of flue gas recirculation connection) to achieve this sound level.
3. Maximum excess oxygen (O2) at MCR: 15%
4. Maximum flue gas recirculation flowrate at MCR: 15%

F. Burner:
1. Natural gas, minimum turndown: 10:1
2. Fuel oil, minimum turndown: 8:1

3. Combustion Control System: Linkageless, parallel positioning, with O2 trim and variable frequency force draft fan.

G. Continuous Blowdown:
   1. Two percent of feedwater flow.

H. Stack
   1. Stack inner diameter shall be designed for a maximum flue gas velocity of 50 feet per second when flue gas recirculation is not in operation.
   2. Top of boiler stack shall be 72'-4" above the base of the boiler. Stack shall be floor supported. Provide concrete pad for mounting of stack. The stack will have lateral support at an elevation of approximately 45’ above the base of the boiler, where it exits the roof of the building.
   3. Two (2) 4" flanged sampling ports shall be provided for emissions testing. The sampling ports shall be oriented at 90 degrees from each other. The building roof will be at approximately 46’-6” above the base of the boiler. The sampling ports shall be located 4’-0” above the building roof.

I. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

J. ASME Compliance: Fabricate and label boilers to comply with ASME BPVC.

2.04 BOILER

A. The boiler shall be a two-drum “D” type, shop assembled, package type water tube design on a heavy steel base frame with integral water-cooled furnace and integrally mounted burner. Welded membrane walls shall be utilized for the length of the boiler except at the gas outlet.

B. The boiler membrane walls shall be designed for pressurized operation. Gas tight construction shall be achieved by providing continuous seal welded membrane tubes for furnace sidewalls and roof. The unit shall be subjected to a pressure test at one and one-half times the maximum furnace pressure with all seams checked with soapy water.

C. Provide a manufactures name plate mechanically attached to the boiler and stamped with the following information:
   1. Manufactures Name and Model Number
   2. Year of Manufacture
   3. Serial Number
   4. Rated Capacity and Maximum Continuous Load
   5. Maximum Allowable Working Pressure

D. The boiler pressure parts shall be designed, fabricated, and hydrostatically tested in accordance with the latest edition of the ASME Code, Section I - Power Boilers.

E. The boiler side walls, roof, and drums shall have a minimum of 12 gauge thick steel outer casing, primed and painted. The external casing shall be of the structural reinforced design, requiring no buck stays and shall be seal welded.

F. The side walls, roof, and floor of the boiler shall be covered with a minimum of 1000 °F insulating blanket. Insulation shall be high density mineral wool insulation and the thickness on the boiler casing shall be a minimum of 3", or greater if required for personnel protection from injury due to burns. The drum ends will be field insulated per the manufacturer's recommendations by others. The average surface temperature of the outer casing shall be 140°F with an ambient temperature of 90°F and with a surface velocity of no less than 2 ft/second.

G. The steam and lower drums shall be fusion welded, fully x-rayed, stress relieved, and hydrostatically tested at 1.5 times the design pressure. The drums shall be made of ASTM SA16-70, SA516, SA106B, or higher alloy steel.

H. The steam and lower drums shall be provided with minimum 12"x16" manhole openings and covers at each end. Manhole covers shall be supported on hinges.

I. Furnish three (3) complete sets of manhole gaskets for each manhole for installation at the job site.

J. The lower drum shall be provided with an internal naturally draining steam coil made of ASTM SA106B or higher alloy steel for the purpose of maintaining the temperature of the boiler when off-line. The steam coil shall have a minimum wall thickness of 0.20". The lower drum steam coil shall be sized to maintain a minimum steam drum temperature of 50°F below the saturation temperature of the supply steam to the coil.

K. All boiler tubes shall enter the drums radially. Boiler tubes shall be made of ASTM SA178A or higher alloy steel and shall have a minimum of 2 inch O.D. All boiler tubes shall be completely drainable and mechanically cleanable, except the front and rear walls which may be only chemically cleanable by conventional means. All tubes shall have a minimum wall thickness of 0.134".

L. No part of the boiler drums shall be directly exposed to furnace radiation.

M. The furnace shall be designed to prevent flame impingement upon any boiler tubes or drums.

N. All drum connections 2" and larger shall be flanged. At a minimum, connections shall be provided for the following:
   1. Minimum 8" Steam outlet.
   2. Safety valves (sized as required to satisfy the ASME Boiler Code).
   3. Minimum 4" Feedwater inlet with internal feed pipe.
   4. 1 ½" Continuous blowdown with internal blowdown pipe.
   5. 1 ½" Water column (upper and lower connections).
   6. 1" Level Transmitter (upper and lower connections).
   7. 1 ½" Auxiliary low water cut-out (upper and lower connections).
   8. (2) x 1 ½" Intermittent blowdown with internal blowdown baffle.
      a. Locate on each side of mud drum.
   9. 1" Chemical feed with internal feed pipe.
   10. 1 ½" Boiler vent.
   11. 1" Superheater vent and drain as required.

12. 1" Pressure Gauge.

O. Auxiliary low water cut-out (ALWCO) shall be magnetic repulsion type equal to McDonnell & Miller, Series 94, rated for 250 psi. Provide with manual reset.

P. Drum internal piping shall be properly supported in order to prevent abnormal vibration and fatigue. All external and internal drum piping which is 2 ½" and larger shall be of butt-welded construction. All external and internal drum piping which is 2" and smaller shall be of socket-welded construction.

Q. The steam drum shall be supplied with suitably designed internal baffles, chevrons, and steam separators as required to maintain the specified steam purity.

R. Internal drum hardware shall be stainless steel. All drum internals shall be designed to be replaceable

S. Refractory in the furnace area shall be kept to the minimum required to protect the drums and other components. Where required, it shall be a robust design using the highest quality components and high temperature firebrick where practical and shall be made pressure tight where applicable.
   1. In no case shall asbestos or asbestos-based products be used. All material shall be asbestos- free.

T. A minimum of two (2) air cooled observation ports shall be provided on the furnace section of the boiler to allow observation of the flame. The design of ports shall allow lens replacement while on-line.

U. A minimum 16"x20" gas tight, fabric insulation lined furnace access door shall be provided on the front or rear of the boiler.

V. Tubes
   1. All tubes shall be constructed with material and thickness required for indicated maximum allowable working pressure and temperature pressure in accordance with ASME BPVC with a minimum thickness of 0.120".
   2. Tubes shall be seamless.
   3. No tube shall enter the lower drum below the horizontal drum centerline or enter the steam drum above the minimum water level.
   4. All tubes shall be attached to the drums by mechanical rolling.
   5. The boiler shall be designed to provide removal of tubes and cleaning of internal tube surfaces. No intermediate headers between the lower and upper drums are allowed.
   6. The convection tubes and headers shall be fabricated complete with tube supports and internal bracing. Tube design arrangement shall allow for easy removal and cleaning of interior and exterior heat exchange surfaces.

2.05 BOILER ACCESSORIES

A. At a minimum, each boiler shall be provided with the following accessories:
   1. Non-return valve.
   2. Safety relief valves for steam drum sized in accordance with the ASME Boiler Code.

3. Intermittent blowdown valves.
4. Continuous blowdown regulating valve.
5. Continuous blowdown stop valve.
6. Water level gauge.
7. Two (2) gauge isolation valves.
8. Gauge glass drain valve.
9. Devices for “high” and “low” level alarms.
10. Water column, probes and remote indicator bi-color drum level indicator (Clark-Reliance Eye-Hye, Yarway 3000 or approved equal).
11. Water column drain valve.
12. Steam drum vent valve.
13. Steam pressure gauge with siphon, shut-off valve, and test connection.
14. Feedwater stop valve and check valve at feedwater inlet.
15. Second steam isolation valve per ASME Boiler Code. Provide valve with warm-up bypass and tell-tale drain.
16. Economizer 3-valve bypass.
17. Economizer safety valve.
18. Chemical feed stop and check valves.
19. Lower drum heater steam and condensate isolation valves.
20. All instruments required for the burner management system functions, and as required for NFPA compliance including but not limited to low water cutout, auxiliary water cutout, high steam pressure, local water bypass hand-switch for blowdown, and all burner related devices. Provide isolation valves for all pressure switches unless restricted by applicable codes.
21. In-situ oxygen sensors with transmitters for signaling to plant combustion control system. Provide all ports and accessories to complete the sensor/transmitter installation.
22. Boiler airflow sensor with transmitter. Include all parts and accessories to complete the sensor/transmitter installation.

B. All valves not easily accessible from the ground or Manufacturer access platforms shall be provided with chain operators.

C. Valves and trim components shall be selected to minimize the number of manufacturers utilized. This requirement is intended to minimize the spare parts requirements.

2.06 CONTROLS

A. All instruments and field devices shall be identified with a unique alpha-numeric designation. The alpha-numeric designation for each instrument and field device will be provided to the Manufacturer. All drawings, lists, references, and other information provided by the Manufacturer, shall use the designations provided.

B. The plant control system will be a Distributed Control System (DCS) provided and installed by others. The plant control system will function to operate the firing rate of the boilers and will coordinate and supervise the operation of multiple boilers and auxiliary systems. The control logic for the operation of all boiler systems shall be provided by the Manufacturer, for configuration into the plant control system. The flame safety or burner management system shall be

provided by the Manufacturer, and must communicate with the plant control system.

C. When available, instruments and positioners shall be provided with a HART interface that directly communicates HART data without requiring any additional adapters or interpreters. All devices without a HART interface shall be identified in the submittals.

D. Provide a HART hand-held interface device for set-up and diagnostics of all HART configurable components.

E. Provide all pneumatic actuators with the latest generation digital positioners with a HART interface. Pneumatic positioners shall accept a 4-20 mA input signal for position control and shall also provide a 4-20 mA output feedback signal spanned to indicate device position.

F. Electric actuators shall accept a 4-20 mA input signal for position control and shall also provide a 4-20 mA output feedback signal spanned to indicate device position. Provide dry contact limit switches with electric actuators for the fully open and fully closed positions. Electric actuators without HART interface shall be identified in the submittals.

G. All Burner Management System (BMS) items shall be factory pre-wired from the fuel trains and boiler devices to terminal boxes. The conduit and wiring between the terminal boxes and the BMS panel shall be field installed by the Contractor. Interfaces between the BMS and plant control system will be field installed by others. Motor and other power connections will be field wired from the components directly to their power source. Power sources (MCC's, panels, etc.) will be supplied and installed by others.

2.07 ECONOMIZER

A. The economizer shall be a counter-flow unit designed, fabricated, constructed, and stamped in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII - Pressure Vessels.

B. The economizer shall be designed to prevent steaming of feedwater over the entire range of operation. The feedwater outlet temperature must be no less than 50 F below the steam drum saturation temperature.

C. The economizer shall be designed and fabricated to be capable of operating with full flue gas flow and no feedwater flow, without damaging the unit.

D. The economizer and the support structure provided by the boiler Manufacturer shall be designed to accept the dead loads and also the seismic loads imposed on the economizer. The vertical loads from the economizer shall transfer through the Manufacturer's support structure to the building floor/foundation.

E. The gas side connections shall be plate flange type with drilling for bolt holes for aligning to adjacent structural and/or ducting components. The water side connections shall be Class 300 flanged. Header to include vent and drain connections to ensure full draining of the tubes. Provide the vent and drain valves on each connection.

F. The economizer shall be designed so that access for tube inspection can be achieved by either hinged access doors in the economizer or from adjacent ductwork incorporating hinged access doors. The unit shall incorporate lifting lugs to facilitate loading and unloading.

G. The economizer internal casing shall be of minimum 3/16" thick steel and shall be seal welded for gas tight construction. The economizer shall be externally insulated and lagged by the Manufacturer.

H. The economizer shall be of the extended surface type with a minimum of 2" O.D. tubes and minimum 0.075" thick fins. There shall be a maximum of 4 fins per inch. Tubes and headers shall be of 316 stainless steel, all welded construction.

I. Provide all necessary structural supports required for the economizer.

J. Provide inlet and outlet pressure gauges, temperature indicators with temperature wells, and isolation valves in the feedwater piping entering and leaving the economizer. In addition, provide temperature wells and pressure connections suitable for standard ¾” NPT threaded instrumentation devices for the installation of pressure and temperature elements by others, for remote monitoring.

K. Provide inlet and outlet temperature indicators in the flue gas duct entering and leaving the economizer. In addition, provide ¾” standard NPT threaded connections on the flue gas inlet and outlet for installation of temperature elements by others, for remote monitoring.

L. Provide a 3“ flanged flue gas test port in the transition duct between the boiler and the economizer to allow use of a portable flue gas analysis probe.

2.08 BREECHING

A. Provide all breeching between boiler flue gas outlet and economizer, and between economizer and stack.

B. All breeching shall be of welded construction and shall be gas tight. Reinforcing and supports shall be provided as required for the pressure and temperature expected. Breeching and ductwork shall be designed and installed per the Sheet Metal and Air Conditioning Contractor’s National Association (SMACNA) industrial duct construction standards.

C. All breeching and transitions shall be insulated by the installation contractor in accordance to the recommendations of the Manufacturer.

2.09 EXPANSION JOINTS

A. Breeching shall include expansion joints designed to accommodate the total axial and lateral movements of the breeching. The expansion joints shall be designed for operation at a minimum of 400 F and a minimum of 15" of water column.

B. Breeching expansion joints shall come complete with Fluoroflex flat belt, companion flanges, back-up bars, ASTM A-606 or higher alloy liner, and ceramic fiber insulation.

2.10 PIPING

A. All piping shall be designed, installed, and inspected per the ASME B31.1 Power Piping and per Section I of the ASME Boiler and Pressure Vessel Code.

B. Provide all ASME Boiler Code steam piping from the boiler to the second steam isolation valve.

C. Provide all ASME Boiler Code feedwater piping from the boiler to the economizer.

D. Provide all ASME Boiler Code feedwater piping from the economizer to the second feedwater isolation valve upstream of the economizer.

E. Provide ASME Boiler Code feedwater bypass piping to remove the economizer from service. The bypass piping shall include two (2) manually operated isolation valves and one manually operated bypass valve. A safety valve shall be located in the piping between the isolation valves.

2.11 BURNER

A. Provide boiler with a packaged low-NOx burner assembly with flue gas recirculation (FGR). The combustion control system will be fully metered and signals will be provided by others. Flow meters for both fuels will be provided by others. All valves and damper actuators will be provided by the boiler Manufacturer and they shall be equipped with an air filter/regulator, I/P positioner, position feedback signal

B. There shall be no flame impingement on the furnace walls as defined by ABMA.

C. See Section 2.02 for listed acceptable burner manufacturers.

D. The windbox shall be of a proven design and fabricated from a minimum of 0.25” thick ASTM A-36 carbon steel plate and shall be complete with all required structural framing, support legs, hinged access door, lifting lugs, and internal baffles for balanced air flow to the burner. The windbox shall be seal welded to the boiler front plate.

E. The burner shall have a minimum of two observation ports on the front.

F. The burner shall come with an atomizing No. 2 oil gun assembly which shall be manually retractable. The oil gun shall be capable of using either compressed air or steam for atomization. During cold start-up, the unit shall be capable of atomization with compressed air and changing to saturated steam atomization once the boiler reaches normal operating pressure. Connections shall be provided for each. A burner guide ring shall be welded to the boiler front plate to align the burner to the burner opening. A spare oil gun shall be provided for

each boiler. A plug shall be provided to replace the oil gun when it is removed during operation of the boiler.

G. The burner shall come with a complete interrupter type ignition assembly with gas-electric igniter, high tension cable and connector, and high voltage transformer.

H. A total of two (2) sets of any required special burner tools shall be provided.

I. The burner and the BMS panel are to be provided with the components and programming needed to accomplish fuel change over at low fire conditions, from gas to oil firing and from oil to gas firing.

J. The burner shall maintain a stable flame at low fire without special adjustment.

K. Burner shall be rated to utilize a propane/air mixture in the natural gas train in an emergency condition with temporary field connections. The propane/air mixture shall have an equivalent Wobbe index to natural gas. No additional piping, valves, or controls are required.

L. Provide a gas pressure regulator for the burner gas train. The pressure regulator shall be sized based on the stated range of inlet pressures.

M. The main gas train shall be completely assembled, factory prewired to a terminal box for final connection to the burner management system (BMS). All components and functions shall be factory tested prior to shipment. The piping shall comply with the requirements of NFPA 85 and safety components shall be UL listed and FM Global approved for the service. As a minimum the following equipment shall be provided.
   1. A modulating gas control valve to provide for fuel/air ratio adjustment throughout the entire turndown range specified. The valve shall be flanged and shall be specifically made for controlling the fuel specified and be used in this type application in other installations.
   2. Two (2) motorized safety shut-off valves of the guillotine type, spring closing in less than one second with proof of closed position switches. The valves shall be provided with position indicators and comply with FM Global requirements.
      a. All gas safety shut-off valves shall have stainless steel bodies with 316SS seat and disc.
   3. One (1) normally open solenoid operated vent valve located to vent between the two (2) safety valves.
   4. One (1) lubricated plug cock located downstream of last safety valve. Plug cock to be designed for the fuel specified.
   5. One (1) lock-open type shut-off valve located in the vent line to provide for leak testing of the safety valves. The valve must be furnished with an adequate lock and brackets.
   6. Two (2) pressure switches to monitor high and low gas supply pressure. The switches shall meet the FM Global requirements and be of proper range to meet the fuel pressure specified.
   7. Two (2) pressure gauges 4 ½-inch dial with polypropylene case, screwed bezel, glass lens, adjustable pointer, bronze bourdon tube and socket, blowout disc, and one percent (1%) accuracy. The range shall meet the

requirements of the fuel pressure specified. The gauges shall be furnished with needle type shut-off valves. One gauge shall be for supply gas pressure and one shall be for gas pressure at the burner

N. The pilot gas train shall be completely assembled, factory mounted, pre-wired to a terminal box for final connection to the burner management system (BMS). All components and functions shall be factory tested prior to shipment. The piping shall comply with the requirements of NFPA 85 and safety components shall be UL listed and FM Global approved for the service. As a minimum, the following equipment shall be provided.
   1. A pilot gas pressure regulator shall be provided to supply a constant gas pressure to the pilot assembly. The regulator shall be of a rugged design and supplied with an internal relief valve.
   2. Two (2) solenoid operated safety shut-off valves normally closed type and meeting all FM Global requirements.
   3. One (1) normally open solenoid operated vent valve located to vent between the two (2) safety valves.
   4. One (1) shut-off valve located upstream of the pilot train. The valve to be supplied for the fuel specified.
   5. Stainless steel double-braided connecting hoses (pilot to stationary piping).
   6. One (1) pressure gauge 4 ½-inch dial with polypropylene case, screwed bezel, glass lens, adjustable pointer, bronze bourdon tube and socket, blowout disc, and one percent (1%) accuracy. The range shall meet the requirements of the fuel pressure specified. The gauge shall be furnished with needle type shut-off valve.
   7. A “tee” fitting with a manual isolation valve shall be supplied in the piping system to allow manually isolating the natural gas supply and temporarily supply pure propane gas to the pilot train in an emergency situation where the normal utility natural gas service is not available and the boiler is started on fuel oil.

O. The main oil train shall be completely assembled, factory mounted, pre-wired to a terminal box for final connection to the burner management system (BMS). All components and functions shall be factory tested prior to shipment. The piping shall comply with the requirements of NFPA 85 and safety components shall be UL listed and FM Global approved for the service. A pressure regulating valve shall be provided if required. As a minimum, the following equipment shall be provided.
   1. A modulating oil control valve to provide for fuel/air ratio adjustment throughout the entire turndown range specified. The valve shall be flanged and shall be specifically made for controlling the fuel specified and be used in this type application in other institutions.
   2. Two (2) motorized shut-off valves of the guillotine-type, spring closing in less than one second with proof of closed position switch. The valves shall be provided with position indicators.
   3. Two (2) hand shut-off valves. One (1) hand shut-off valve at the supply connection, and one (1) hand shut-off valve at the oil gun.
   4. One (1) pressure switch to monitor low oil supply pressure.
   5. One (1) “y” type oil strainer with 1/16" perforated screen.

6. Two (2) pressure gauges, 4.5" dial with polypropylene case, screwed bezel, glass lens, adjustable micrometer pointer, 316 stainless steel bourdon tube and socket, blowout disc, and 0.5 percent (0.5%) accuracy. The gauges shall be furnished with needle-type shut-off valves. One gauge shall be for supply pressure and the other shall be for burner pressure.
7. Two (2) stainless steel double-braided connecting hoses (oil gun to stationary piping) for oil.
8. A means for relieving pressure shall be provided in the piping between the safety shut-off valves, if required, based on the ambient temperature and a fuel oil temperature between 20°F and 80°F.

P. The steam and compressed air oil atomizing train shall be completely assembled, factory mounted and pre-wired to a terminal box for final connection to the burner management system (BMS). All components and functions shall be factory tested prior to shipment. The piping shall comply with the requirements of NFPA 85 and all safety components shall be UL listed and FM Global approved for the service. As a minimum, the following equipment shall be provided.
   1. One (1) solenoid operated normally closed atomizing shut-off valve.
   2. A pressure regulator shall be provided to supply constant pressure of the steam or compressed air to the oil gun for atomizing the fuel oil.
   3. Three (3) hand shut-off valves. One (1) hand shut-off valve at each of the supply connections (atomizing air and atomizing steam), and one (1) hand shut-off valve at the oil gun.
   4. One (1) pressure switch to monitor low steam or compressed air supply pressure.
   5. One (1) differential pressure switch to monitor low steam or compressed air flow to the burner oil gun.
   6. One (1) “y” type atomizing media strainer with 1/16" perforated screen.
   7. Two (2) pressure gauges, 4.5" dial with polypropylene case, screwed bezel, glass lens, adjustable micrometer pointer, 316 stainless steel bourdon tube and socket, blowout disc, and 0.5 percent (0.5%) accuracy. The gauges shall be furnished with siphons and isolation valves. One gauge shall be for steam or compressed air supply pressure and the other shall be for compressed air or steam pressure at the burner.
   8. Two (2) stainless steel double braided connecting hoses (oil gun to
   9. stationary piping) for atomizing media.
   10. Steam trap with isolation valve.

Q. All required boiler safety interlocks and devices shall be provided as part of the burner assembly. The interlocks and limits shall comply with the requirements of NFPA 85 and all safety components shall be UL listed and FM approved for the service. Provide set points and completed calibration sheets for all field devices with “as-left” settings for each device. As a minimum, the following equipment shall be provided.
   1. Flow or pressure switches to monitor combustion air and purge air flow. The switches shall meet the specified insurance requirement and be of proper range to meet the combustion air fan static and differential requirements.

2. One (1) pressure switch to monitor high boiler pressure. The switch shall meet the specified insurance requirement and be of proper range to meet the boiler design pressure.
3. Switches as required to monitor the combustion control position for low fire start. The switches shall meet the specified insurance requirements and shall prove the low fire position of the burner system.
4. Necessary steam drum water level interlocks for High-High Level Trip, High Level Alarm, Low Level Alarm, and Low Water Trips.

2.12 BURNER MANAGEMENT SYSTEM

A. A complete burner management system (BMS) shall be provided and housed in a NEMA 12 enclosure with all necessary equipment to comply with the requirements of FM Global. Each boiler's burner management system shall be suitable for free-standing installation near each boiler. All the flame monitoring components shall be UL listed and FM Global approved for the service. It is the responsibility of the Burner Management System Manufacturer to design the complete system to assure that all safety related functions are of the fail safe design. The system shall be provided with all equipment required to provide for a complete, fully operable system. As a minimum, the system shall be provided with the following:
   1. Programmable Logic Controller (PLC)
      a. The system shall be provided with an Allen Bradley Programmable Logic Controller (PLC) based upon a latest ControlLogix or CompactLogix generation system (or approved equal) to provide the burner start-up sequence, to monitor purge, low fire position, ignition, main fuel, combustion air and automatic control release. The PLC shall have adequate I/O capacity to provide a reliable and fail safe type system. The PLC memory shall be large enough to provide for the sequence plus an additional 25% spare. The PLC shall be capable of communications via Ethernet I/P with the plant control system (DCS) for remote monitoring and alarm management by the plant control system.
      b. Because each BMS PLC for the individual boilers will communicate to the plant control system over a common network, all system tags must be globally unique so that the plant control system may properly address and identify each tag. The use of programming that directly copies the BMS program without regard for unique addressing and tag identifiers for each unit is unacceptable. Each BMS address and associated PLC point must be able to be uniquely identified for communication to the plant control system.
      c. The PLC shall be provided to accept 120 VAC inputs and be capable of operating on voltages of 85 to 132 VAC. The outputs for all normal sequencing functions shall be provided with dry isolated contacts with a two-amp continuous rating and an inrush rating of 15 amps. The outputs for operating safety valves and other safety functions shall be provided with a five-amp continuous rating and in inrush rating of 30 amps. Outputs to motor starters shall be fully isolated contacts rated for the required starter size.
      d. The PLC shall be provided with a hardware watchdog timer to monitor the software and if the software does not send a pulse to the

hardware watchdog every 50 MS or less, the processor RAM is cleared and the system will fail safe.

e. The PLC shall be supplied with a non-volatile program memory to assure memory is not lost during prolonged power outages. The system shall also be provided with a password to prevent unauthorized personnel from entering the program.

f. Each PLC input and output shall be protected with fuses sized for the application. Fusing of an I/O on a system or card basis is unacceptable. The fuses shall be mounted in a fusible switch type terminal with blown fuse indication for easy replacement.

g. The PLC shall control the start/stop function of the forced draft fan. The BMS shall provide isolated contact outputs wired to terminals for at least the following functions:
   1) Low fire required.
   2) Purge required.
   3) Purge in progress.
   4) Purge complete. Boiler tripped.
   5) Burner released to auto-oil.
   6) Burner released to auto-gas.
   7) Burner limits satisfied.
   8) Fuel selection (gas or oil)

h. Provide a local Master start for the burner to initiate a fully automatic burner start and releases control to the plant combustion controls upon successful start-up.

i. Provide the PLC ready for connection to the plant DCS Ethernet I/P network. Provide all hardware required at the PLC necessary to facilitate this connection. Program the PLC and provide a data table so that data is consolidated in sequential words or objects ready to handshake with the DCS. The data communication with the DCS must include as a minimum.
   1) Status information on burner limits and fuel selection.
   2) All alarms available at the BMS HMI including first-out information.
   3) Remote Stop (but no remote start.)

j. Provide a copy of the configuration software needed to download the operational program to each PLC in the event of a processor failure. Provide the “as-built” configuration routine for each PLC upon completion of start-up. For example, include all interface drivers necessary to implement the communications, including the application name and version necessary for the particular PLC furnished.

2. Flame Control Relays and Scanners

a. The system shall be provided with flame control relays and scanners to monitor the pilot and main burner flames. The flame scanners shall include purge air connections. The control shall be arranged so that all wiring is connected to a mounting base and the flame control chassis can be removed without disconnecting any field wiring.

b. The flame controls shall be of the self-checking type and operate continuously in the UV and IR light spectrums for flame sighting regardless of the fuel being fired, shall provide shutdown of the pilot or main fuel valves in four seconds or less if the flame is lost or not detected on either burner.

c. Provide redundant flame scanners. Self-checking feature of the flame scanner shall evaluate failure mode of the scanners such that it cannot produce a false flame indication with no flame present.
d. A purge air system is preferred for scanners.

3. An HMI display must be provided for routine operator display of information and for operator commands. Provide a hard-wired E-Stop on the BMS panel front and provide terminals for field connection of at least four (4) field mounted E-Stops (by others). Configure wiring such that any unused E-Stop connections can be jumper wired.
4. The Burner Management System shall be housed in a NEMA 12 enclosure with 90-degree opening door, zinc die cast hinges and slotted quarter turn oil tight latch. The cabinet shall be provided with an equipment mounting plate and all external wiring shall be connected through tubular screw terminal blocks. The terminals shall have a minimum voltage rating of 300 V for 120 V control and 600 V for higher voltages. The terminals housing shall be made of nylon or polypropylene and attach to the equipment mounting plate with a mounting channel.
   a. The control wiring in the Burner Management cabinet shall be 16-gauge MTW or equal. The wiring shall be color coded and tagged on both ends for easy identification. All power wiring shall be furnished for the service and sized accordingly with identification tags on both ends. Tags shall be printed slip-on tags. Handwritten or wrap-on numbering of wire tags is unacceptable.
   b. The Burner Management System shall be provided with the necessary circuit breakers to allow for maintenance and equipment protection.

B. The BMS shall be provided with a 14 inch (minimum) color HMI display screen that will provide the operator with normal operating information, as well as indicating malfunctions for interlocks and other failures. The HMI shall also be used for a first-out annunciator for all safety limit alarms. A touch-screen will be provided for operator responses.
   1. Operating Functions.
      a. Operating Limits.
      b. Safety Limits On.
      c. Purge On.
      d. Purge Complete.
      e. Ignition On.
      f. Main Fuel On.
      g. Control On Auto.
   2. Interlock and Other Malfunctions Messages for Solving Problems. Examples include, but are not limited to the following.
      a. Fuel Valves Not Closed.
      b. Flame Detected Early.
      c. Purge Flow Not Proven.
      d. Low Fire Not Proven.
      e. PLC Critical Output Failure.
   3. Annunciated Safety Limits with Messages for Solving Problems. Examples include, but are not limited to the following:
      a. Low Water Level.
      b. High Steam Pressure.
      c. Low Air Flow.

d. High Gas Pressure.
e. Low Gas Pressure.
f. Abnormal Oil Pressure.
g. Low Atomizing Pressure.
h. Pilot Flame Failure.
i. Main Flame Failure

4. With all annunciated safety limits, the Indicating Module will provide a first-out indication, and at the same time, an audible alarm will sound alerting the operator of the malfunction.
5. The PLC of the BMS shall provide the necessary logic and communications to support the HMI.

2.13 BOILER CONTROL SYSTEM

A. The boiler control system shall contain the boiler master control, combustion control and feedwater control and shall be furnished by a 3rd party to integrate with UT's existing Yokogawa Distributed Control System (DCS).

B. Refer to specification section 230911-Instrumentation and Control for Boiler Plant for additional requirements.

2.14 COMBUSTION AIR FAN

A. Provide a single-width, single inlet direct-driven fan with backward inclined or airfoil non-overloading wheel. The fan shall be driven by a 1750 RPM, 460 Volt, 60 Hertz, Premium Efficiency, inverter duty TEFC, 3-phase motor with Class F insulation, shaft grounding rings, and suitable for use with a Variable Frequency Drive (VFD) that is furnished by boiler manufacturer. The fan assembly will be flange mounted for easy removal.

B. The fan wheel shall be supplied from the fan manufacturer balanced to a maximum of 0.15"/second velocity.

C. The fan shall meet all necessary requirements of OSHA and meet a noise level of 85 DBA at 3 feet.

D. Fan BHP shall have 15% factor of safety above operating conditions.

2.15 FLUE GAS RECIRCULATION (FGR)

A. Provide a Flue Gas Recirculation (FGR) system to enable compliance with the emission limits specified herein, complete with all ducts, dampers, actuators, positioners, and instrumentation required for control.

B. FGR flow shall be induced by the combustion air fan and shall not require the addition of a separate fan.

2.16 AIR DUCTS AND DRAFT CONTROL

A. Provide the combustion air duct from the discharge of the combustion air fan to the windbox on the boiler.

B. Provide all fan inlet and/or draft control dampers required for additional air flow control beyond the range of the fan VFD drive control, and for control of flue

gas recirculation. All dampers shall be rigidly mounted and shall have pneumatic actuators, grease lubricated linkage, and shall be fitted with position switches for low fire and purge positions. The VFD and VFD control shall be by others.

C. Provide the flue gas recirculation duct. Flue gas recirculation duct shall be fabricated with flanged connections, and include expansion joints to allow for thermal expansion. The flue gas recirculation duct shall be fitted with a modulating damper and all instruments for flue gas recirculation flow control. The insulation for this duct will be provided and installed by the installing Contractor, based on recommendations by the Manufacturer.

2.17 STACK

A. The stack for each boiler shall be constructed of minimum of 3/16" thick ASTM-A-242 Corten Steel.

B. The stack shall be provided with a rain shield as detailed on the drawings. The stack shall be structurally designed, fabricated, and installed per ASME STS-1-2011 - Steel Stacks.

C. Mechanical Contractor shall provide field installed stack insulation per this section.
   1. Insulation shall be Pre-molded, High Temperature Pipe Insulation, rated to 1200ºF, high fiber density, low shot content (<20%), high temperature thermal control, low shrinkage, two (2) 1.5" layers. The insulation shall have a flame spread of 5 and a smoke developed rating of 0. One piece hinged sections shall be opened, placed over breeching, closed and secured with wires, bands or tape. First insulation layer shall be installed and secured prior to second layer. Joints shall be staggered. All joints shall be filled with cement. Over the insulation apply insulating cement and cover with
   2. The insulation shall not contain any formaldehyde or petroleum products.
   3. Aluminum Jacket-circular breeching and stacks: ASTM B209, 3003 alloy, H-14 temper, 0.023 inch minimum thickness with locking longitudinal joints. Jackets for elbows, tees and other fittings shall be factory-fabricated to match shape of fitting and of 0.024 inch minimum thickness aluminum. Fittings shall be of same construction as straight run jackets but need not be of the same alloy. Factory-fabricated stainless-steel bands shall be installed on all circumferential joints. Bands shall be 0.5 inch wide on 18 inch centers. System shall be weatherproof where utilized for outside service. Stucco-embossed finsihed.

2.18 ELECTRICAL

A. All motors rated greater than ½ horsepower shall be premium efficiency 460 volt, 3 phase, 60 Hz.

B. Motors ½ horsepower and smaller shall be 120 volt, single phase, 60 Hz.

C. All inverter duty motors shall be provided with Class F insulation and shaft grounding rings.

2.19 STRUCTURAL STEEL

A. Provide all structural steel for supporting the unit and all components. Supports for piping and combustion air ducts shall be by others.

B. Platforms and ladders shall be provided at the burner, at the economizer, at each end of the steam drum, and along the steam drum. Platforms and ladders shall meet OSHA requirements. Safety chains shall be provided across the top of each ladder. Grating shall be hot-dipped galvanized.

C. All walkways, stairs, and platforms shall be rated for 50 psf live load. Provisions for boiler thermal expansion shall be included.

D. Provide adequate means of egress in compliance with OSHA regulations.

E. The boiler shall be provided with suitable lifting attachments to enable the unit to be lifted in its final position and shipping positions. The equipment members to which lifting eyes are attached shall be of sufficient strength to withstand stress in the amount and direction of pull specified for the lifting eye. Where required, suitable reinforcements shall be used to meet requirements specified herein. The lifting attachments shall be capable of withstanding expected handling conditions which might be encountered such as rapid lowering and violent braking of load.

2.20 FINISHES

A. All exposed steel surfaces (equipment and structural) shall be thoroughly prepared prior to painting using a combination of hand and power tool cleaning as required by the paint manufacturer. After cleaning, all surfaces shall be coated with an industrial grade primer and an alkyd enamel finish coat. Boiler, breeching, economizer, or other high temperature surfaces shall be painted using high temperature painting components. Surfaces of bolted components not accessible after assembly shall be coated and allowed to dry prior to final assembly. Primer only will not be accepted.

2.21 SOURCE QUALITY CONTROL

A. Test and inspect factory-assembled boilers, before shipping, according to ASME BPVC.

B. Burner and Hydrostatic Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.

PART 3 EXECUTION

3.01 GENERAL

A. All design and fabrication shall be in accordance with the design codes identified in Section 1.07.

B. The Owner or his appointed agents reserve the right to visit the Manufacturer’s fabrication shop or their subcontractor’s shops at any time to witness progress

or certain equipment tests. The Manufacturer must inform the Owner at least fifteen (15) business days in advance before hydrostatic testing of boilers.

3.02 COORDINATION

A. The equipment procured under this specification will be assigned to an installing Contractor. The Manufacturer shall be responsible for coordination of delivery, shipments, installation, and start-up and commissioning activities with the installing Contractor.

3.03 SHIPPING

A. All equipment and components shall be suitably boxed or crated and wrapped or covered to prevent entrance of dirt or moisture and to prevent accidental damage during shipment to the site, outdoor storage at the site, and handling at the site.

B. All components shall be shipped to the site with adequate shipping and lifting supports to accommodate unloading and handling at the site.

C. All components shall be shipped to the site with labels to identify each component and aid in erection of the system.

3.04 EXAMINATION

A. Examine concrete equipment bases, locations, connection sizes, and any conditions affecting performance, maintenance, and operations.

B. Determine exact boiler and equipment locations before establishing piping and electrical connections.

C. Be sure spaces and conditions where boilers will be installed are suitable and to code according to Authority Having Jurisdiction.

D. Proceed with installation after correction of unsatisfactory conditions.

3.05 INSTALLATION

A. Manufacturer shall coordinate with the assigned Contractor and provide all requested information and instructions to aid in the unloading and installation of the equipment.

B. Install boilers on cast-in-place concrete equipment base(s).

C. Oil-Fired Boilers: Install according to NFPA 31.

D. Gas-Fired Boilers: Install according to NFPA 54.

3.06 PRE-COMMISSIONING REVIEW

A. Provide a factory trained field service technician on site for a period of two (2) days to review the installation and provide a list of outstanding items to be completed prior to boil out, at no additional cost to the Owner. The schedule

for this work will be coordinated with the assigned Contractor and shall occur approximately one week prior to the planned date for boil out.

B. The list of outstanding items to be completed prior to boil out shall be submitted in to the Owner's representative.

3.07 STARTUP, TESTING, TRAINING, AND OPERATION AND MAINTENANCE DATA

A. General:
   1. Boiler manufacturer shall provide services of factory-trained field representative/technician to approve installation, oversee boiler boil-out, conduct start- up, test and adjust for proper operation, and instruct and train Owner's representative in operation and maintenance of equipment. Representative/technician(s) shall have at least 5 yrs of experience commissioning similiar packaged boiler systems.

B. Boiler Boil-out:
   1. Boiler boil-out will require the Contractor to develop a written boil-out procedure, a waste management plan and a written waste disposal plan in accordance with the boiler manufacturer boil out procedure and UT's water treatment consultant [Chem-Aqua].
   2. The written cleaning, waste management and waste disposal plans must be developed by the contractor and approved by the Owner prior to mobilizing and beginning the boil out process. Contractor shall check with local authorities if the boil-out water can be drained to a municipal sewer. If it cannot, contractor shall provide provisions for capturing the waste in tanks and removing it off site.
   3. Manufacturer's representative shall verify in writing that boiler has been cleaned according to their recommendations and is ready for operation.
   4. Isolate boiler from piping system during boil-out.
   5. Owner's representative and/or Engineer will observe boil-out. Contractor shall notify the Owner and Engineer at least 20 business days prior to boil-out.
      a. Contractor shall provide necessary chemicals and equipment to perform the boil-out of each boiler.
      b. UT has an existing water treatment contract with Chem-Aqua, Inc. in Knoxville, TN.
         1) Contact: Craig Cole, craig.cole@chemaqua.com, (865) 202-0775

C. Boiler Startup: Boiler manufacturer's representative shall conduct startup of boiler per manufacturer's recommended startup procedures. Startup shall include the following in addition to manufacturer's recommended startup procedures:
   1. Complete inspection of installation and boiler condition.
   2. Fireside and waterside inspections.
   3. Verification of installation of field installed components, connections, wiring, and mountings. This verification shall include remote-mounted burner controller panel and interconnections to boiler skid components, VFD installation, O2 trim panel and all interconnections to boiler skid package, and stack sensors.
   4. Verification and sealing of doors, manways, hand holes, and all other openings.

5. Verify operation and water/steam tightness of all manual valving including blowdown valves, shut-off valves, bypass valves, stop check valves, check valves, and free blow valves.
6. Verify strainers are clean and watertight.
7. Setup of gas and fuel trains.
8. Setup of combustion air system including complete VFD setup.
9. Setup of all operating parameters.

D. Boiler Pre-Testing: After startup is complete, boiler manufacturer's representative shall conduct testing of boiler functional operations per manufacturer's recommended testing procedures. All testing shall require detailed, written procedures and shall be submitted to Owner and Engineer for approval prior to testing. All testing shall be witnessed by the Owner's Commissioning Engineer. Boiler manufacturer's representative shall provide all temporary testing equipment and instrumentation required for commissioning. Testing shall include the following in addition to manufacturer's recommended test procedures:
   1. Coordinate and assist Distributed Control System (DCS) Contractor and/or third-party integrator in installation and verification of all boiler controls interface functions. Testing shall not be considered complete until all interface functions are verified to operate correctly.

E. Verify operation of all boiler safeties including gas limits, oil limits, flame safeguards including timings, low water cutout, auxiliary low water cutout, proof of air pressure/flow, high limits, relief valves, indication of correct fault messages/codes and alarm reporting, etc.
   1. Verify operation of combustion process for each fuel including timings.
   2. Verify operation of feedwater system including interface controls/functions with deaerator feedwater pumps.
   3. Testing of boiler combustion air/fuel ratios and emissions analysis throughout firing range and for each fired fuel. Flue gas analysis report shall include measurements of the following throughout the firing range and shall be reported in units to allow comparison with permit limits (rate based):
      a. % oxygen
      b. % carbon dioxide
      c. % carbon monoxide
      d. Temperatures
      e. % combustion efficiency
      f. NOX ppm
      g. SOX ppm
   4. Verification of boiler turndown for each fired fuel.
   5. Verification of boiler efficiency per ASME PTC 4.1 procedure at conditions indicated herein.

F. Final Report:
   1. Upon completion of these services, boiler manufacturer's representative shall submit complete report, signed by manufacturer's service representative, including start-up and test log. Final test report shall include reports for all commissioning tests and procedures. Final completed commissioning functional test procedures shall be signed-off

from manufacturer’s technician and Owner's Commissioning Engineer for each witnessed function.

3.08 START-UP AND COMMISSIONING

A. Provide a factory trained field service technician on site for a period of two (2) weeks to supervise start-up and commissioning at no additional cost to the Owner. The start-up activities will include function performance testing, system readiness inspections and checklists.

B. The Manufacturer shall coordinate the schedule for start-up and commissioning with the assigned Contractor. The assigned contractor will provide mechanics, electricians, and controls technicians to assist in the start-up and commissioning activities.

C. The field service technician will instruct and provide technical support to the Owner’s personnel, and the mechanics, electricians, and controls technicians provided by the Contractor.

D. The field service technician shall have available all necessary programming devices, test equipment, tools, and instruments to accomplish the work. Technician must be capable of observing PLC logic functions and making changes or adjustments to correct any problems encountered in the BMS during initial start-up. This functionality includes the ability to reprogram or adjust functions within the flame scanners if programmable scanners are supplied.

E. The field service technician must provide combustion analyzer in order to monitor and assist in boiler characterization for fuel/air ratio and FGR setup.

F. The field service technician must provide laptop computer with all software needed to adjust BMS program, flame scanners and all other configurable components furnished within the boiler vendor’s scope.

3.09 ACCEPTANCE TESTING

A. The Manufacturer shall provide an authorized representative on site for five (5) days to witness and provide technical assistance during the acceptance testing, at no additional cost to the owner.

B. Each boiler will be operated continuously for a minimum of eight (8) consecutive hours. The boilers shall be operated for four (4) consecutive hours at Maximum Continuous Rating (MCR), and for the remaining four (4) hours at a load between ninety percent (90%) and one hundred percent (100%) of MCR. This test will be conducted for each boiler while firing natural gas, and a separate test will be conducted for each boiler while firing fuel oil.

C. Each boiler will be started with fuel oil while atomizing the oil with compressed air. Once stable operation has been achieved with fuel oil and compressed air atomizing media, the atomizing media shall be changed from compressed air to steam while continuously operating. Once stable operation has been achieved with fuel oil and steam atomization, the fuel shall be changed to natural gas.

Once stable operation has been achieved with natural gas, the fuel shall be switched to fuel oil with steam atomization.

D. The Owner's representative will witness and collect data during testing of the performance of each boiler.

E. Acceptance of the performance for each boiler will be demonstrated by the following:
   1. The boiler delivers at or above the specified steam output at a pressure of 125 psig when firing natural gas and operating at MCR.
   2. The boiler delivers at or above the specified steam output at a pressure of 125 psig when firing fuel oil and operating at MCR.
   3. The calculated efficiency of the boiler is eighty-two percent (82%) or more based on the simple output/input method. The calculations for efficiency will be developed by the Owner's representative. The Manufacturer will have access to the data collected to calculate efficiency.
   4. The boiler is capable of operating successfully during each of the conditions specified in Paragraph 3.10.C of this Specification.

3.10 OWNER TRAINING

A. Provide a factory trained field service technician on site for a period of ten (10) days to conduct training of up to twenty (20) owner designated operators and/or maintenance personnel at no additional cost to the Owner. The Owner shall have the option of splitting up the ten (10) days of training into two (2) different weeks at no additional cost.

B. The field service technician will instruct the Owner's personnel in the operation and maintenance of the equipment and systems during the prescribed training. The Operations and Maintenance Manuals submitted by the Manufacturer will be reviewed with the Owner's personnel during the training sessions.

C. This training effort will be conducted separately from all start-up and testing services provided by the Manufacturer.

3.11 EMISSIONS TESTING

A. All testing of emissions from the boilers will be conducted by a third party agency contracted by the Owner.

B. At the Manufacturer's discretion, the Manufacturer may have personnel on site during the testing for emissions to witness the testing.

C. Emissions testing will be conducted as soon as practical, but no later than one-hundred and eighty (180) days after start-up and commissioning.

D. The results from the emissions testing must demonstrate emission levels at or below those specified within this Specification.

3.12 RETURN SITE VISITS

A. The Manufacturer's field service technician shall make six (6) return site visits of one (1) week each, to the steam plant in the calendar year following the

Phase All Substantial Completion. The site visits will be for the purpose of making adjustments to the equipment, providing additional training to the plant operators, or to address other issues of concern of the Owner. These visits are to be performed without additional cost to the Owner.

3.13 OPERATION AND MAINTENANCE MANUALS:

1. Provide Operation and Maintenance (O&M) Manuals including cut-away drawings of boilers, boiler piping diagrams including fuel trains, complete boiler electrical wiring diagrams with interface points, controls sequences and schematic diagrams with interface points, component cut-sheets, complete spare parts lists, maintenance procedures/intervals, inspection procedures, safeties testing procedures, and trouble- shooting procedures.

END OF SECTION