**SECTION 23 09 00**

**INSTRUMENTATION AND CONTROL FOR HVAC**

**\*\*(Based on two-cell cooling tower sized at 50% each, three open loop pumps each at 50%, three closed loop pumps at 50% open and closed loops, one heat exchanger, two risers to the building (no separate tenant, maybe pony pump)**

**PART 1 GENERAL**

1. **DESCRIPTION** 
   1. All work specified in this Section is governed by the Common Work Results for HVAC Section 23 05 00.
   2. This Section 23 09 00 and the accompanying drawings cover the provision of all labor, equipment, appliances and materials, and performing all operations in connection with the construction and installation of the Building Automation System (BAS) as specified herein and as shown. This work includes, but is not limited to the following:
      1. Web enabled access platform
      2. Remote network access capability
      3. System software and graphics (on Owner central server)
      4. Control panels (main and remote)
      5. Space thermostats
      6. HVAC system sensors
      7. Control valves and dampers with actuators
      8. Life safety shutdowns and interlock wiring
      9. Relays, contactors and transformers
      10. Wiring (24 and 120 volt)
      11. Point capacity for future interior fit-up
      12. Point capacity for lighting control including future exterior and tenant fit-up
      13. Point capacity for future Owner use
      14. Computer for Owner control and access
2. **SCOPE OF WORK**
   1. The scope of work includes, but is not limited to, provision of all equipment, hardware, software, programming and graphics for a complete system of automatic temperature and pressure control, energy management and integrated life safety functions. The BAS shall be performed by a central operating system (program software) installed on a central server provided under this scope and by separate central and remote panels, controllers, relays, etc.
   2. The control system shall be a 100% electronic DDC system.
   3. The BAS shall include control points and interlocks for the following as a minimum. Additional points shall be provided as required to implement the sequence of control and code required control functions. Any necessary sensors, probes, etc. shall be installed to implement the sequence of control and noted points:
      1. Vertical self-contained units (variable air volume)
         1. Start/Stop control with positive status indication
         2. Supply air temperature
         3. Return air temperature
         4. Outside air temperature
         5. Mixed air temperature (mechanical room)
         6. Mixed air humidity (mechanical room)
         7. Entering Water Temperature
         8. Leaving Water Temperature
         9. Dirty filter alarm
         10. Refrigerant pressures / alarm
         11. All control damper status and position
         12. Interlock with Fire Alarm System
         13. Air static pressure (at unit discharge)
         14. Air static pressure (remote)
         15. High/low static cutout switch
         16. Adjustable point for duct static pressure control
         17. Adjustable point for supply air temperature control
         18. \*\*Adjustable point for outside air terminal unit (morning warm-up/cool down demand control ventilation, etc.)
         19. Separate start/stop point for Tenant fan powered and variable air volume (PIU & VAV) terminal unit control for night setback, override, fire alarm shutdown, etc.
         20. Fan variable frequency drive status and speed
         21. \*\*CO2 Sensor set point and reading (where applicable)
         22. Unit compressor status (on/off)
         23. Alarm outputs
         24. All wiring for above
      2. Water Source Heat Pumps (constant volume)
         1. Start/Stop Control with positive status indication
         2. Supply Air Temperature
         3. Return Air Temperature
         4. Outside Air Temperature
         5. Mixed Air Temperature (duct)
         6. Mixed Air Humidity (duct)
         7. Entering Water Temperature
         8. Boilerless Controls for transition from heat pump heat to auxiliary heat
         9. Dirty Filter Alarm
         10. \*\*Outside air airflow station
         11. All Control Damper Status and Position
         12. All Control Valve Status and Position
         13. All Wiring for above
         14. Interlock with Fire Alarm System
         15. \*\*Electric heating coil: on / off and status
         16. Thermostat set point and space temperature
         17. Night set back control
         18. Adjustable point for outside air terminal damper (morning warm-up/cool down, pressure control, etc.)
         19. Tenant override control
      3. Condenser Water System:
         1. CWS and LWS Temperature (open and closed loops)
         2. CWR and LWR Temperature (open and closed loops)
         3. CWS Temperature Setpoint, Open and Closed Loops
         4. Adjustable point for CWS Temperature Reset, Open and Closed Loops
         5. All automatic control valves
         6. All flow and differential pressure switches
         7. HX entering water temperature (hot and cold side)
         8. HX leaving water temperature (hot and cold side)
         9. Economizer cycle status
         10. Outdoor air enthalpy
         11. Outdoor air temperature
      4. Open and Closed Loop Condenser Water Pumps
         1. Automatic lead/lag switchover for each of the closed and open systems
         2. Automatic start of lag or standby pump upon lead pump failure based on differential pressure switch at each pump
         3. Start/stop status
         4. System differential pressure sensor and setpoint for each of the closed and open systems
         5. VFD speed and status
      5. Cooling Tower
         1. Cooling Tower start/stop each tower and each speed (variable frequency drive status)
         2. Cooling tower isolation valve position (open/closed)
         3. Cooling tower basin temperature (each basin)
         4. Cooling tower basin water level (low/standard)
         5. Cooling tower basin high water level alarm
         6. Cooling tower basin low water level and condenser water pump not running alarm
         7. Cooling tower basin heater status (on/off)
         8. Cooling tower lead/lag/standby status
         9. Cooling tower fan vibration alarm
         10. Water treatment system interlock
         11. \*\*Sand filter / centrifugal filter motor-operated valves
      6. VAV and PIU Systems:
         1. Sensors and all associated wiring
         2. Thermostat set point and space temperature
         3. Tenant override control
         4. Night setback, Morning warm up/cool down control
         5. Discharge air temperature
         6. Primary airflow CFM
         7. Fan status
      7. Split System Air Conditioning Units
         1. Sensors and all associated wiring
         2. Thermostat set point and space temperature
      8. Mini-Split System Air Conditioning Units
         1. Space temperature
      9. Energy Recovery Ventilator – (\*\*Energy Wheel Only)
         1. Supply air temperature and humidity
         2. Supply fan VFD speed and status
         3. Supply air temperature setpoint, interlocked with central HVAC supply air setpoint
         4. Exhaust duct static pressure sensor and setpoint
         5. Exhaust air temperature and humidity
         6. Exhaust fan VFD speed and status
         7. Enthalpy wheel VFD speed / \*\*starter and status
         8. Outside air damper position
         9. Exhaust air damper position
         10. Wheel rotation sensor and alarm
         11. Air static pressure (at unit discharge)
         12. Air static pressure (remote)
         13. High/low static cutout switches
         14. Adjustable point for duct static pressure control
         15. Building lobby pressure sensor
         16. Building pressure sensor located on a typical floor
         17. \*\*Outside air bypass as applicable
      10. Domestic Water Booster Pump System:
          1. Operation status of pumps
          2. System discharge pressure
      11. Elevator Sump Pump System
          1. Pump operation status
          2. Sump level alarm via paging/email to Owner designated Employee
          3. Pump failure alarms
      12. Life Safety Controls
          1. Interlocks to the life safety controls
          2. Interlocks to the fire alarm system provided under Division 28
          3. Required interface to high rise fire control panels
      13. Emergency Power System
          1. Transfer switch status (life safety \*\*and future tenant)
          2. Generator status and alarms (via Generator communication card)
      14. \*\*\*\*Electrical Distribution
          1. Interface to switchboard power monitoring system
          2. Interface for meters and submeters as indicated and in coordination with Division 26
      15. Lighting Control
          1. Interface to all lighting control panels or breakers
          2. \*\*Lighting control panel status and alarms
          3. Exterior lighting control based on daylight sensor and/or daily dawn/dusk schedule
      16. Miscellaneous Points
3. **BAS SYSTEM MEMORY \*\*AND GENERATOR BACK-UP**
   1. BAS system CPU and controllers are \*\*not required to be provided with emergency power unless required for life safety. All CPUs, controllers, etc. are required to be provided with internal memory as described below.

* 1. System re-boot after power outage shall be adjusted to allow proper restart of operation of all systems.

1. **AUTOMATIC SHUTDOWNS**
   1. All recirculating air systems (self-contained units, air handling units, outside air units, heat pumps, PIUs, fan coil units etc.) which supply air to paths of egress (exits, corridors, lobbies, etc.) shall be provided with smoke detectors in the supply and all return air paths for automatic shutdown of that system in the event of smoke detection.
   2. All recirculating air systems (self-contained units, air handling units, outside air units, heat pumps, PIUs, fan coil units, etc.) having a design airflow capacity of 2,000 CFM or greater shall have smoke detectors installed to detect the presence of smoke and automatically stop the fan(s):
      1. In the supply system downstream of the filters
      2. In the return system at each point of entry into the common return prior to any mixing with outside air
   3. Smoke detectors shall be furnished by Division 26 for installation under this Division 23 in accordance with NFPA 72E. All smoke detectors shall be connected to the Life Safety System in accordance with the requirements of the NFPA Signaling System Standards (NFPA 72) such that actuation of any smoke detector will sound the Fire Alarm. No system shall restart until the Fire Alarm controls are reset. Coordinate interlocks (quantity, location, etc.) with Division 28.
   4. Activation of any smoke detector shall sound an audible alarm in a normally occupied area of the building.
   5. Detector trouble condition shall be indicated visually or audibly in a normally occupied area of the building and shall be identified as air duct detector trouble.
   6. Smoke dampers shall be installed in systems over 15,000 CFM capacity serving multiple floors to isolate the air handling equipment (including filters) from the remainder of the system so as to restrict circulation of smoke and arranged to close automatically when the system is not in operation.
   7. Dedicated smoke detectors or interface to area smoke detectors shall be provided for all smoke and fire/smoke dampers. Special attention is called to smoke and fire/smoke dampers installed in vertical shaft openings. Interlock or detector shall be provided in compliance with code. Coordinate with Division 26 for interlock as required.
   8. All system shutdowns shall comply with required Building Code, NFPA, Authority Having Jurisdiction, and Fire Marshal requirements.
   9. All life safety dampers shall fail to their safe position on loss of power.
2. **INTENT**
   1. It is the intent of this Section of the specifications to provide a complete, operable, adjusted Automatic Control and Energy Management System as shown and specified which is free of hunting and excessive cycling.
3. **SYSTEM ENVIRNOMENTAL REQUIREMENTS**
   1. All control system devices, sensors, controllers, wiring, relays, etc. shall be selected for the environment for which they are installed (indoor, outdoor, ventilated space, etc.). An appropriate enclosure shall be provided where required. Systems installed in return air plenums shall meet ASTM 84E requirements for smoke / flame development.
4. **ACCEPTABLE MANUFACTURERS**
   1. Basis of design is the Trane Summit facility management system.
   2. Acceptable substitute manufacturers for the automatic controls and BAS are Honeywell (Tridium AX / Niagra platform), Schneider Electric, Carrier, and Automated Logic Controls.
   3. The BAS shall be installed by technicians who are either directly employed by the manufacturer or are properly trained technicians in the direct employ of an authorized dealer and installer for the manufacturer.
5. **OPEN PROTOCOL REQUIREMENTS** 
   1. The new BAS shall utilize an open protocol communication system (BACnet, LonTalk) and shall be an open platform for interface by multiple component suppliers and integrators.
   2. The open protocol access shall be to the extent that any control system integrator may access and interface with the BAS without the need for proprietary controller, hardware, software, etc.
   3. Common access and integration tools shall be able to be utilized to interface with the system.
   4. The system shall not require sole source or proprietary device suppliers.

* 1. The BAS system installer shall indicate any and all proprietary devices in their package that may not meet this requirement in the proposal response. Should proprietary devices or software limit the open protocol concept, that system shall be removed from consideration for this project.

1. **NEW SYSTEM SOFTWARE UPGRADES**
   1. Control system software updates shall be included with no additional future cost, annual maintenance agreement, etc. This includes routine program updates for improvements, maintenance, etc. It is not intended to include a major upgrade to a new platform. The intent is to allow for indefinite system operation without required upgrade to a new platform.
2. **PROJECT PRICING AND SUBMITTAL** 
   1. Project pricing and scope of work descriptions shall be provided to the Owner. The scope description should refer to this specification and state the complete scope included comprehensively. Items excluded shall be outlined in the pricing.
   2. \*\*Provide unit pricing for terminal unit integration on a per terminal unit basis (PIU and VAV boxes).
   3. \*\*Provide unit pricing for installation of additional controllers (all included).
   4. Provide confirmation of point capacity as required in this specification. Confirmation shall be based on all known projects, including known future project upgrades. It is the intent that adequate point capacity be included for reasonable flexibility without the need to add network controllers or other devices on an ongoing basis.
   5. The control system shall be submitted to the Owner and Engineer for approval. The submittal shall include all hardware, point list summaries, wiring diagrams, control diagrams, sequence of operation, etc. for the entire system. The submittal shall be a supplement to this specification and included as an attachment to represent the project as-built condition.

**PART 2 PRODUCTS**

1. **WEB ACCESSIBLE FACILITY MANAGEMENT SYSTEM**
   1. The BAS system shall be fully accessible from a secure user computer workstation on the Owner network or any station with secured internet connection via a standard web.
   2. Software installation and setup shall be by the Controls Contractor on a PC workstation, laptop, or server located as directed by the Owner.
   3. Control communication shall be on an independent LonTalk or BacNet network. Control contractor shall review system interface and communication protocol with the Owner’s IT representative to gain a full understanding of any communication parameters or interface required to the Owner’s network.
   4. Any access to the Owner’s network shall be coordinated before and during construction.
2. **MINIMUM STANDARDS**
   1. BAC Net or Lon compliant per ASHRAE / ANSI standard 135.
   2. The BAS shall be capable of controlling multiple building functions such as lighting, alarm systems and HVAC equipment.
   3. The BAS shall be modular and shall permit modular expansion of both capacity and functionally through the addition of sensors, actuators, stand-alone DDC panels.
   4. The system architecture shall eliminate dependence on any single device for alarm reporting and control execution.
   5. The system shall provide global setpoint and schedule modifications and pop-up operation sequence for any device shown by graphic.
   6. This Division 23 scope shall include all integration, coordination, programming, etc. for systems and equipment installed as part of the base building scope, as well as pre-programming and integration of typical future systems.
   7. \*\*The BAS shall include unlimited data point license analytics and fault detection and diagnostics (FDD) software.

1. **CENTRAL CONTROL PANEL (CCP)**
   1. The function of the Center Control Panel (CCP) shall be to provide global commands and data for the Remote Control Panels (RCP) and to allow for remote communication with central server software (see 2.1 above). Provide all required data communication devices for communication between CCP and the server system. Communication between the server system and CCP is via the Owner’s communication network.
   2. The CCP shall contain the complete building operating system so that continuous connection to the user workstation is not required for normal operation.
   3. The CCP shall contain the system scheduling functions subject to central system software.
   4. The CCP battery backed by a self-charging battery system for uninterrupted operation upon power outage. This system shall be capable of all system functions for a minimum of 7 days. The control contractor shall reprogram CCPs should a memory failure occur during the first five years of system operation. This reprogramming shall be at no cost to the Owner.
   5. The CCP shall continuously scan all remote control panels (RCPs) and zone control panels (ZCPs) storing field data and alarms to allow for quick retrieval by the central server software.
   6. All communication ports for the CCP shall be provided with lightning protection devices. These devices shall include gas discharge diodes and metal oxide varisters and shall be capable of suppressing spikes up to 1000 V in less than 100 nanoseconds.
   7. High resolution color graphics shall be provided as described in this specification. These graphics shall be dynamic displaying the most current data on the screen. Set points shall be changeable through these color graphic screens. Provide a manual control menu to allow the Operator to manually turn on or off points, start and stop equipment, manually adjust outputs, restart control calculations, or release points to automatic control.
   8. The CCP shall be able to inform the Operator of communication failures between CCP, CCP and RCPs, and CCP and ZCPs. Statistics on these communications shall be maintained and stored in the CCP to aid in the identification of problems in the communication wiring.
2. **REMOTE CONTROL PANELS (RCPs)**
   1. Stand-alone Remote Control Panels (RCP) shall be provided on all HVAC system equipment, air handling unit, fan coil unit, etc.
   2. RCPs shall be standalone controllers responsible for all input/output and local control loop algorithms. Control programs for local control shall be contained in the RCP so that control is maintained should communication with the CCP be lost.
   3. The RCP battery backed by a self-charging battery system for uninterrupted operation upon power outage. This system shall be capable of all system functions for a minimum of 7 days. The control contractor shall reprogram RCPs should a memory failure occur during the first five years of system operation. This reprogramming shall be at no cost to the Owner.
   4. Control programs shall be stored in nonvolatile yet changeable EEPROM type memory. Set points for all control loops shall be changeable in the field by the owner using an Contractor provided laptop. Provide all interface devices and software so that these changes can be made. DDC controllers requiring their programs to be downloaded from the RCP are not acceptable.
   5. Provide a means for Operator interface to provide local display and adjustment of all inputs, outputs and set points.
3. **ZONE CONTROL PANELS (ZCP)** 
   1. Zone control panels shall be provided for each terminal unit to provide standalone control of that unit. These controllers shall have point capacity as required to accomplish the specified sequence of operation and point list.
   2. ZCP software shall be non-volatile yet changeable EEPROM type memory. Systems using non-changeable ROM or battery backed RAM are not acceptable due to servicing problems.
   3. The ZCP battery backed by a self-charging battery system for uninterrupted operation upon power outage. This system shall be capable of all system functions for a minimum of 7 days. The control contractor shall reprogram ZCPs should a memory failure occur during the first five years of system operation. This reprogramming shall be at no cost to the Owner.
   4. All control devices mounted in the return air plenum including the ZCP shall be UL rated for use in return air plenums. Provide evidence of the UL rating during the submittal process.
   5. \*\*Contractor provided laptop shall be programmed with necessary software to allow the operator to plug into the zone temperature sensor and read inputs and outputs, adjust set points, and manually operate the associated terminal unit.
   6. Controls for the terminal units shall be mounted, wired, and tested by the terminal unit manufacturer. Provide the terminal unit manufacturer with control devices, point-to-point wiring diagrams, and a checkout simulator board to aid in the control installation.
4. **VARIABLE FREQUENCY DRIVES**
   1. Variable frequency drives shall be networked to the control system through a network (BACNet, etc.) and shall also be hard-wired to the nearest control panel.
5. **HVAC SYSTEM SENSORS**
   1. Sensors shall be high accuracy, (plus or minus 0.1%), resistance temperature type.
      1. Mixed air sensors shall be of the averaging type with a 22-foot minimum element strung evenly across the entering side of the coil bank and securely attached.
      2. Discharge air sensors shall be insertion type sensor mounted in a location that will permit measurement of an average discharge temperature as tested by the AHU manufacturer or shall be an averaging sensor with 20 foot element strung and evenly spaced across the discharge duct.

* + 1. Outside air sensor shall be a mounted in a shaded location in a weatherproof housing.
    2. Mixed air low limit thermostat shall be the manual reset type with a minimum 20-foot multi-point sensing element, securely and evenly spaced across the entering side of the coil bank. Provide multiple low limits when coil face area exceeds 16 square feet and factory wire in series.
    3. Pressure sensors and remote HVAC system sensors shall be selected for the required environment (duct mounted, plenum rated, etc.).

1. **ACTUATORS**
   1. Damper and valve actuators shall be low-voltage electronic, positive positioning, spring return, positive closure; factory selected, mounted and tested for proper operation based on unit size, type, and torque requirements.
   2. Coordinate stroke speed, torque, etc. with equipment manufacturer for application.
   3. Line voltage (120V) devices shall be provided for actuators that require higher capability than low voltage actuators can provide. Electrical connection shall be coordinated with Division 26.
   4. Actuator power shall be provided and installed by the Controls SubContractor and coordinated with Division 26.
2. **CONTROL VALVES**
   1. Control valves shall be provided with electronic low-voltage, positive positioning, full modulation, positive closure, spring return, actuators selected for the valve body and service. Valve bodies shall be 3-way or 2-way (as indicated); normally open or normally closed to suit application. Valves shall meet the requirements of specification 23 21 00.
3. **ROOM SENSORS AND THERMOSTATS**
   1. Room sensor and thermostat cover type and color shall be as directed by the Architect. All space temperature sensors shall be provided with a user temperature adjustment wheel or push button, LCD readout, and zone override.
   2. Sensors in public spaces shall be thermistor “button” type, without screen, user adjustment, or wall box. Coordinate button finish with Architect.
   3. Refer to design documents and equipment schedules for specialty area sensor requirements.
   4. Thermostats for wall heaters, unit heaters and ventilating fans shall be line-voltage, low-voltage type to control the fans, heaters, etc. indicated. Thermostats shall be single or dual temperature as required for each specific application. Thermostats for heating-only and ventilation-only service shall have adjustable dead-bands to provide at least 5°F between ON and OFF to prevent short-cycling. Dead band dual-temperature thermostats shall be used to control all services having both heating and cooling/ventilating functions. Covers shall be plain with concealed set points.
   5. Thermostats shall be located where shown. Where installed on an exterior wall or partition, the sensor shall be provided with an insulated backing to avoid influence by wall cavity temperatures.
   6. Thermostat and sensor elevation shall be as directed by the Architect.
4. **PRESSURE SENSORS**
   1. Duct static pressure sensors shall be located within the ductwork in a representative location and shall have an installed accuracy of + 5% over the normal operating range of the sensed medium. These sensors shall be capable of withstanding 200% of the maximum pressure of the system.
5. **HUMIDITY SENSORS**
   1. Electronic humidity sensors shall be provided as required to provide installed accuracies of + 3% from 10 to 90% relative humidity. Humidity sensors shall be capable of recovering from complete saturation without changing calibration point.
   2. Space humidity sensors shall be provided with a cover similar to the space sensors with no user adjustment capability. Humidity sensors in lobbies and high finish public areas shall be remote type similar to temperature sensors.
   3. Where thermostats and humidity sensors are co-located, they may be a combination sensor meeting the requirements of the applicable sections.
6. **LIGHTING CONTROLS**
   1. \*\*Lighting control panels provided by Division 26 shall be provided with an interface to the BAS system. This Contractor shall coordinate the necessary requirements with Division 26. All zone control programming shall be by Division 26. BAS system tie-in and on/off control shall not affect lighting control panel programming.
   2. \*\*Lighting control breakers provided by Division 26 shall be provided with interface to the BAS system. This Contractor shall coordinate the necessary requirements with Division 26. All zone control programming shall be by Division 26. BAS system tie-in and on/off control shall not affect lighting control panel programming.
7. **CONTROL SYSTEM CAPACITY**
   1. Provisions shall be made for future Tenant system integration. Reasonable future system expansion/integration shall be possible without the need for additional CPUs or main system controllers. Contractor shall review interior system drawings to determine the general scope. Provide a summary scope for accommodating future systems as part of the system submittal.

**PART 3 EXECUTION**

1. **INSTALLATION**
   1. The controls shall be installed in strict accordance with the Manufacturer's recommendations.
   2. The control system shall be completely wired under this Division 23. Wiring shall be in accordance with the NEC and shall meet all requirements for this installation.
   3. This scope shall include wiring of all cooling-only terminal units, regardless of voltage. Coordinate with the terminal unit submittal and Division 26.
2. **SOFTWARE CAPABILITIES**
   1. General Operation
      1. The central control panel (CCP) shall have the following control routines:
         1. Time-of-day scheduling
         2. Remote scheduling override
         3. Temperature control
         4. Night setback and Occupied/Unoccupied sequences
         5. Optimum start and optimum stop
         6. Demand limiting
         7. Temperature compensated duty cycling
         8. Analog monitoring
      2. The program shall be based upon a Georgian calendar and it shall provide automatic leap year compensation. It shall automatically set forward for daylight savings time and setback for standard time.
   2. Anti-recycle Equipment Protection Timers
      1. Protection of each HVAC unit shall be provided through individually programmable "minimum on", and "minimum off" timers. These shall have the highest priority over the software functions. All timers shall be individually programmable from 0 to 120 minutes.
   3. User Access
      1. User access shall be through the use of a prompted, menu driven, English language communications routine. Entries will be made on the unit-mounted keypad with liquid crystal display (LCD).
      2. The control program shall have individual security passwords. It shall be partitioned into multiple levels of user access with data entry restrictions being assignable by password. User log on/log off attempts shall be recorded.
      3. The automatic controls and BAS shall be remotely accessible through an internet browser. Access shall be provided as outlined above.
   4. Time-of-Day Scheduling
      1. Full calendar / holiday scheduling capability shall be provided and shall be user adjustable.
   5. Optimum Start/Stop
      1. The optimum start/stop program shall determine start/stop timing by comparing inside/outside temperatures and building historical data. Optimum start/stop shall be done for each zone independently.
   6. Analog Monitoring and Control
      1. The central control panel shall be able to monitor any analog sensor whose control format is based upon a variable resistance, current, or voltage signal. Each analog input shall have a day and night, and high and low alarm limits.
      2. The control program shall have the functions of day and night temperature control and optimum start and stop. In all cases, it shall be able to initiate contact closure and/or adjust equipment operation based upon occupied (day) and unoccupied (night) heating and cooling set points. The program shall include user selectable dead bands for automatic adjustment of demand, night setback and duty cycling strategies based upon deviation from zone temperature.
   7. Trend Prints
      1. The system shall be able to monitor and independently generate trend prints for up to twenty (20) independent parameters. A sampling period from 5 seconds to 24 hours shall be assignable to each load, with a total sampling period of at least 120 days or 50,000 points, whichever is less. Trends shall be able to be saved and exported to a user-friendly Excel file format.
3. **SEQUENCES OF OPERATION** – This sequence is an outline of the major equipment basic operation.
   1. Condenser Water System
      1. Mechanical refrigeration system shall be automatically controlled by the central server, CCP and remote devices based on Owner provided schedules and parameters. The basic operation shall be based on scheduled Occupied and Unoccupied modes.
      2. On a start signal, the central control panel shall initiate the following sequence:
         1. The lead open condenser water pump shall be energized and running pending confirmation of cooling tower isolation valve being fully open. The lag open condenser water pump shall energize as needed to maintain differential pressure setpoint. Pump shall alternate lead/lag/standby duty on a daily basis. The standby pump shall remain off unless there is a failure of the lead pump during the day. The standby shall energize on a lead or lag pump failure and an alarm message shall be sent to the CCP.
         2. The lead closed condenser water pump shall energized based on a 24/7 schedule, adjustable, and/or upon a LWR temperature of 97°F (adjustable) or above. The lag closed condenser water pump shall energize as needed to maintain differential pressure setpoint. Pump shall alternate lead/lag/standby duty on a daily basis. The standby pump shall remain off unless there is a failure of the lead pump during the day. The standby shall energize on a lead or lag pump failure and an alarm message shall be sent to the CCP.
         3. The open loop condenser water system shall be put into occupied mode at a closed loop water temperature of 95°F, adjustable, and may go back to unoccupied if overall schedule allows at a close loop water temperature of 90°F, adjustable, subject to a minimum run time of 30 minutes (adjustable).
         4. Cooling tower isolation valves for CT-01 or CT-02 (lead tower cell) shall open and the fan shall energize and ramp up to full speed. A temperature sensor with its sensing element in the condenser water suction piping at the cooling towers shall modulate the fan speed to maintain open loop set point temperature in the open loop piping. If the lead cooling tower cell is not able to maintain leaving setpoint temperature for more than 5 minutes (adjustable), the lag cooling tower cell shall be energized and the cooling tower fans shall modulate together. The lag open loop pump shall be energized. The tower fan motor(s) shall de-energize in a similar reverse sequence at a temperature of 2°F (adjustable) below their "start" setting and the lag cooling tower shall be de-energized and isolation valves closed when the fans are below 40% speed (adjustable) for more than 5 minutes (adjustable).
         5. Upon failure of any tower fan speed to automatically start, the next tower fan in sequence shall automatically start and an alarm signal shall be sent to the CCP.
         6. Open loop pump shall ramp up to maintain required system differential pressure. The lag open loop condenser water pump shall energize if pressure cannot be maintained by the lead pump. Standby pump shall enter the operational rotation upon failure of any lead or lag pump. Lag cooling tower shall be brought on as needed to not exceed maximum cooling tower flowrate.
         7. Open loop differential pressure sensor shall located across the heat exchanger .
         8. Closed loop differential pressure sensors shall be location at the most remote representative self-contained unit or heat pump / coil on each branch line. The location shall be representative of the most pressure drop to allow for proper delivery of loop water to all loop coils. Additional pressure sensors shall be provided in branch lines as required to ensure adequate delivery at the lowest optimum required pressure drop.
         9. The system shall be provided with differential pressure setpoint reset sequence for the closed loop. The BAS shall poll all control valves and adjust the setpoint accordingly for the critical valve. Sequence shall be in accordance with ASHRAE 90.1.
         10. Upon proving condenser water flow through differential pressure type flow switches in each unit, the self-contained unit or heat pump may start, subject to its time schedule and any override mode.
         11. Cooling towers shall alternate lead/lag status weekly to maintain equal runtime hours.
         12. \*\*If the condenser water in the tower basin falls to 35°F (adjustable), the tower bypass valve shall open, and the water shall go into the basin and not over the fill.
      3. Waterside Economizer
         1. Waterside economizer shall be controlled by an outdoor air enthalpy sensor. Economizer cycle shall be energized at an outdoor air wet bulb of 60°F (adjustable).
         2. The cooling tower fan shall be energized and all tower fans shall run when the basin water temperature is above 46°F (adjustable). Fans shall operate to maintain economizer mode condenser water temperature. If the lead cooling tower cannot maintain WSE setpoint for more than 10 minutes (adjustable), the lag cooling tower shall be energized and operate similarly and fans shall modulate together. If the WSE setpoint is maintained and fans are less than 40% speed (adjustable) for more than 5 minutes (adjustable), the lag cooling tower shall be de-energized and isolation valves closed.
         3. No tower fans shall run when the outside air wet bulb falls below 33°F (adjustable) or the basin water temperature is less than 41°F (adjustable).
         4. The waterside economizer is de-energized when the outdoor air web bulb rises above 62°F (adjustable). The automatic changeover returns the system to its normal operation.
   2. Self-Contained Units (variable air volume)
      1. Each Self-Contained Unit shall be controlled by its dedicated, stand-alone Direct Digital Control (DDC) Remote Control Panel (RCP) which shall contain all hardware and software to control each unit as outlined in this sequence of operation. Each unit control system, including the RCP, shall be completely wired, programmed and tested. The DDC control system shall provide the following:
         1. The RCP shall be capable of communications to the central control panel to accomplish the following:
            1. time of day scheduling
            2. optimal start/stop
            3. demand limiting
            4. custom programming
            5. run time and maintenance
            6. duty cycle program
            7. alarm messages
            8. diagnostic functions
            9. report and logs
            10. after hours operation time logging
         2. Units shall operate on a schedule provided by the Owner. Upon start-up the following sequence shall occur:
            1. The fan shall "soft start" the frequency inverter and slowly ramp up to static pressure set point. Associated system terminal units shall be opened to allow fan operation. Terminal units shall modulate to minimum air flow or as required to allow stable fan operation. Duct static pressure sensors shall be provided in each system. Multiple sensors shall be provided if required to maintain proper pressure in systems without a looped duct system.
            2. If space temperature is below morning warm-up (MWU) set point, the outside air fan shall remain off and the outside air VAV shall remain closed until MWU set point is reached. The air handling unit cooling cycle shall be locked out. Terminal units shall operate in heating mode, with the supply air valve fully open to circulate air and provide space heat.
            3. If space temperature is above morning cool-down (MCD) set point, the outside air fan shall remain off and the outside air VAV shall remain closed until MCD set point is reached. The air handling unit cooling cycle shall operate to provide normal cooling. Terminal units shall operate in cooling mode to provide space cooling.
            4. Once space warm up/cool down set point is achieved, the unit shall operate in normal occupied mode. The outside air VAV shall open to its minimum set point air volume. MWU / MCD set point shall be proven through a sampling of exterior and interior terminal units.
            5. A supply air temperature sensor shall be located in the system supply ductwork. The unit shall modulate to maintain duct set point temperature. Set point temperature shall be user programmable.
            6. A supply air temperature reset routine shall be provided to adjust temperature set point in 1°F (adjustable) increments. The CCP shall poll each VAV and PIU terminal served by the air handling unit. If 90% (adjustable) of the terminal units served by the air handling unit are at set point temperature, the duct supply temperature shall be raised by 1°F (adjustable) up to a high limit of 65°F (adjustable). This routine shall occur at a frequency no more than once every fifteen minutes (adjustable) to avoid continual fluctuations in space temperature. The supply air set point shall return to the original supply air set point if the air handling unit reaches 95% (adjustable) of full capacity. There shall be a user input maximum supply temperature that shall not be exceeded under any condition. The air handling unit graphic shall display the original system set point and the currently operating set point.
            7. Provide and install humidity sensor mounted in each mechanical room and/or spaces shall override this sequence if they register relative humidity greater than 55% (adjustable). Upon high humidity levels for more than ten (10) minutes (adjustable), the supply air temperature shall be reset down 1°F (adjustable).
            8. The supply duct static pressure (SP) set point shall be operator adjustable through the RCP. At system start-up the duct static pressure set point shall be at the user programmed setting. The CCP shall poll each VAV and PIU terminal served by the air handling unit to determine the current critical zone. The critical zone is that zone requiring the air valve to be closest to 100% wide open. If no zone has an air valve more that 90% (adjustable) wide open, then the SP set point will be lowered by 5%. This reset will continue every 2 minutes (adjustable) until the system identifies at least one zone at 90% wide open. When the system identifies any zone at or above 95% (adjustable) wide open, then the SP will be raised by 5%. This reset will continue until no zone is at or above 95% wide open. The floorplan graphic shall identify the current critical zone for each VAV system.
            9. Mixed air low limit protection will protect the unit coil from damage by stopping the fan, closing the outside air VAV / damper and closing the condenser water coil valve. A "MA LOW LIMIT" message will be displayed locally on the RCP LCD. Manual reset of the low limit thermostat (freezestat) is required before the unit will start.
            10. An internal, adjustable fan "minimum-off" timer shall prevent cycling of the fan until a minimum off time has elapsed.
            11. Unit internal controls shall operate equipment in normal cooling or economizer mode and switch over without interruption.
         3. \*\*(CALCULATION-BASED) Demand control ventilation controls (where required) shall consist of logic to accomplish the following:
            1. Primary air flow of each terminal unit shall be measured.
            2. The outside air volume provided by the air handling unit outside air VAV boxes shall be measured.
            3. Calculate the proportional outside air volume provided to each zone based on the calculated outside air percentage provide by the air handling unit. Poll all units to determine the highest outside air fraction reported. This fraction defines the critical zone.
            4. Calculate the ventilation efficiency (EV as defined in ASHRAE 62.1-2007) and the required outside air flow rate (VOT as defined in ASHRAE 62.1-2007) and adjust the outside air rate accordingly. High CO2 levels shall be capable of calling for increased ventilation over and above the required outside air flow rate.CO2 sensors shall be provided at each return air opening into the mechanical room. The average CO2 level shall be displayed on the floorplan graphic. If the CO2 sensor measures more than 1,500 ppm (adjustable), the DCV sequence shall be overridden and the ventilation rate shall increase until such a time as the CO2 levels fall below 1,300 ppm (adjustable). The building BAS shall monitor air CO2 concentration at each sensor.
         4. \*\*(CO2 BASED ONLY) CO2 sensors shall be provided at each return air opening into the mechanical room. The average CO2 level shall be displayed on the floorplan graphic. The ventilation rate shall modulate proportionally between 450 ppm (adjustable) and 1,400 ppm (adjustable) from the minimum to maximum scheduled outside air rate. The building BAS shall monitor air CO2 concentration at each sensor. Tenant buildouts shall install CO2 sensors as needed during their build-out. BAS shall have ability to integrate future tenant CO2 sensors for DCV sequence.
         5. When the building is un-occupied or in MWU/MCD mode, the outside air damper shall be closed. When the building is occupied, the outside air VAV terminal unit on each system shall open to the scheduled minimum outside air volume (to maintain building pressure).
         6. As the outside air volume modulates, the pressure relief system terminal unit shall modulate open/closed to maintain positive space pressure. The building BAS system shall monitor the outside air volume and reset the relief air volume accordingly.
         7. \*\*During tenant fit-up, additional CO2 sensors shall be added based on the requirements of LEED-BD+C: Core and Shell v4.1. Controls shall be available for integration of tenant space CO2 sensors for monitoring only, per LEED requirements.
         8. Outside air, pressure relief, and toilet exhaust systems shall operate as described in the building ventilation system description below subject to air handling unit system operating parameters described herein.
         9. The RCP will enter night setback mode (NSB) as scheduled by the CCP. The \*\*outside air, toilet exhaust and pressure relief fans \*\*energy recovery ventilator supply and exhaust fans shall stop and the associated VAV boxes shall close. A NSB message will appear locally on the RCP and/or on the CCP. Night setback temperatures shall be 85°F (summer, adjustable) and 60°F (winter, adjustable) or as required by the Owner for proper space temperature.
         10. If the space temperature drops below the NSB set point, the PIU heating circuits shall be enabled to satisfy the NSB set point (on a floor-by-floor basis).
         11. If the space temperature rises above NSB set point, the associated unit fan shall energize and the cooling mode shall operate to maintain NSB set point temperature (on a floor-by-floor basis).
         12. The outside air VAVs / dampers shall remain closed during NSB.
         13. The RCP shall have failure modes to protect and maintain operation of the air handling unit.
             1. Space sensor failure will disable all reset functions. All other functions will operate as normal.
             2. Mixed air sensor failure will close the outside air VAV and all other functions to operate as normal.
             3. Outside air VAV airflow sensor failure will close the outside air damper to minimum unless overridden by mixed air control loop.
             4. Fan failure will de-energize the fan start and generic binary outputs. A "FAN FAIL" message will appear on the RCP.
         14. Smoke dampers shall be provided in accordance with local code. Each unit shall stop and its dampers close on detection of smoke or fire alarm.
   3. Refrigerant Purge
      1. Upon refrigerant leak detection inside the RTU, the RTU fan shall be engaged and all terminal unit primary air valves shall open to 100%.
      2. During unoccupied, night setback, etc. times the BMS shall open 40% of the terminal unit primary air valves to 100%. The RTU fan shall remain off unless otherwise commanded.
   4. Water Source Heat Pumps and Constant Volume Air Handling Units
      1. This sequence is applicable to all constant volume units. Note that all units are subject to Owner scheduling requirements. Those serving building exits, lobbies, 24/7 spaces, and other critical functions shall be subject to Owner scheduling which may differ from typical office space schedules for occupied/unoccupied and night set back operating parameters.
      2. Each unit shall be controlled by its dedicated, stand-alone Direct Digital Control (DDC) Remote Control Panel (RCP) which shall contain all hardware and software to control each unit as outlined in this sequence of operation. Each unit control system, including the RCP, shall be completely wired, programmed and tested. The DDC control system shall provide the following:
         1. The RCP shall be capable of communications to the central control panel to accomplish the following:
            1. Time of day scheduling
            2. Custom programming
            3. Run time and maintenance
            4. Alarm messages
            5. Diagnostic functions
            6. Report and logs
            7. After hours operational time logging
         2. When scheduled to start normal operation by a switch, the clock or the CCP, RCP will enable the fan and the following functions:
            1. If space temperature is below morning warm-up (MWU) set point, the outside air motor operated damper shall close. The unit cooling mode shall be locked out. The system heat pump shall operate in heating mode to provide space heat except if the condenser water supply temperature from this WSHP falls below the factory boilerless setpoint (adjustable), the WSHP shall shutoff heating in heat pump and electric duct heater shall operate.
            2. If space temperature is above morning cool-down (MCD) set point, the outside air motor operated damper shall close until MCD set point is reached. The unit cooling mode shall operate to provide normal cooling. The electric duct heater shall de-energize.
            3. Normal day operation will then enable the cooling control loop and open the OA damper when MWU / MCD set point is achieved.
            4. In normal occupied operating mode the unit cooling mode and/or heater shall modulate to maintain space thermostat set point setting (75°F, adjustable).
            5. \*\*Duct heaters in the units shall be interlocked and controlled by the same thermostat / sensor controlling the unit. As the space temperature drops, the electric duct heaters shall be energized in stages to maintain the thermostat setting (70°F, adjustable).
            6. Mixed air low limit protection will protect the unit coil from damage by stopping the fan, closing the outside air damper. A "MA LOW LIMIT" message will be displayed locally on the RCP LCD. Manual reset of the low limit thermostat (freezestat) is required before the unit will start.
            7. An internal, adjustable fan "minimum-off" timer shall prevent cycling of the fan until a minimum off time has elapsed.
         3. The RCP will enter night setback mode (NSB) as scheduled by a switch, time clock or the CCP. The \*\*outside air, toilet exhaust, and pressure relief \*\*ERV fans shall stop and the outside air damper shall close. A NSB message will appear locally on the RCP and/or on the CCP. Night setback temperatures shall be 85°F (summer, adjustable) and 60°F (winter, adjustable) or as required by the Owner for proper space temperature.
            1. If the space temperature drifts below the NSB set point, the heating circuits in the duct heaters and the unit fan shall be enabled to satisfy the NSB set point. The outside air damper shall remain closed during NSB. The unit cooling cycle shall be locked out.
            2. If the space temperature drifts above the NSB set point, the unit cooling modes operate to maintain set point temperature. The outside air damper shall remain closed during NSB. The heater shall be de-energized.
         4. The RCP shall have failure modes to protect and maintain operation of the unit.
            1. Space sensor failure will disable all reset functions. All other functions will operate as normal.
            2. Mixed air sensor failure will close the outside air damper and all other functions to operate as normal.
            3. Outside air sensor failure will close the outside air damper to minimum unless overridden by mixed air control loop.
            4. Fan failure will de-energize the fan start and generic binary outputs. A "FAN FAIL" message will appear on the RCP.
   5. Zone Overrides
      1. Overrides shall be provided so that each zone (terminal unit, heat pump, or air handling unit) may be operated independently whenever the HVAC system is in setback or unoccupied mode.
      2. Zone override shall be via a pushbutton on the associated system thermostat.
      3. Activation of any override shall enable occupied mode the associate unit on the selected floor, condenser water system, towers, etc. to operate in occupied mode.
      4. The activated terminal unit and adjacent terminal units selected by the Owner only shall operate to maintain its thermostat settings. Terminal unit grouping shall be capable of being adjusted by the Owner. As a minimum, if no other direction is given all terminal units in the associated quadrant of the floor shall be activated.
      5. The air-handling units and terminal units not activated shall remain in the prior selected mode.
   6. Variable Air Volume (VAV) Units
      1. The VAV units shall be able to modulate from closed position to 100%. Units shall modulate through digital control to provide the required air flow to maintain set point (75°F adjustable, cooling only). The VAV boxes shall be normally closed. \*\*See terminal unit schedule for minimum and maximum design conditions.
      2. VAV units are subject to other system control functions as described herein (NSB, MWU, MCD, etc.).
      3. The outside air VAV units (OAVs) shall report airflow to the BAS. The airflow monitoring device shall be capable of an accuracy of ±5% in the scheduled range of airflows or, at minimum, ±10% of the design. The BAS shall alarm when conditions vary by 10% or more from the setpoint value, after an adjustable timeout.
   7. Powered Induction Units (PIU)
      1. Powered induction units shall have intermittent fan operation (except units serving lobbies, core areas and toilets) and shall modulate primary airflow from 0% \*\*(or scheduled minimum) to 100% to maintain the cooling set point (75°F, adjustable). Below 30% to 40% primary airflow, the fan shall be energized and primary air shall continue to modulate down to shut off; thereby delivering mixed primary and plenum air to the space. After the VAV valve completely closes, plenum air shall be used to meet heating demand. Upon a further call for heat, the heating coil shall be energized to maintain the thermostat setting (70°F, adjustable). \*\*See terminal unit schedule for minimum and maximum design conditions.
      2. Powered induction units serving lobbies, core areas and toilets shall be series type with constant fan operation and shall deliver a constant air quantity to these areas. The VAV valve shall modulate to maintain the cooling set point of the thermostat and the electric heater shall energize to maintain the heating set point.
   8. Split Systems
      1. Split systems shall be controlled by a programmable heating/cooling thermostat (set at 70°F, adjustable). Units shall be engaged as programmed in coordination with the Owner or 24 hours a day if no direction is given.
      2. Space temperature of the machine and controller rooms and run status of the split systems shall be monitored by the BAS system.
   9. Electric Heaters
      1. Unit heaters shall be controlled by unit-mounted thermostats unless noted otherwise. Thermostats shall be set to energize the unit at 65°F set point (adjustable).
      2. Wall heaters shall be controlled by an integral electric thermostat. Thermostats shall be set to energize the unit at a 60°F set point (adjustable).
   10. Building Ventilation Systems (Outside Air / Pressure Relief / Toilet Exhaust)
       1. Building ventilation shall be via \*\*an energy recovery ventilator (ERV) \*\*individual fans. Fans shall operate based on the Owner programmed schedule. This sequence shall be subject to warm-up, cool down, setback, freeze-stats, and other sequences described in the air handling unit sequence of controls above.
       2. \*\*ERV outside air fans shall be energized in coordination with building system operation (occupied/unoccupied) as described above. The fan speed shall be controlled by static pressure sensor located in a representative location in the outside air riser. The fan shall soft start and ramp up slowly to maintain set point pressure (adjustable), to be set during T&B. VAV terminal units located on each floor or each air handling unit shall operate as described in the air handling unit sequences.
       3. \*\*ERV exhaust fans shall be energized by the DDC central control panel; subject to morning warm-up / cool down, night setback, and demand control ventilation sequences described above. The fan shall operate during occupied modes and shall be de-energized during unoccupied modes. The fan speed shall be controlled by static pressure sensor located a representative location in the exhaust air riser. The fan shall soft-start and the variable frequency drive shall ramp up slowly to maintain building pressure. Fan VAV terminal units on each floor for toilet exhaust and pressure relief shall modulate based on demand control ventilation sequences described above.
       4. Outside air, pressure relief, and toilet exhaust terminal unit air volumes shall be monitored and operated to maintain 10% positive airflow at all times while in occupied mode (on a floor-by-floor basis).
       5. Fan systems shall allow for operation of an individual floor if selected for after-hours user override. Additional floors shall be brought online as needed for equipment minimum flow. Coordinate with the equipment Manufacturer and T&B for the minimum airflow.
       6. The ERV shall monitor the unit’s leaving air temperature and shall operate the energy recovery enthalpy wheel to maintain the lowest supply air temperature setpoint used by the self-contained units. This shall be not less than 52°F and shall be able to modulate up to 65°F (adjustable).
       7. \*\*If enthalpy wheel is not required to operate to maintain discharge conditions, the ERV outside air bypass shall be engaged.
   11. Loading Dock Ventilation Fans
       1. Dock ventilation shall be tied into the BAS system for Owner directed scheduling.
       2. Fans shall also be capable of manual operation by a switch located in the Dock Master office. Switch shall be provided with an on/off pilot light.
   12. Stair Pressurization Fans
       1. Fans shall be engaged and controlled by the Fire Alarm system. Upon activation, interlocked motor-operated dampers at intake and pressure relief openings, as applicable, shall open. \*\*Fan VFD shall be interlocked to a static pressure sensor to maintain setpoint (adjustable), set empirically during 3rd party pressurization testing. Coordinate with the Fire Alarm SubContractor.
   13. \*\*Lobby Pressurization Fan
       1. Lobby heating and pressurization fan shall be engaged during occupied times when outside air temperature is less than 40°F (adjustable) and shall modulate to maintain lobby pressure setpoint of 0.05” WC (adjustable). Heater shall modulate to maintain lobby space temperature.
   14. Miscellaneous Fans
       1. Unless otherwise noted, all ventilation fans serving electrical and miscellaneous rooms shall be controlled by a thermostat (set at 80°F, adjustable). Interlock the associated motor operated dampers to open when the fan is running.
   15. Domestic Water Booster Pump
       1. Pump status shall be monitored. An alarm shall be sent to the BAS system upon detection of any pump failure.
       2. A pressure sensor shall monitor pump system discharge pressure.
       3. See specification 22 11 23.13 for booster pump control. Coordinate with equipment supplier.
   16. Startup
       1. Provide the services of a factory trained and qualified service technician employed by the BAS manufacturer who shall inspect the installation including external interlock and power connections; supervise testing, initial operation and calibration of these operating and safety controls.
       2. This service technician shall forward a report in four (4) copies to the Owner when the BAS is in safe and proper operating condition. This report shall include all pressure and control settings, during start and run, and shall list minor discrepancies to be corrected that affect safe and reliable operation. One additional copy of the report shall be left in the central control panel. One copy of bound installation, operation, maintenance service and parts brochures, including applicable serial numbers and parts ordering sources, shall be placed in the central control panel at the time of startup; four (4) additional copies shall be forwarded to the Owner.
4. **CONTROL SYSTEM WIRING**
   1. All control system wiring shall be provided and installed by the Controls SubContractor. Coordinate with all trades. This includes line voltage (120V) and low voltage wiring. Line voltage wiring shall be installed by a licensed Electrician employed by the Control SubContractor or contracted through the Division 26 SubContractor, under this scope.
   2. Coordinate with Division 26 for available circuits for control system power.
   3. Coordinate with the Fire Alarm Contractor for life safety system interface including all code required alarms, shut down, fire control panel interface, etc.
   4. All control wiring shall be installed in strict compliance with Division 26 specifications.
   5. Low voltage wiring in ceiling plenums shall be plenum rated cable and shall be installed in compliance with intended Interior Design finish throughout all tenant spaces.
5. **GRAPHICS** 
   1. Graphics shall be provided for each mechanical system including the all HVAC equipment controlled or monitored by this system. Graphics shall show each point that is monitored. Graphics for each piece of equipment shall be indexed by its name. Additional graphics shall show each floor with zone temperatures. If one graphic is not sufficiently large to capture an entire system or floor then it shall be logically separated into two graphics.
   2. A graphic for each piece of equipment shall be provide and include all system points monitored or required for system function and user interface.
   3. Floor plan graphics shall show all ductwork, diffusers, interior walls, equipment locations, and thermostat locations. Floor plans served by VAV systems shall identify the current critical zone and the current self-contained unit SP setpoint. Functionality of the critical zone reset shall be demonstrated to the Engineer’s satisfaction prior to building acceptance.
   4. System schematics, risers, flow diagrams, etc. shall be included showing overall system parameters.
   5. Electrical risers and floorplans for any and all electrical meters. Coordinate with Division 26.
   6. Floorplans for any and all plumbing and mechanical meters, including water meters, irrigation meters, BTU meters, etc.
   7. Provide sketches of proposed graphics for review by the owner to coordinate the design of these graphics. Existing Owner system graphics shall be used if required by the Owner.
   8. Graphics for the lighting control shall be independent of the mechanical system floorplans. Lighting control graphics shall include lighting control zones shown on an Architectural floorplan. Similar to the mechanical graphic, the lighting control floorplan graphic shall be updated by each Tenant as appropriate. The lighting control system shall have full integration with the BAS for monitoring and control, as required by the lighting control package. \*\*Coordinate lighting control \*\*panel/\*\*controllable breaker output with Division 26 as applicable.
   9. All graphics are subject to the approval of the Owner and shall be submit for review and approval.
   10. The graphics package shall have pre-programmed dashboards with configurable widgets, including but not limited to trend line, bar, and pie graphs, sliders for setpoint, alarm, etc. adjustment, and data tables. The submittal shall have example graphics for each of these items.
6. **SCHEDULES**
   1. All equipment shall be able to be individually scheduled. Coordinate all schedules and breakdowns with the Owner, including for future tenant occupancy.
   2. Contractor shall set up all initial schedules and setpoints in coordination with Owner and Commissioning Agent. Schedules and setpoint adjustment shall be included with Owner training.
7. **OWNER TRAINING**
   1. Refer to the general specifications for training requirements. At a minimum, provide the service of a qualified BAS system technician for three (3), 8-hour days for Owner training. The three (3) days shall be non-consecutive and shall be coordinated and scheduled with the Owner and Commissioning Agent, as applicable.
8. **COMMISSIONING TESTS**
   1. Testing of systems/equipment specified in this Section shall be coordinated, scheduled, and documented in accordance with the requirements of commissioning specifications.
9. **COMMISSIONING DEMONSTRATION**
   1. Demonstration of operation and training of Owner’s personnel in operation and maintenance of systems/equipment specified in this Section is required. Coordination of the demonstration/training by qualified, factory authorized representatives is required with the Commissioning Authority. Instruction shall include a minimum number of hours as specified herein and approval of the formal training program is required by the Commissioning Authority. Refer to commissioning specifications.

**END OF SECTION**