PART 1 - GENERAL

1.1 SUMMARY

A. The local Building Automation System (BAS) provided for this project shall be an addition to the existing base-wide BAS installed in the base. The local BAS in the facility shall be fully integrated into the existing BAS workstation, based on Ascent Compass by Alerton, in Building 43. The contractor shall be responsible for making any modifications to the existing base-wide BAS workstation, which will be necessary to facilitate communications between the server and local BAS. The contractor shall be responsible for configuration, programming and necessary graphical displays for existing BAS workstation for remote control and monitoring of local BAS. Local BAS shall be connected to the existing base-wide BAS via the base network backbone using VLAN and BACnet/IP. Coordinate with COTR and NC ANG IT Department for network connection, system access, security and other requirements.

B. Furnish a BACnet-based BAS, which shall be based on a distributed control system in accordance with this specification. Provide all necessary hardware, software and control devices to execute the sequence of operation and comply with the control diagrams and BAS point function schedule shown on the mechanical drawings. The Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC) and all input/output devices shall communicate using the protocols and network standards as defined by ANSI/ASHRAE Standard 135–2012, BACnet. In other words, all controllers, including unitary controllers, shall be BACnet devices. The building controller shall communicate with the existing base-wide BAS workstation in Building 43. This Section includes building controllers and application controllers capable of monitoring and controlling all HVAC equipment indicated.

1. Provide BC, AAC and ASC for control of HVAC equipment, including but not limited to, make-up air units, air handling units, terminal units, exhaust fans and heating hot water system. When more than one HVAC unit is controlled from a single panel, provide separate power fuses for each controller within the panel. Also, provide a separate fuse for the power supply to each unit’s control and sensing points not powered through the controller, so a blown fuse will only affect the operation of a single HVAC unit.

2. Each BC and network hardware such as Ethernet switch and router provided for the BAS shall be provided with an Uninterruptible Power Supply (UPS) that can supply electrical power for at least four hours to the attached load.

3. Any software provided shall be of the latest available version for the BAS installed in the building.

4. BC, AAC and ASC shall be capable of accepting analog and digital inputs and shall provide analog and digital outputs in accordance with the control diagrams and the “BAS Point Function Schedule.”

5. The controllers shall be distributed in such a manner that no more than one major mechanical system component, including but not limited to MAU, AHU and VAV box, shall be controlled and monitored using a single controller. Loss of one controller shall not cause the loss of another mechanical system component.
6. Provide BAS control wiring and conduit for this system as described in Part 3, “3.2 Electrical Installation” of this Section. 120 VAC power circuits are provided for BCs and AACs under Division 26 as shown on the electrical plans. In addition, power circuits are provided for multiple ASCs under Division 26 as shown on the electrical plans. ASCs for the Fan Powered VAV Boxes to be powered from fan power circuit. Provide additional 120 VAC control power circuits when required for proper operation of the BAS. The control system installer shall make connections as necessary to complete the system.

C. Related Sections include the following:

1. Division 01, "General Requirements" contains requirements that relate to this Section.
2. Division 23, “Mechanical”, specifications contain requirements that relate to this Section.
3. Division 26, “Electrical”, specifications contain requirements that relate to this Section.
4. Division 28, “Electronic Safety and Security”, specifications contain requirements that relate to this Section.

1.2 REFERENCE STANDARDS: Compliance with the following standards is required. Work, which does not meet the requirements of these standards, will be rejected and shall be redone at the contractor’s expense.

A. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

1. 135-2012: BACnet Data Communication Protocol for Building Automation and Control Networks, including all published addenda.

B. Electronic Industries Association/Telecommunications Industry Association (EIA/TIA)

1. EIA/TIA-568: Commercial Building Telecommunications Cabling Standard - All parts and Addendums.

C. National Fire Protection Association (NFPA)

4. 262: Standard Method of Test for Fire and Smoke Characteristics of Wires and Cables.

D. Federal Communications Commission (FCC)


E. Underwriters Laboratories (UL)

2. 268A: Smoke Detectors for Duct Applications.
3. 468A: Wire Connectors and Soldering Lugs for Use with Copper Conductors.
F. National Electrical Manufacturer's Association (NEMA)

1. ICS6: Enclosures for Industrial Control Systems.

G. Institute of Electrical and Electronic Engineers (IEEE)

1. 802.3: Information technology - Telecommunications and information exchange between systems-Local and metropolitan area networks.

1.3 DEFINITIONS

A. Modulating Control: Direct digital closed loop Proportional + Integral (PI) control which maintains the controlled variable (temperature, humidity, etc.) at a set point by adjusting the position of a valve, damper or similar controlled device in small increments and decrements between fully open and fully closed positions. PI loop shall include an adjustable dead band, which is a range of the controlled variable around the set point in which no change in output to the controlled device is made. Dead bands shall be initially set at plus or minus 0.5 °F for temperature control loops and plus or minus 2 percent RH for humidity control loops.

B. 2-Position Control: On/off control in which the controlled device is either fully open or fully closed with no intermediate operating positions available.

C. Advanced Application Controller (AAC): A fully programmable control module. This control module may be capable of some of the advanced features found in Building Controllers (storing trends, initiating read and write requests, etc.) but it does not serve as a master controller. Advanced Application Controllers may reside on either the Ethernet/IP backbone or on a subnet.

D. Application Specific Controller (ASC): A pre-programmed control module which is intended for use in a specific application. ASCs may be configurable, in that the user can choose between various pre-programmed options, but it does not support full custom programming. ASCs are often used on terminal equipment such as VAV boxes or fan coil units. In many vendors' architectures ASCs do not store trends or schedules but instead rely upon a Building Controller to provide those functions.

E. BACnet/IP: An approved BACnet network type, which uses an Ethernet carrier and Internet Protocol (IP) addressing.

F. BACnet MS/TP: An approved BACnet network type, which uses a Master-Slave Token Passing configuration. MS/TP networks are unique to BACnet and utilize EIA485 twisted pair topology running at 9600 to 76,800 bps.

G. BACnet over ARCNET: An approved BACnet network type, which uses an ARCNET (attached resource computer network) carrier. ARCNET is an industry standard that can utilize several speeds and wiring standards. The most common configuration used by BACnet controllers is an EIA485 twisted pair topology running at 156,000 bps.

H. Building Controller (BC): A fully programmable control module, which is capable of storing trends and schedules, serving as a router to devices on a subnet, and initiating read and write
requests to other controllers. Typically this controller is located on the Ethernet/IP backbone of the BAS. In many vendors' architectures a Building Controller will serve as a master controller, storing schedules and trends for controllers on a subnet underneath the Building Controller.

I. Operator’s Workstation (OWS): A data processing system loaded with necessary hardware and software, which is intended to use as a primary access point for control and monitoring of BACnet system. The OWS shall directly communicate with BACnet controllers via BACnet network types as a BACnet device. It shall comply with the requirements of a BACnet device profile and shall support all BACnet services and functional groups.

J. PICS - Protocol Implementation Conformance Statement: A written document, created by the manufacturer of a device, which identifies the particular options specified by BACnet that are implemented in the device.

1.4 SYSTEM DESCRIPTION

A. Provide and install a distributed logic Building Automation System complete with software and hardware functions required. Provide a complete control system including BACnet controllers, raceways, wiring, temperature and humidity sensing elements, flow and pressure sensing elements, element wells and relays. Non-BACnet-compliant or proprietary equipment or systems (including gateways) shall not be acceptable and are specifically prohibited.

B. The BAS application program shall be written to communicate specifically utilizing BACnet protocols. Software shall include password protection, scheduling (including optimum start), alarming, logging of historical data, full graphics including: animation, after-hours billing program, demand limiting, full suite of field engineering tools including graphical programming and applications. Systems, which do not utilize BACnet protocols, are strictly prohibited.

C. Control system hardware consists of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, and accessories connected to controllers to operate mechanical systems according to sequences of operation specified.

D. Control system software consists of control software, communication software, alarm reporting software, and graphical operator interface software, programmed to operate mechanical systems according to Sequences of Operation specified.

1.5 SEQUENCE OF OPERATIONS

A. Point List: See the “BAS Point Function Schedule” shown on the drawings for a list of required hardware points and associated software functions. Points (physical, software, calculated, etc.) required to perform the specified Sequence of Operation, but not listed, shall be provided.

B. Set Point Adjustment: The set points listed in the Sequence of Operation are initial settings, which shall be adjustable. BAS software data for the system, including but not limited to set points, differentials, alarm limits, and PID control parameters shall be adjustable through the OWS by operators who have received the Operator Training described in Part 3 of this Section. Control set points shall be included on the graphical displays for each system, along with the analog value of each controlled variable. An operator with the proper password shall be able to
raise or lower these control set points through a pull-down menu while the system graphic is displayed on the OWS monitor. It shall not be necessary to revise the system control programs to adjust the control set points.

C. Alarm Limits: Alarm limits shall be programmed into the system when required by the “BAS Point Function Schedule” on the mechanical plans. The control system installer shall initially set alarm limits, so that alarms will be activated when the sensed variable is 10% above or below the control set point. The alarm limits may be changed during start-up, if required, to meet actual operating conditions.

D. Alarm monitoring: Alarms identified on the “BAS Point Function Schedule” shall be enunciated on the displays of the OWS and on the alarm printer. In addition, specific critical alarms, to be identified by the NC ANG, shall initiate automated paging of maintenance personnel by the OWS. Coordinate alarms which shall be paged to maintenance personnel with the NC ANG.

E. VAV Air Handling Unit (RTU-01 and RTU-02)

1. Supply Fan Hand-Off-Auto Operation: Hand-Off-Auto settings shall be provided as part of the variable frequency drive (VFD) through the drive's keypad. In the Off mode, the fan shall be stopped. In the Hand mode, the fan shall run continuously. In the Auto mode, the BAS will start/stop the unit through the unit controller as described below. Program a time delay into the VFD, in both the Hand and Auto modes, to stagger the restart of each unit after a power failure to prevent creating a spike in the facility electrical demand. Upon activation, safeties shall be hard wired to the VFD to stop the unit supply fan in the Hand and Auto modes.

2. Supply Fan Local-Remote Speed Control: Local-Remote settings shall be provided as part of the VFD through the drive's keypad. In the Local mode, the fan speed shall be controlled through a manual speed control located at the respective drive control panel. In the Remote mode, the fan speed shall be controlled by the BAS through the unit controller.

3. Automatic Mode Start/Stop Control: The BAS shall start and stop the air handler. To start the unit, the BAS shall send a start signal to the unit controller, which will start the supply fan. If the fan does not start after a 60 second (adjustable) time delay, a unit failure alarm shall be issued and the start command shall be canceled. To stop the unit, the BAS shall send a stop command to the unit controller, which will de-energize the supply fan. The unit shall be placed on a time schedule.

   a. Optimal Start: The BAS shall start the unit according to an optimal start routine. Cool down mode shall be used if the space temperature, as sensed by any one of the associated VAV box room temperature sensors, is above the occupied set point. At the scheduled occupancy time, the unit shall start if not already started by the optimal start routine, and the unit shall be switched to the occupied mode.

   b. Optimal Stop: The BAS shall stop the unit according to an optimal stop routine. The routine shall monitor the warmest and coolest room temperatures as sensed by the associated VAV box room temperature sensors, and stop the unit up to 30 minutes early if the temperatures are within acceptable limits.

   c. Unoccupied Start/Stop: In the unoccupied mode, the BAS shall start the unit and the unit controller will operate the system in the unoccupied cooling mode if any space temperature as sensed by any one of the associated VAV box space temperature sensors rises above 90°F (adjustable). The unit shall operate until all
space temperatures have dropped below 85°F (adjustable). The unit controller will operate the system in the unoccupied heating mode if any space temperature as sensed by any one of the associated VAV box space temperature sensors drops below 55°F (adjustable). The unit shall operate until all space temperatures are at least 60°F (adjustable).

4. Supply Fan Automatic Speed Control: When the supply fan VFD is started, the unit controller shall control the speed of the VFD to maintain the supply duct static pressure as sensed by static pressure sensors PD-1 at the supply duct static pressure set point. When the supply duct static pressure is below the set point at any one of the static pressure sensors, the speed shall increase and when the supply duct static pressure is above the set point at all of the static pressure sensors, the speed shall decrease. When the VFD is stopped, the unit controller shall return the VFD to a speed of zero.

5. Supply Duct Static Pressure Set Point: The set point shall be reset based on the VAV box requiring the most static pressure. The BAS shall monitor the positions of the dampers in the VAV boxes and send a reset signal to the unit controller. The supply air static pressure set point shall be lowered until one of the VAV box dampers has modulated completely open. This set point shall be increased should more than one VAV box damper completely open. The static pressure set point shall not be allowed to rise above 1.5 inches w.c. or fall below 0.25 inches w.c.

6. Supply Air Temperature Set Point Reset Control: The BAS shall monitor the VAV Box controllers and send a supply air temperature set point reset signal to the unit controller to reset the supply air temperature based on the VAV box with the highest demand for cooling. The supply air temperature set point shall be reset between 53 °F and 60°F, to the highest possible value while maintaining all VAV zone temperatures at the required set point.

7. Cooling Control: When there is a demand for cooling, the BAS shall cycle on and off the cooling stage to maintain the supply air temperature, as sensed by TS-1, at the supply air temperature cooling set point. When the supply fan is off, the cooling shall be off.

8. Fire alarm shutdown: When particles of combustion are sensed by the supply air duct smoke detector S-1, or the return air duct smoke detector S-2, a duct smoke alarm signal shall be sent to the fire alarm system. Upon receiving an alarm signal from duct smoke detector S-1 or S-2, the fire alarm system shall activate a Control Module (CM) to stop the fan. When the fire alarm condition has been cleared, and the fire alarm system has been reset, the unit shall be returned to normal operation.

9. High Duct Static Pressure Shutdown: The supply fan shall stop and an alarm shall be signaled when static pressure rises above excessive-static-pressure set point. When the high static condition has been cleared, and the device has been manually reset, the air handling unit shall be returned to operation.

10. Dirty Filter Alarm: Differential pressure switch DP-1 shall monitor the pressure drop at the filters. When the pressure exceeds an adjustable limit, an alarm signal will be sent to the unit controller and the BAS. Pressure difference indicator (PDI-1) located at the filters shall indicate the differential pressure across the filters.

11. Fan Status: The fan VFD status contact shall be used to monitor the status of the unit supply and relief fans. If the status indicated does not match the commanded output for the fan an alarm shall be generated at the unit controller and the BAS.

12. Failure Mode: Upon loss of control signal or electrical power the control devices shall fail in the manner indicated in the "BAS Point Function Schedule" on the mechanical sheets.
13. Additional Monitoring: In addition to the points mentioned in these sequences provide the additional monitoring points listed in the "BAS Point Function Schedule."

F. VAV Air Handling Unit (AHU-01S)

1. Supply Fan Hand-Off-Auto Operation: Hand-Off-Auto settings shall be provided as part of the variable frequency drive (VFD) through the drive's keypad. In the Off mode, the fan shall be stopped. In the Hand mode, the fan shall run continuously. In the Auto mode, the BAS will start/stop the unit through the unit controller as described below. Program a time delay into the VFD, in both the Hand and Auto modes, to stagger the restart of each unit after a power failure to prevent creating a spike in the facility electrical demand. Upon activation, safeties shall be hard wired to the VFD to stop the unit supply fan in the Hand and Auto modes.

2. Supply Fan Local-Remote Speed Control: Local-Remote settings shall be provided as part of the VFD through the drive's keypad. In the Local mode, the fan speed shall be controlled through a manual speed control located at the respective drive control panel. In the Remote mode, the fan speed shall be controlled by the BAS through the unit controller.

3. Automatic Mode Start/Stop Control: The BAS shall start and stop the air handler. To start the unit, the BAS shall send a start signal to the unit controller, which will start the supply fan. If the fan does not start after a 60 second (adjustable) time delay, a unit failure alarm shall be issued and the start command shall be canceled. To stop the unit, the BAS shall send a stop command to the unit controller, which will de-energize the supply fan. The unit shall be placed on a time schedule.
   a. Optimal Start: The BAS shall start the unit according to an optimal start routine. Cool down mode shall be used if the space temperature, as sensed by any one of the associated VAV box room temperature sensors, is above the occupied set point. At the scheduled occupancy time, the unit shall start if not already started by the optimal start routine, and the unit shall be switched to the occupied mode.
   b. Optimal Stop: The BAS shall stop the unit according to an optimal stop routine. The routine shall monitor the warmest and coolest room temperatures as sensed by the associated VAV box room temperature sensors, and stop the unit up to 30 minutes early if the temperatures are within acceptable limits.
   c. Unoccupied Start/Stop: In the unoccupied mode, the BAS shall start the unit and the unit controller will operate the system in the unoccupied cooling mode if any space temperature as sensed by any one of the associated VAV box space temperature sensors rises above 90°F (adjustable). The unit shall operate until all space temperatures have dropped below 85°F (adjustable). The unit controller will operate the system in the unoccupied heating mode if any space temperature as sensed by any one of the associated VAV box space temperature sensors drops below 55°F (adjustable). The unit shall operate until all space temperatures are at least 60°F (adjustable).

4. Supply Fan Automatic Speed Control: When the supply fan VFD is started, the unit controller shall control the speed of the VFD to maintain the supply duct static pressure as sensed by static pressure sensors PD-1 at the supply duct static pressure set point. When the supply duct static pressure is below the set point at any one of the static pressure sensors, the speed shall increase and when the supply duct static pressure is
above the set point at all of the static pressure sensors, the speed shall decrease. When the VFD is stopped, the unit controller shall return the VFD to a speed of zero.

5. Supply Duct Static Pressure Set Point: The set point shall be reset based on the VAV box requiring the most static pressure. The BAS shall monitor the positions of the dampers in the VAV boxes and send a reset signal to the unit controller. The supply air static pressure set point shall be lowered until one of the VAV box dampers has modulated completely open. This set point shall be increased should more than one VAV box damper completely open. The static pressure set point shall not be allowed to rise above 1.5 inches w.c. or fall below 0.25 inches w.c.

6. Supply Air Temperature Set Point Reset Control: The BAS shall monitor the VAV Box controllers and send a supply air temperature set point reset signal to the unit controller to reset the supply air temperature based on the VAV box with the highest demand for cooling. The supply air temperature set point shall be reset between 53 °F and 60°F, to the highest possible value while maintaining all VAV zone temperatures at the required set point.

7. Cooling Control: When there is a demand for cooling, the BAS shall cycle on and off the cooling stage to maintain the supply air temperature, as sensed by TS-1, at the supply air temperature cooling set point. When the supply fan is off, the cooling shall be off. Cooling control shall be activated in coordination with heating control so both cooling and heating control do not operate simultaneously.

8. Heating Control: When there is a demand for heating, the BAS shall enable and modulate the electric heater to maintain the supply air temperature, as sensed by TS-1, at the supply air temperature heating set point. When the supply fan is off, the heating shall be off. Heating control shall be activated in coordination with cooling control so both cooling and heating control do not operate simultaneously.

9. Minimum Outdoor Air Damper Control: When the unit is started in the occupied mode, the unit controller shall modulate outdoor air damper CD-1 to maintain the minimum outdoor air flow, as sensed by air flow measuring station PD-1. During unoccupied and cool down modes of unit operation, the outdoor air damper CD-1 shall be closed.

10. Fire alarm shutdown: When particles of combustion are sensed by the supply air duct smoke detector S-1, or the return air duct smoke detector S-2, a duct smoke alarm signal shall be sent to the fire alarm system. Upon receiving an alarm signal from duct smoke detector S-1 or S-2, the fire alarm system shall activate a Control Module (CM) to stop the fan. When the fire alarm condition has been cleared, and the fire alarm system has been reset, the unit shall be returned to normal operation.

11. High Duct Static Pressure Shutdown: The supply fan shall stop and an alarm shall be signaled when static pressure rises above excessive-static-pressure set point. When the high static condition has been cleared, and the device has been manually reset, the air handling unit shall be returned to operation.

12. Dirty Filter Alarm: Differential pressure switch DP-1 shall monitor the pressure drop at the filters. When the pressure exceeds an adjustable limit, an alarm signal will be sent to the unit controller and the BAS. Pressure difference indicator (PDI-1) located at the filters shall indicate the differential pressure across the filters.

13. Fan Status: The fan VFD status contact shall be used to monitor the status of the unit supply and relief fans. If the status indicated does not match the commanded output for the fan an alarm shall be generated at the unit controller and the BAS.

14. Failure Mode: Upon loss of control signal or electrical power the control devices shall fail in the manner indicated in the "BAS Point Function Schedule" on the mechanical sheets.
15. Additional Monitoring: In addition to the points mentioned in these sequences provide the additional monitoring points listed in the "BAS Point Function Schedule."

G. CAV Air Handling Unit (AHU-02S)

1. Supply Fan Hand-Off-Auto Operation: Hand-Off-Auto operation switch on motor starter shall control the fan. In the Off mode, the fan shall be stopped. In the Hand mode, the fan shall be energized. In the Auto position the BAS will start/stop the unit through the unit controller as described below. Program a time delay into the unit controller to stagger the restart of unit, after a power failure, to prevent creating a spike in the facility electrical demand. Safeties shall be hard wired to stop the supply fan.

2. Automatic Mode Start/Stop Control: The BAS shall start and stop the unit. To start the unit, the BAS shall send a start signal to the unit controller, which will start the supply. If the fan does not start after a 60 second (adjustable) time delay, a unit failure alarm shall be issued and the start command shall be canceled. To stop the unit, the BAS shall send a stop command to unit controller, which will de-energize the supply. The unit shall be placed on a time schedule.
   a. Optimal Start: The BAS shall start the unit according to an optimal start routine. Cool down mode shall be used if the space temperature is above the occupied set point. Warm up mode shall be used if the space temperature is below the occupied set point. At the scheduled occupancy time, the unit shall start if not already started by the optimal start routine, and the unit shall be switched to the occupied mode.
   b. Scheduled Stop: The BAS shall stop the unit when the occupancy schedule indicates that the occupied period has ended.
   c. Unoccupied Start/Stop: In the unoccupied mode, the BAS shall start the unit and the unit controller will operate the system in the unoccupied heating mode if the space temperature drops below 55°F (adjustable). The unit shall operate until the space temperature is at least 60°F (adjustable). The BAS shall start the unit and the unit controller will operate the system in the unoccupied cooling mode if the space temperature rises above 90°F (adjustable). The unit shall operate until the space temperature has dropped below 85°F (adjustable).

3. Space Temperature Set Point: The space temperature cooling set point shall be initially set at 76°F (adjustable) and the space temperature heating set point shall be initially set at 70°F (adjustable).

4. Cooling Control: When there is a demand for cooling, the BAS shall cycle on and off the cooling stage to maintain the space temperature, as sensed by TS-S127, at the space temperature cooling set point. When the supply fan is off, the cooling shall be off. Cooling control shall be activated in coordination with heating control so both cooling and heating control do not operate simultaneously.

5. Heating Control: When there is a demand for heating, the BAS shall enable and modulate the electric heater to maintain the space temperature, as sensed by TS-S127, at the space temperature heating set point. When the supply fan is off, the heating shall be off. Heating control shall be activated in coordination with cooling control so both cooling and heating control do not operate simultaneously.

6. Minimum Outdoor Air Damper Control: When the unit is started in the occupied mode, the unit controller shall modulate outdoor air damper CD-1 to maintain the minimum
outdoor air flow, as sensed by air flow measuring station PD-1. During unoccupied and cool down modes of unit operation, the outdoor air damper CD-1 shall be closed.

7. Fire alarm shutdown: When particles of combustion are sensed by the supply air duct smoke detector S-1, or the return air duct smoke detector S-2, a duct smoke alarm signal shall be sent to the fire alarm system. Upon receiving an alarm signal from duct smoke detector S-1 or S-2, the fire alarm system shall activate a Control Module (CM) to stop the fan. When the fire alarm condition has been cleared, and the fire alarm system has been reset, the unit shall be returned to normal operation.

8. Dirty Filter Alarm: Differential pressure switch DP-1 shall monitor the pressure drop at the filters. When the pressure exceeds an adjustable limit, an alarm signal will be sent to the unit controller and the BAS. Pressure difference indicator (PDI-1) located at the filters shall indicate the differential pressure across the filters.

9. Fan Status: Current switches shall be used to monitor the status of the unit supply fan. If the status indicated does not match the commanded output for the fan an alarm shall be generated at the unit controller and the BAS.

10. Failure Mode: Upon loss of control signal or electrical power the control devices shall fail in the manner indicated in the "BAS Point Function Schedule" on the mechanical sheets.

11. Additional Monitoring: In addition to the points mentioned in these sequences provide the additional monitoring points listed in the "BAS Point Function Schedule."

H. Air Handling Unit (AHU-03S)

1. Supply Fan Hand-Off-Auto Operation: Hand-Off-Auto operation switch on motor starter shall control the fan. In the Off mode, the fan shall be stopped. In the Hand mode, the fan shall be energized. In the Auto position the BAS will start/stop the unit through the unit controller as described below. Program a time delay into the unit controller to stagger the restart of unit, after a power failure, to prevent creating a spike in the facility electrical demand. Safeties shall be hard wired to stop the supply fan.

2. Automatic Mode Start/Stop Control: The BAS shall start and stop the unit. To start the unit, the BAS shall send a start signal to the unit controller, which will start the supply. If the fan does not start after a 60 second (adjustable) time delay, a unit failure alarm shall be issued and the start command shall be canceled. To stop the unit, the BAS shall send a stop command to unit controller, which will de-energize the supply. Normal operation shall be for the fan to operate continuously, 24 hours a day, year round.

3. Cooling Control: When there is a demand for cooling, the BAS shall cycle on and off the cooling stage to maintain the space temperature, as sensed by TS-S124, at the space temperature cooling set point. When the supply fan is off, the cooling shall be off.

4. Fire alarm shutdown: When particles of combustion are sensed by the supply air duct smoke detector S-1, a duct smoke alarm signal shall be sent to the fire alarm system. Upon receiving an alarm signal from duct smoke detector S-1, the fire alarm system shall activate a Control Module (CM) to stop the fan. When the fire alarm condition has been cleared, and the fire alarm system has been reset, the unit shall be returned to normal operation.

5. Dirty Filter Alarm: Differential pressure switch DP-1 shall monitor the pressure drop at the filters. When the pressure exceeds an adjustable limit, an alarm signal will be sent to the unit controller and the BAS. Pressure difference indicator (PDI-1) located at the filters shall indicate the differential pressure across the filters.
6. Fan Status: Current switches shall be used to monitor the status of the unit supply fan. If the status indicated does not match the commanded output for the fan an alarm shall be generated at the unit controller and the BAS.

7. Failure Mode: Upon loss of control signal or electrical power the control devices shall fail in the manner indicated in the "BAS Point Function Schedule" on the mechanical sheets.

8. Additional Monitoring: In addition to the points mentioned in these sequences provide the additional monitoring points listed in the "BAS Point Function Schedule."

I. Energy Recovery Ventilation Unit (DOAS-01):

1. The Energy Recovery Ventilation Unit shall be controlled by a BACnet-compatible unit controller provided by the unit manufacturer, as specified in Division 23. The unit shall be directly connected to the BAS network using BACnet MS/TP and communicate with the BAS. The controls contractor shall coordinate with unit provider and provide necessary control point mapping and software modification to the BAS for remote control and monitoring of the unit. Refer to "BAS Point Function Schedule" on the mechanical sheets for a list of control and monitoring points that shall be incorporated into the BAS.

J. Make-up Air Unit & Exhaust Fan (MAU-01/EF-01 & MAU-02/EF-02):

1. Supply/Exhaust Fan Hand-Off-Auto Operation: Hand-Off-Auto settings shall be provided as part of the variable frequency drive (VFD) through the drive's keypad. In the Off mode, the fan shall be stopped and outdoor air damper CD-1 shall be closed. In the Hand mode, the isolation damper CD-1 shall open, and the associated damper position switch DI-1 shall start the fan when the damper is fully open. In the Auto position the BAS will start/stop the unit through the unit controller as described below. Program a time delay into the VFD, in both the Hand and Auto modes, to stagger the restart of each unit after a power failure to prevent creating a spike in the facility electrical demand. Upon activation, safeties shall be hard wired to the VFD to stop the unit supply fan in the Hand and Auto modes.

2. Supply/Exhaust Fan Local-Remote Speed Control: Local-Remote settings shall be provided as part of the VFD through the drive's keypad. In the Local mode, the fan speed shall be controlled through a manual speed control located at the respective drive control panel. In the Remote mode, the fan speed shall be controlled by the BAS through the unit controller.

3. Automatic Mode Start/Stop Control: The BAS shall start and stop the unit. To start the unit, the BAS shall send a start signal to the unit controller, which will open the outdoor air damper CD-1. When the damper is fully open, as sensed by damper position switch DI-1, the fan shall start. If the fan does not start after a 60 second (adjustable) time delay, a unit failure alarm shall be issued and the start command shall be canceled. To stop the unit, the BAS shall send a stop command to unit controller, which will close the outdoor air damper and stop the supply fan. Normal operation shall be for the fan to operate continuously, 24 hours a day, year round. Provide the 2-position (Normal and Maintenance) manual selector switch for each unit:

   a. Normal Mode: When the manual selector switch is in Normal position, the unit shall run at a reduced air flow rate and the unit controller shall control the speed of the VFD to maintain the supply/exhaust air flow rate at 10,000 cfm (adjustable).
The speed of the VFD set point shall be determined in consulting with the air balancing contractor during the TAB process.

b. Maintenance Mode: When the manual selector switch is in Maintenance position, the unit shall run at a full air flow rate and the unit controller shall control the speed of the VFD to maintain the supply/exhaust air flow rate at 30,000 cfm (adjustable). The speed of the VFD set point shall be determined in consulting with the air balancing contractor during the TAB process.

4. Supply Air Temperature Set Point: The supply air temperature heating set point shall be initially set at 70°F (adjustable).

5. Heating Control: When there is a demand for heating as sensed by supply air temperature sensor TS-1, the BAS shall enable the gas heater and send a heating demand signal to the unit controller. The unit controller shall modulate the gas burner to maintain the supply air temperature as sensed by TS-1 at the supply air temperature heating set point. Gas fired heating shall be hard wire interlocked with an airflow switch, which shall disable heating if no airflow is present. The airflow switch is provided with the gas fired heater. When the supply fan is off, the heating shall be off.

6. Fire alarm shutdown: When particles of combustion are sensed by the supply air duct smoke detector S-1, a duct smoke alarm signal shall be sent to the unit controller and fire alarm system. Upon receiving an alarm signal from supply air duct smoke detector S-1, the fire alarm system shall activate a Control Module (CM) to stop the fan. When the fire alarm condition has been cleared, and the fire alarm system has been reset, the unit shall be returned to operation.

7. Dirty Filter Alarm: Differential pressure switch DP-1 shall monitor the pressure drop at the filters. When the pressure exceeds an adjustable limit, an alarm signal will be sent to the unit controller and the BAS. Pressure difference indicator (PDI-1) located at the filters shall indicate the differential pressure across the filters.

8. Fan Status: A current relay shall be used to monitor the status of the unit supply fan and exhaust fan. If the status indicated does not match the commanded output for the fan an alarm shall be generated at the unit controller and the BAS.

9. Failure Mode: Upon loss of control signal or electrical power the control devices shall fail in the manner indicated in the "BAS Point Function Schedule" on the mechanical sheets.

10. Additional Monitoring: In addition to the points mentioned in these sequences provide the additional monitoring points listed in the "BAS Point Function Schedule."

K. Make-up Air Unit & Exhaust Fan (MAU-03/EF-03 & MAU-04/EF-04):

1. Supply Fan Hand-Off-Auto Operation: Hand-Off-Auto operation switch on motor starter shall control the fan. In the Off mode, the fan shall be stopped and outdoor air damper CD-1 shall be closed. In the Hand mode, the outdoor air damper CD-1 shall open, and the associated damper position switch DI-1 shall start the fan when the damper is fully open. In the Auto position the BAS will start/stop the unit through the unit controller as described below. Program a time delay, initially set at 2 minutes (adjustable), into the unit controller to stagger the restart of unit, after a power failure, to prevent creating a spike in the facility electrical demand. Safeties shall be hard wired to stop the supply fan.

2. Automatic Mode Start/Stop Control: The BAS shall start and stop the unit. To start the unit, the BAS shall send a start signal to the unit controller, which will open the outdoor air damper CD-1. When the damper is fully open, as sensed by damper position switch
DI-1, the fan shall start. If the fan does not start after a 60 second (adjustable) time delay, a unit failure alarm shall be issued and the start command shall be canceled. To stop the unit, the BAS shall send a stop command to unit controller, which will close the outdoor air damper and stop the supply fan. Each unit shall be manually started and stopped by the manual On/Off switch. Provide 2-position (On and Off) manual selector switch for each unit.

3. Exhaust Fan Automatic Start/Stop Control: The exhaust fan motor starter shall be software interlocked with the associated make-up air unit. When the status of make-up unit supply fan is on as sensed by a current switch, the exhaust fan shall start automatically. When the status of supply fan is off as sensed by a current switch, the exhaust fan shall stop.

4. Space Temperature Set Point: The supply air temperature cooling set point shall be initially set at 60°F (adjustable) and the supply air temperature heating set point shall be initially set at 50°F (adjustable).

5. Cooling Control: When there is a demand for cooling, the BAS shall cycle on and off the cooling stage to maintain the supply air temperature, as sensed by TS-1, at the supply air temperature cooling set point. When the supply fan is off, the cooling shall be off. Cooling control shall be activated in coordination with heating control so both cooling and heating control do not operate simultaneously.

6. Heating Control: When there is a demand for heating, the BAS shall enable and modulate the electric heater to maintain the supply air temperature, as sensed by TS-1, at the supply air temperature heating set point. When the supply fan is off, the heating shall be off. Heating control shall be activated in coordination with cooling control so both cooling and heating control do not operate simultaneously.

7. Fire alarm shutdown: When particles of combustion are sensed by the supply air duct smoke detector S-1, a duct smoke alarm signal shall be sent to the unit controller and fire alarm system. Upon receiving an alarm signal from supply air duct smoke detector S-1, the fire alarm system shall activate a Control Module (CM) to stop the fan. When the fire alarm condition has been cleared, and the fire alarm system has been reset, the unit shall be returned to operation.

8. Dirty Filter Alarm: Differential pressure switch DP-1 shall monitor the pressure drop at the filters. When the pressure exceeds an adjustable limit, an alarm signal will be sent to the unit controller and the BAS. Pressure difference indicator (PDI-1) located at the filters shall indicate the differential pressure across the filters.

9. Fan Status: A current relay shall be used to monitor the status of the unit supply fan and exhaust fan. If the status indicated does not match the commanded output for the fan an alarm shall be generated at the unit controller and the BAS.

10. Failure Mode: Upon loss of control signal or electrical power the control devices shall fail in the manner indicated in the "BAS Point Schedule" on the mechanical sheets.

11. Additional Monitoring: In addition to the points mentioned in these sequences provide the additional monitoring points listed in the "BAS Point Schedule."

L. Single Duct VAV Box with Hot Water Reheat (Typical):

1. VAV Box Damper Control: The VAV box Application Specific Controller (ASC) shall modulate the VAV box damper CD-1 to maintain the amount of air supplied to the space, as sensed by PD-1, at the space airflow set point. The space airflow set point shall be reset by the space temperature between the box minimum airflow and box maximum airflow. As the space temperature increases above the space temperature set point, the
VAV box shall increase airflow set point. As the space temperature decreases below the space temperature set point, the VAV box shall decrease airflow set point. See VAV terminal schedule on the mechanical sheets for VAV box minimum and maximum airflow set points.

2. VAV Box Electric Reheat Control: Upon a further drop in space temperature, as sensed by the local space temperature sensor, after the VAV box is delivering the minimum airflow, the VAV box ASC shall modulate the VAV box electric reheat coil to maintain the space temperature at set point. When the air handling unit is off, the electric reheat coil shall be off.

3. VAV Box Set Point Control: The ASC shall automatically switch the VAV box temperature set point according to the following (all set point shall be adjustable):
    a. Occupied heating set point - 70 F.
    b. Occupied cooling set point - 76 F.
    c. Unoccupied heating set point - 60 F.
    d. Unoccupied cooling set point - 85 F.

4. Damper Manual Override: Provide the capability, through a single operator command at the OWS, to override all VAV box dampers, CD-1, associated with a specific unit to the fully open or to the fully closed position.

5. Unoccupied Mode Override: During the unoccupied mode, it shall be possible to return the VAV Box and the associated air handling unit to the occupied mode by activating a switch on the space temperature sensor. Once the after-hour override switch is activated, the system shall run for a predetermined time period (adjustable) and automatically return to the unoccupied mode.

6. Failure Mode: Upon loss of control signal or electrical power the control devices shall fail in the manner indicated in the "BAS Point Function Schedule" on the mechanical sheets.

7. Additional Monitoring: In addition to the points mentioned in these sequences provide the additional monitoring points listed in the “BAS Point Function Schedule.”

M. Exhaust Fans – Emergency Ventilation (EF-05, 06 and 07):

1. Exhaust Fan Hand-Off-Auto Operation: A Hand-Off-Auto switch shall be provided as part of the motor starter for the exhaust fan. In the Off mode, the isolation damper shall be closed and the exhaust fan shall be stopped. In the Hand mode, the isolation damper shall be opened and the exhaust fan shall start. In the Auto mode, the exhaust fan and isolation damper shall be controlled by the BAS as described below.

2. Automatic Mode Start/Stop Control: The BAS shall start and stop the fan by the manual switch or based on the space volatile organic compounds (VOC) level. When the manual switch is activated by the occupants or the space VOC level, as sensed by PID-X (PID-1 through PID-4), rises above the set point, initially set at 14 ppm (adjustable), the BAS shall start the fan. When the fan is started with high VOC level, an alarm shall be generated at the BAS and OWS. To start the fan, the BAS shall send a start signal to the fan motor starter. This shall enable the hard wire interlock that opens the isolation damper. To stop a fan, the BAS shall send a stop command to the fan motor starter which will de-energizes the fan and close the isolation damper.

3. Fan Status: A current switch shall be used to monitor the status of the fan. If the status indicated does not match the commanded output for the fan an alarm shall be generated and sent to the BAS and the fan start command shall be canceled.
N. Exhaust Fans – Trench Ventilation (EF-08, 09, 10, 11 and 12):

1. Exhaust Fan Hand-Off-Auto Operation: A Hand-Off-Auto switch shall be provided as part of the motor starter for the exhaust fan. In the Off mode, the isolation damper shall be closed and the exhaust fan shall be stopped. In the Hand mode, the isolation damper shall be opened and the exhaust fan shall start. In the Auto mode, the exhaust fan and isolation damper shall be controlled by the BAS as described below.

2. Automatic Mode Start/Stop Control: The BAS shall start and stop the fan based on a time schedule. To start the fan, the BAS shall send a start signal to the motor starter. To stop the fan, the BAS shall send a stop command to the motor starter which will de-energizes the fan and close the isolation damper. Normal operation shall be for the fan to operate continuously, 24 hours a day, year round. Provide the 2-position (Auto and On) manual selector switch for each unit.

   a. Auto Mode: When the manual selector switch is in Auto position, the BAS shall start and stop the fan based on a time schedule (user programmable).
   
   b. On Mode: When the manual selector switch is in On position, the BAS shall start and run the fan continuously, regardless of time schedule.

3. Fan Status: A current switch shall be used to monitor the status of the fan. If the status indicated does not match the commanded output for the fan an alarm shall be generated and sent to the BAS and the fan start command shall be canceled.

O. Destratification Fans (Typical)

1. Destratification fans will be tied together and controlled by the BAS. All destratification fans will be powered by a single circuit. Coordinate with unit supplier and Div. 26, and provide necessary relay and control wiring for fan control from the BAS.

2. Automatic Mode Start/Stop Control: The BAS shall start and stop the fans. To start the fans, the BAS controller shall send a start signal, which will start the fans in each bay. To stop the fans, the BAS controller shall send a stop command, which will de-energize the fans. The BAS shall cycle the fans on and off to maintain the differential temperature between floor level and ceiling level, as sensed by TS-160A and TS-160B, at set point, initially set at 5 °F (adjustable). If the differential temperature rises above the set point, the fan shall be energized. If the differential temperature drops below the set point minus 2 °F (adjustable), the fan shall be de-energized. The fan shall cycle on and off to maintain the differential temperature year around, regardless of season.

P. Exhaust Fan (EF-01S):

1. Exhaust Fan Hand-Off-Auto Operation: A Hand-Off-Auto switch shall be provided as part of the motor starter for the exhaust fan. In the Off mode, the exhaust fan shall be stopped. In the Hand mode, the exhaust fan shall start. In the Auto mode, the exhaust fan and isolation damper shall be controlled by the BAS as described below.

2. Automatic Mode Start/Stop Control: The BAS shall start and stop the fan based on a time schedule. To start the fan, the BAS shall send a start signal to the motor starter, which will start the fan. To stop a fan, the BAS shall send a stop command to the motor starter which will de-energizes the fan.
3. Fan Status: A current switch shall be used to monitor the status of the fan. If the status indicated does not match the commanded output for the fan an alarm shall be generated and sent to the BAS and the fan start command shall be canceled.

Q. Exhaust Fans:

1. Exhaust Fan (EF-02S): The exhaust fan shall be started and stopped by a light switch. When the light switch is placed in the On position, the exhaust fan shall run. When the switch is placed in the off position, the fan shall stop.

2. Exhaust Fans (EF-13 and EF-FP): When the space temperature exceeds space thermostat set point, the exhaust fan shall be started and associated damper(s) shall open. The space temperature set point shall be set at 85°F (adjustable). When the space temperature drops below set point, the exhaust fan shall be stopped and damper(s) shall be closed. The exhaust fan and associated damper shall be controlled by local space thermostat, not through the BAS.

R. Split System Heat Pump Units (Typical):

1. The Split System Heat Pump Units shall be controlled by a wall mounted space thermostat provided by the unit manufacturer as specified in Division 23. Each unit shall be controlled by a unit mounted thermostat, not through the BAS.

S. Electric Unit Heater (Typical)

1. When the temperature drops below the set point, initially set at 55°F (adjustable), the electric heater shall be enabled and the fan shall operate. When the temperature rises above the set point, the electric heater shall be disabled and the fan shall stop. The electric unit heater shall be controlled by a unit mounted thermostat, not through the BAS.

T. Emergency Air Distribution Shut Down

1. Emergency Air Distribution Shut Down Switch: Provide Emergency Air Distribution Shut Down Switches where indicated in the mechanical floor plans. When the switch is activated, all mechanical equipment controlled by the BAS within the building shall be shut down. When the emergency condition has been cleared, and the manual switch has been reset, the mechanical equipment shall be returned to normal operation. Program a time delay sequence into the BAS to stagger the restart of mechanical equipment after an emergency shutdown to prevent creating a spike in the facility electrical demand.

U. Breathing Air/Compressed Air Pressure Control

1. The BAS shall monitor the air pressure in the compressed air line to CA outlets, as sensed by PT-CA, and open/close the control valve, CV-BA, in the breathing air line to BA outlets to maintain the pressure at or above the low limit, initially set at 75 psig, (adjustable). If the pressure drops below the low alarm limit, initially set at 70 psig (adjustable), an alarm shall be generated at the BAS. Refer to Detail C1/P-502 for locations of pressure transducer and control valve, and coordinate exact pressure settings with system supplier/manufacturer.
1.6 SUBMITTALS

A. General: Submit each item in this Section according to the Conditions of the Contract and Division 1 specification sections. Drawings shall be prepared using a Computer Aided Design (CAD) system. Submittal shall be provided on half size 11” by 17” drawings. Upon successful installation, as-built drawings shall be delivered to the NC ANG on CD ROM in DXF or VSD compatible electronic format, as well as on 22” by 34” reproducible drawings. Drawings prepared for or used for this work shall become the property of the North Carolina Air National Guard (NC ANG). The NC ANG reserves the right to reproduce, in part or whole, the delivered drawings for internal purposes.

B. Control diagrams: Submit a control diagram as part of pre-construction submittal data for each system on an individual and separate sheet complete with a bill of material, a sequence of operation in a text format, and tagging information. The diagram shall consist of a system flow diagram showing the location of each control device, a control schematic drawing showing the function of each item, scale drawings of the panel layouts of both inside and face plate, and a complete terminal drawing for electrical devices connected with the system controls. Submit “BAS Point Function Schedule” with the control diagram. In addition to the above requirements, submittals shall include:

1. Control diagram with required variables, air flow diagrams, ladder diagrams, and wiring diagrams. Control diagrams shall include at least the following: set points, reset ranges, throttling ranges, differentials, operating ranges, normal positions, controller action, dial ranges, voltage, currents, mounting locations, indicators, and terminal strip points.

2. Composite wiring diagrams: Submit complete, detailed control and interlock wiring diagrams. Show mechanical and electrical equipment furnished and all electrical interlocks, indicating terminal designation for all equipment. Respective equipment manufacturers shall furnish, through the supplier, approved drawings of equipment to be incorporated in this diagram. Clearly differentiate between factory-installed and field-installed wiring (Coordinate with Division 26).

3. Communication cable installation plans showing OWS locations, controller locations, hub locations, switch locations, router locations, and communication cable conductors and routing, distinguishing between different forms of media (i.e. Fiber, Category 5e, shielded twisted pair, coaxial cable, etc.). Various types of LANs shall be identified and distinguished from each other. Each LAN shall be labeled according to its designated LAN address.

4. Damper Schedule: Provide damper schedule indicating duct size, damper size, damper type, damper model number, damper torque requirements, loaded damper operator full rotation time, damper actuator type, quantity of actuators per damper, damper actuator model number and damper failure position.

5. Valve Schedule: Provide valve schedule indicating valve model number, body type, calculated required Cv, valve Cv factor, actual pressure drop, actuator model number, and valve pressure shutoff rating.

6. Sequence of Operation: As a minimum, all control processes that are controlled by a digital signal shall be clearly shown in a text narrative form. Sequences shall be written in the contractor’s own words in order to demonstrate a clear understanding of how the system is to operate and be specific to the control system equipment used. Copying or duplication of the sequences presented in this specification is not acceptable.

7. Device Tag Schedule and Point List: Provide device tag schedule that at a minimum indicates device type, tag identifier, terminal connection points for wiring on the
controller, BAS software point name, complete BAS point address and BAS expanded point descriptor. A separate listing shall be provided for each BC, AAC and ASC. Device tags used shall be the same as those used in the contract documents as shown on the associated flow control diagrams and the “BAS Point Function Schedule”. BAS software point names and associated BAS expanded point descriptors shall incorporate the device tags used. Coordinate point-naming conventions with NC ANG facility personnel.

8. Bill of Materials: Provide a complete listing of all parts and materials utilized. List shall include part name, original manufacturer of part and original manufacturer’s part number.

9. Provide complete description and documentation of any proprietary (non-BACnet) services and/or objects used in the system.

C. Technical Specification Data Sheets: Submit the data sheets as part of pre-construction submittal data supplied by the original manufacturer of the item. These documents include salient characteristics and shall be included in a special section of the instruction book titled Manufacturer's Literature:

1. Technical specification data for each type of product specified: Include manufacturers technical product data for each control device furnished, indicating dimensions, capacities, performance characteristics, electrical characteristics, finishes of materials, installation instructions, startup instructions, and maintenance instructions.

2. Technical specification data sheets for raceway, wire, cable and installation materials.

3. Technical specification data sheets for each software module, including the system theory.

D. Installer qualifications: Submit resume listing installer’s qualifications as part of pre-construction submittal data including manufacturer’s certification as an approved system installer and a list of recently completed projects demonstrating 2 years of system installation experience. Provide name(s), address, and telephone numbers for installer supervisory personnel.

E. Startup personnel qualifications: Submit resume listing startup personnel qualifications as part of pre-construction submittal data including manufacturer’s certification as an approved system technician and a list of recently completed projects demonstrating 2 years of system startup experience. Provide name(s), address, and telephone numbers for supervisory personnel.

F. Graphical Displays: Prior to the commissioning of this project, submit printed copies of all graphical displays that will be installed at the OWS for approval. Provide a separate graphic display for each system and each logical group of points, as indicated in the “Graphics” column of the “BAS Point Function Schedule”. The graphical displays shall be schematic representations of the as-built systems and shall include, as a minimum, a dynamic reading for each point listed in the “BAS Point Function Schedule”. Where floor plan graphics are indicated on the schedule include, as a minimum, a dynamic reading for each space sensor, at the location on the floor plan that represents the actual location of the sensor. Each piece of equipment shall be linked to the appropriate floor plan. For the terminal units, the space temperature sensor display and point description shall indicate both terminal unit number and room number. Complete floor plans for the entire building shall be provided. Provide a main menu display with page navigation tools for easy access of each floor or a group of equipment, and a summary page of equipment that is found in a quantity of 3 or more in the building.
G. Submit software documentation as part of as built data including descriptive data and sequence of operation, flow charts, and machine listings of operating, user, and application software including complete Programmer’s Manual tailored to the project. Control process and control loop documentation shall be provided in logical, graphical flow diagram format to allow control sequence to be easily interpreted and modified at any time in the future.

H. Operation and Maintenance Manual: Prepare and distribute six (6) copies of the operations and maintenance data as part of as built data. The Operation and Maintenance Manual must include all information required during the submittal process, updated to reflect the final conditions at the end of construction. In addition, provide the following:

1. General troubleshooting and repair instructions.
2. Specific, explicit installation, troubleshooting, calibration, and repair instructions for each sensor, controller, interface device and controlled device.
3. Specific, explicit instructions for operation of each sensor, controller, interface device and controlled device.
4. Maintenance instructions and spare parts lists for each type of control device.
5. Interconnection wiring diagrams with identified and numbered system components and devices.
7. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
8. Calibration records, list of set points, differentials, alarm limits, alarm instructions, and time schedules.
9. Sequence of operation in computer flow chart format. The flow chart shall show how each control action is derived.

I. Test plans and inspection reports specified in Part 3, “Execution”, in this Section.

J. As built drawing requirements located in Part 3, “Execution”, in this Section.

1.7 QUALITY ASSURANCE

A. Installer Qualifications: Engage an Installer specializing in control system installations with a minimum of 2 years of experience installing systems of similar type, size and complexity. Control system manufacturer shall certify that installer has been trained on the proper installation of this type of system and is an approved system installer.

B. Startup Personnel Qualifications: Engage specially trained personnel in direct employ of manufacturer of primary temperature control system with a minimum of 2 years of experience programming, testing and commissioning systems of similar size and complexity. Control system manufacturer shall certify that the startup personnel have been trained on the proper installation, programming, testing, and commissioning of the system.

1.8 DELIVERY, STORAGE AND HANDLING

A. Store equipment and materials inside and protected from weather.
B. Factory-Mounted Components: Where control devices specified in this Section are factory mounted on equipment, arrange for shipping control devices to unit manufacturer.

1.9 EXTRA MATERIALS

A. Line Replaceable Unit (LRU) and spares: Provide a complete list of spare parts, which will be turned over at the completion of this project. List shall include part name, original manufacturer of part, original manufacturer’s part number and quantity being provided. An LRU is defined as the lowest unit to be replaced within the system during site corrective maintenance. It is a separate, replaceable, physical package, performing a single function or a group of closely related functions. An example of an LRU is a plug-in printed circuit card. These units shall be identified as parts readily available from several commercial sources in addition to the manufacturer and parts available only from the manufacturer and shall indicate the exact source of each including price and lead time of each. Submit a unit price list for line replaceable units.

B. Re-procurement package: Submit a re-procurement package at the completion of this project, which includes documentation required to re-procure parts available only from the manufacturer from alternate sources. This list shall identify:

1. Actual manufacturer of the part;
2. Unit cost;
3. Parts that are electrostatic sensitive;
4. Total usage for each unit LRU; and
5. Schematics and board drawings

C. At the completion of this project, furnish extra (except as noted) LRUs of each type installed, packaged with protective covering for storage, and identified with labels clearly describing contents, as described below. Quantity shall be determined by taking 2% of the total quantity of the devices used on the job and rounding up to the next highest whole number.

1. Space Temperature Sensor
2. Duct Temperature Sensor
3. Air Differential Pressure Sensor
4. Filed Mounted Relay
5. Damper Actuator (Each Type Used)
6. Damper Position Switch
7. Control Panel power supply
8. BC (One of each type)
9. AAC (One of each type)
10. ASC (One of each type)
11. Control Relays
12. Current Switches
PART 2 - PRODUCTS

2.1 MANUFACTURER

A. Acceptable Manufacturer: The Building Automation System (BAS) shall be an Alerton, or approved equal, that is fully compatible with and integrated into the existing BAS workstation loaded with Ascent Compass by Alerton.

2.2 SYSTEM PERFORMANCE

A. Performance Standards. At the completion of the project with all panels and system operational, the BAS shall conform to the following:

1. Graphic Display: The BAS shall display a graphic with 20 dynamic points/objects with all current data within 10 seconds.
2. Graphic Refresh: The BAS shall update a graphic with 20 dynamic points/objects with all current data within 8 seconds.
3. Object Command: The maximum time between the command of a binary object by the operator and the reaction by the device shall be less than 10 seconds. Analog objects should start to adjust within 10 seconds.
4. Object Scan: All changes of state and change of analog values will be transmitted over the high-speed BACnet Ethernet network such that any data used or displayed at a controller or workstation will have been current within the previous 10 seconds.
5. Alarm Response Time: The maximum time from when an object goes into alarm to when it is annunciated at OWS shall not exceed 45 seconds.
6. Program Execution Frequency: Custom and standard applications shall be capable of running as often as once every 1 second. The Contractor shall be responsible for selecting execution times consistent with the mechanical process under control.
7. Performance: BC, AAC and ASC shall be able to execute PID control loops at a frequency of at least once per second. The controller shall scan and update the process value and output generated by this calculation at this same frequency.
8. Spare I/O Points: As a minimum, the contractor shall provide 15% of spare I/O points, or at least one of each type of spare point, analog input, analog output, digital input and digital output, for each system controller(s).
9. The BAS shall be capable of being expanded through either the use of additional controllers or expansion cards to provide complete control of future HVAC equipment.

2.3 BUILDING CONTROLLER (BC)

A. General: Each BC shall be classified as a BACnet and conform to the BACnet Building Controller (B-BC) device profile.

B. System Operation: The BC shall operate the equipment as described in the sequence of operation. The system shall include the following:

1. Software: The BC complete with software shall be capable of controlling and monitoring electrical equipment; heating, ventilating and air conditioning equipment; and energy
management systems. The BC shall route communications between the BACnet/IP network and BACnet MS/TP field network. The BC shall be specifically designed to be monitored by and communicate with the OWS.

2. Controllers: Microprocessor based processors, with one or more microprocessor based input/output (I/O) modules interfacing controllers to the sensors and output devices. The system shall utilize EPROM or RAM memory. RAM and the clock for EPROM/RAM systems shall be provided with power backup of 4-hour instant recharge capacitor or 12-hours trickle recharge batteries. The battery backup shall protect the memory for a minimum of 72 hours. Controllers shall have memory error checking. Upon detection of a memory error, the controller processor shall correct the error or halt the unit to prevent erroneous operation. The BC shall be listed in UL 916 PAZX.

3. Optional Inputs and outputs: The BC may support inputs and outputs as follows.

   a. Analog Input: Analog inputs shall be compatible with temperature sensors, 0-20 mA, 0-5 V DC, 0-10 V DC or potentiometer inputs with 12 bit A/D conversion resolution minimum. Match inputs types to sensors provided.

   b. Analog Output: Analog output or pulse width modulated outputs shall be provided for control of end actuator devices. Overall analog output range of 0 to 10 volts or 4-20 mA with 8 bit D/A resolution minimum shall be provided.

   c. Digital Inputs: Digital inputs shall be processed for change of status. Alarm monitor points shall be assignable to normally open or to normally closed contacts.

   d. Digital Outputs: Digital outputs shall be assigned a priority with higher priorities able to override lower priorities. Controller digital, two positions signals may operate the positioning device directly or have an interposing relay to give the proper signal level. All digital outputs shall include Hand-Off-Auto override switches built into the controller.

   e. I/O Point Distribution: All I/O points specified for a piece of equipment shall be integral to a single controller. The contractor shall submit an approval request to the NC ANG when more than one piece of equipment is controlled by a single controller.

   f. Controller Capacity: Each BC shall have the ability to monitor, control and address the required data points. The mix of addressable points shall include analog inputs, analog outputs, digital inputs and outputs required to perform the functions indicated.

4. Communication:

   a. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BC(s) to networks of AACs and ASCs.

   b. Service Port: Each controller shall be provided with a service communication port, which is BACnet Data Link/Physical layer compatible, for connection to a Portable Operator’s Terminal.

   c. Signal Management: BC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.

   d. Data Sharing: Each BC shall share data as required with each networked BC, AAC and ASC. All points on the BC shall be communicated to the local OWS.
5. **BC Configuration**: It shall be possible to configure the BC over the network. This configuration shall include application program assignments; group and point assignments; data point modifications (additions and deletions); alarm parameter assignments; and peripheral assignments.

6. **Software**: The BC, complete with software, shall provide a real time control language for HVAC system applications designed to accomplish easy transition from hardware control system design to local loop based control system design. The system software shall allow the user to provide control sequences directly into the controller and operators terminal memory.

7. **Alarms**: Whenever a field point status exceeds preset limits, or there are other indications of system exceptions, alarms, error or failure, there shall be at least the following indications:
   
   a. The OWS shall sound an integral audible tone. The audible tone shall be capable of being enabled or disabled on operator command.
   b. The alarm point identification, along with individual point alarm messages, shall appear at the OWS. Upon operator command, a list of alarm points programmed into the BAS, along with their alarm messages, shall be listed on the OWS.
   c. Alarm prioritization shall be configured in accordance to the applicable categories as specified in ANSI/ASHRAE 135-2004, BACnet. The contractor shall consult with the NC ANG during the commissioning and configure in a manner that distinguishes between the facilities involved and to meet other operational needs requested by the NC ANG.

8. **Memory, processing and functional capability**: Specifically, a BC shall contain memory, processing and functional capability to perform the following in a stand-alone mode:
   
   a. Scheduled start/stop; based on time of day, calendar, holiday, lead/lag schedule and temporary schedules;
   b. Adaptive start/stop;
   c. Duty cycling;
   d. Automatic temperature and humidity control;
   e. Demand control using a sliding window, predictive algorithm;
   f. Event initiated control;
   g. Calculated point including energy calculations;
   h. Scanning and alarm processing;
   i. Full direct digital control;
   j. Trend logging;
   k. Global communications;
   l. Maintenance scheduling;
   m. BACnet communications with the OWS and other controllers;
   n. Night setback control;
   o. Variable frequency drive/air flow control;
   p. Enthalpy or dry bulb switch-over (economizer); and
   q. Temperature compensated load reset.

9. **BC global communications**: Global data values required by the installation shall be updated using change-of-value notifications.
10. **BC upload and download capability:** Each BC shall support backup and restore functionality.

11. **Communications Loss - Stand-Alone Operation:** The BC shall continue, without interruption, to operate peripheral equipment if communications with the network bus is interrupted. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network. Alarms shall be stored for up to 48 hours, or until memory is filled, and then when communications are restored, the alarms and abnormal operating conditions shall be transmitted to the OWS.

12. **Fail Safe Operation - BC power loss or component failure:** When the BC is disabled or in the event of a power failure to the BC, outputs shall fail as indicated in the sequence of operation and the “BAS Point Function Schedule”. For such items as remote temperature adjustment, the reset signal shall maintain its last setting. Upon the resumption of normal power, the BC shall analyze the status of controlled equipment, compare it with normal occupancy scheduling, and turn equipment on or off as necessary to resume normal operation.

13. **Real time clock.** Routines shall be provided to maintain time of day, date and interval timers.

### 2.4 ADVANCED APPLICATION CONTROLLER (AAC)

**A.** Advanced Application Controller: A limited capacity microprocessor based controller that is custom programmable. Each AAC shall be classified as a BACnet and conform to the BACnet Advanced Application Controller (B-AAC) or Application Specific Controller (ASC) device profile. The controllers shall be EPROM based with sufficient I/O point capacity for controlling the units in accordance with the control drawings and the sequence of operation. The controllers shall be capable of processing the signals of the specified sensors, and shall have the capability to drive the outputs required. The AAC shall be listed in UL 916 PAZX.

1. **Memory:** The controller shall have sufficient memory to support its own operating system and database. All set points, proportional bands, control algorithms, custom programming, and any other programmable parameters shall be stored for a minimum of 72 hours without requiring reprogramming, in the event of the loss of power.

2. **Operator Interface:** The controller shall have the capability of receiving configuration and program loading from the OWS.

3. **Communications:** Each AAC shall reside on a BACnet network using BACnet MS/TP. In the event of a network failure, the controller shall be capable of operating in a stand alone mode.

4. **Service Port:** Each controller shall provide a service communication port for connection to a Portable Operator's Terminal.

5. **Signal Management:** AAC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.

6. **Data Sharing:** Each AAC shall share data as required with each networked BC, AAC and ASC. All points on the AAC shall be communicated to the local OWS.

7. **Memory, processing and functional capability:** Specifically, a BC shall contain memory, processing and functional capability to perform the following in a stand-alone mode:
a. Analog Input: Analog temperature inputs shall be compatible with temperature sensors. Analog inputs shall also accept 4-20 mA or 0-10 VDC. Match inputs types to sensors provided.

b. Analog Output: Analog output or pulse width modulated outputs shall be provided for control of end actuator devices. Overall analog output range of 0 to 10 volts or 4-20 mA with 8 bit D/A resolution minimum shall be provided.

c. Digital Inputs: Digital inputs shall be processed for change of status. Alarm monitor points shall be assignable to normally open or to normally closed contacts.

d. Digital Outputs: Digital outputs shall be assigned a priority with higher priorities able to override lower priorities. Controller digital, two position signals may operate the positioning device directly or have an interposing relay to give the proper signal level. All digital outputs shall include Hand-Off-Auto override switches built into the controller.

e. I/O Point Distribution: All I/O points specified for a piece of equipment shall be integral to a single controller. The contractor shall submit an approval request to the NC ANG when more than one piece of equipment is controlled by a single controller.

f. Controller Capacity: Each AAC shall have the ability to monitor, control and address the required data points. The mix of points shall include analog inputs, analog outputs, digital inputs and outputs in sufficient quantities to perform the function indicated.

8. AAC Configuration: It shall be possible to configure the AAC over the network. This configuration shall include application program assignments; group and point assignments; data point modifications (additions and deletions); alarm parameter assignments; and peripheral assignments.

9. Software: The AAC, complete with software, shall provide a real time control language for HVAC system applications designed to accomplish easy transition from hardware control system design to local loop based control system design. The system software shall allow the user to provide control sequences directly into the controller and operators terminal memory.

10. Alarms: Whenever a field point status exceeds preset limits, or there are other indications of system exceptions, alarms, error or failure, there shall be at least the following indications:

   a. The OWS shall sound an integral audible tone. The audible tone shall be capable of being enabled or disabled on operator command.

   b. The alarm point identification, along with individual point alarm messages, shall appear at the OWS. Upon operator command, a list of alarm points programmed into the BAS, along with their alarm messages, shall be listed on the OWS.

   c. Alarm prioritization shall be configured in accordance to the applicable categories as specified in ANSI/ASHRAE 135-2004, BACnet. The contractor shall consult with the NC ANG during the commissioning and configure in a manner that distinguishes between the facilities involved and to meet other operational needs requested by the NC ANG.

11. Memory, processing and functional capability: Specifically, a BC shall contain memory, processing and functional capability to perform the following in a stand-alone mode:
2.5 APPLICATION SPECIFIC CONTROLLER (ASC)

A. Application Specific Controller: A limited capacity microprocessor based controller with limited adjustability. Each ASC shall be classified as a BACnet and conform to BACnet Application Specific Controller (B-ASC) device profile. The controllers shall be EPROM based with sufficient I/O point capacity for controlling the units in accordance with the control drawings and the sequence of operation. The controllers shall be capable of processing the signals of the specified sensors, and shall have the capability to drive the outputs required. The ASC shall be listed in UL 916 PAZX.
1. Memory: The controller shall have sufficient memory to support its own operating system and database. All set points, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure up to 72 hours long will not necessitate reprogramming the controller.

2. Operator Interface: The controller shall have the capability of receiving configuration and program loading from the OWS.

3. Communications: Each ASC shall reside on a BACnet network using the BACnet MS/TP. In the event of a network failure, the controller shall be capable of operating in a stand alone mode.

4. Service Port: Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. For VAV Box ASC, the connection shall be extended to space temperature sensor ports shown on drawings.

5. Signal Management: ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.

6. Data Sharing: Each ASC shall share data as required with each networked BC, AAC and ASC. All points on the ASC shall be communicated to the local OWS.

7. Controller local loops: Controllers shall be totally stand alone and independent of the OWS, for indicated control applications. Failure of the OWS shall in no way inhibit the operation or program execution of the controllers. Controllers software shall include a complete operating system, application packages as indicated, standard control algorithm application packages, and a user control and calculation application package and the following:

   a. Analog Input: Analog temperature inputs shall be compatible with RTD temperature sensors. Analog inputs shall also accept 4-20 mA or 0-10 V DC. Match inputs types to sensors provided.

   b. Analog Output: Analog output values shall be provided for control of end actuator devices.

   c. Digital Inputs: Digital inputs shall be processed for change of status. Alarm monitor points shall be assignable to normally open or to normally closed contacts.

   d. Digital Outputs: Digital outputs shall be assigned a priority with higher priorities able to override lower priorities. Controller digital, two position signals may operate the positioning device directly or have an interposing relay to give the proper signal level. All digital outputs, with exception of VAV terminal unit ASC, shall include Hand-Off-Auto override switches built into the controller.

   e. Fail Safe Operation: Outputs shall be designed to interface with the equipment being monitored to fail as indicated in the sequence of operation or the “BAS Point Function Schedule”. For such items as remote temperature adjustment, the reset signal shall maintain its last setting.

   f. Controller Capacity: Each ASC shall have the ability to monitor, control and address the required data points. The mix of points shall include analog inputs, analog outputs, digital inputs and outputs in sufficient quantities to perform the function indicated.

B. VAV Box Accessories - Provide the following additional hardware for VAV terminal unit applications.

1. The ASC shall operate totally stand-alone and independent of the OWS and other controllers, for all specified control applications. Software shall include a complete
operating system, communications handler, point processing, standard control algorithms and control sequences.

2. ASC upload and download capability: Each ASC shall support backup and restore functionality.

3. All modifications to set-points, parameters, etc., shall be made electronically via an OWS.

4. VAV Box ASC shall be capable of step-by-step air balancing procedure. The air distribution system balance contractor shall be able to balance all VAV boxes with ASCs by the use of a portable operator’s terminal and specific menu-prompted balancing software. The contractor shall provide the software and/or applicable graphical display for air balancing prior to the commissioning.

2.6 OPERATOR WORK STATION (OWS)

A. Utilize the existing BAS workstation in Building 43 for control and monitoring of new HVAC equipment provided as part of this project.

2.7 OPERATOR WORK STATION (OWS) USER INTERFACE

A. The existing front-end software, Ascent Compass by Alerton on the existing OWS will be the primary operator interface for new BAS. New BAS provided as part of this project shall have functionality described below.

B. The OWS shall conform to the BACnet Operator Workstation (B-OWS) device profile.

C. The OWS shall be loaded with the BAS manufacturer’s front-end interface software with required license and other utilities to permit operation as the primary operator interface for the building.

D. Communications: The OWS shall communicate using BACnet/IP and use Ethernet to connect to the IP network, while using the same Ethernet LAN for non-IP communications to other BACnet devices on the LAN. Interoperability on wide area networks (WANs) must be supported. The OWS shall reside on a high-speed network with the building controllers. The OWS shall be able to access all system information.

E. The OWS interface shall allow each authorized operator to execute the following functions as a minimum:

1. Log In and Log Out: System shall require user name and password to log in to operator interface.

2. Point-and-click Navigation: Operator interface shall be graphically based and shall allow operators to access graphics for equipment and geographic areas using point-and-click navigation.

3. View and Adjust Equipment Properties: Operators shall be able to view controlled equipment status and to adjust operating parameters such as set points, PID gains, on and off controls, and sensor calibration.

4. View and Adjust Operating Schedules: Operators shall be able to view scheduled operating hours of each schedulable piece of equipment on a weekly or monthly...
calendar-based graphical schedule display, to select and adjust each schedule and time period, and to simultaneously schedule related equipment. System shall clearly show exception schedules and holidays on the schedule display.

5. Time Clock: Operators shall be able to set the date and time in any device on the network that supports time-of-day functionality. This capability shall be provided for individual devices, groups of devices, or all devices simultaneously. The workstation shall be able to synchronize time. The workstation shall be able to perform as a BACnet network "time master."

6. View and Respond to Alarms: Operators shall be able to view a list of currently active system alarms, to acknowledge each alarm, and to clear (delete) unneeded alarms.

7. View and Configure Trends: Operators shall be able to view a trend graph of each trended point and to edit graph configuration to display a specific time period or data range. Operator shall be able to create custom trend graphs to display on the same page data from multiple trended points.

8. View and Configure Reports: Operators shall be able to run pre-configured reports, to view report results, and to customize report configuration to show data of interest.

9. Manage Control System Hardware: Operators shall be able to view controller status, to restart (reboot) each controller, and to download new control software to each controller.

10. Manage Operator Access: Typically, only a few operators are authorized to manage operator access. Authorized operators shall be able to view a list of operators with system access and of functions they can perform while logged in. Operators shall be able to add operators, to delete operators, and to edit operator function authorization. Operator shall be able to authorize each operator function separately.

11. Manage Demand Limiting Control Strategies: Operator shall be able to configure and adjust demand limiting control strategies for the building to reduce peak demand and consumption. Demand limiting control strategies shall adjust a building’s operations when a predetermined demand threshold is met to keep demand below the threshold during critical peak load periods of the day.

F. Dynamic Color Graphic Displays

1. Provide graphical screen displays of each system and each system component in color as indicated in the “BAS Point Function Schedule”. Provide individual, unique symbols for valves, fans, dampers, filters, and other mechanical and control system components. Arrange the symbols for each component so that the entire system is graphically represented. Graphical screen shall include dynamic display of associated temperature, pressure, flow, and humidity readings as well as status indication of each associated digital point. Graphical screens shall include a dynamic display of set points for each controller variable, to allow an authorized operator to adjust the set point. Include the following:

   a. Temperature and flow control diagram for each RTU, ERV, VAV Box, Exhaust Fan, etc.;
   b. Temperature and flow control diagram for hot water system;
   c. Temperature and flow control diagram for chilled water system
   d. Building Controller diagrams;
   e. Advanced Application Controller diagrams;
   f. Application Specific Controller diagrams;
   g. Floor Plans;
   h. Incorporate space sensor locations into floor plans;
i. Incorporate BC, AAC and ASC locations into floor plans; and
j. Incorporate BC, AAC and ASC loops into flow charts for critical loops.

2. The interface shall allow users to access the various system schematics and floor plans via a graphical penetration scheme using a mouse, menu selection or text-based commands.

3. Dynamic airflow values, temperature values, humidity values and status indication shall be shown in their actual respective locations and shall automatically update to represent current conditions without operator intervention.

4. For the terminal units, the space temperature sensor display and point description shall indicate both terminal unit number and room number.

5. Point groupings: Points for each system shall be grouped together to provide a complete listing of all information associated with that system on a single display screen. As a minimum, this shall include input points, output points, and set points.

6. Where calculated points such as airflow are indicated, they shall appear in their respective logical groups. The respective unconditioned real data, such as the logarithmic differential pressure points, shall also be grouped in a special group for display and observation, independent of the logical groups.

7. Graphics shall be saved in an industry-standard format such as BMP, JPEG, PNG, or GIF. Web-based system graphics shall be viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format shall require no plug-in (such as HTML and JavaScript) or shall only require widely available no-cost plug-ins (such as Active-X and Macromedia Flash).

8. Group Command Display: Provide the capability, through an operator’s command display at the OWS, to add a certain number of mechanical equipment as a group and change the set points and unit modes using a single command for all units within the group. The following points shall be available for the group command; occupied heating/cooling set points, unoccupied heating/cooling set points and unit on/off override.

G. System Tools: System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs.

1. Automatic System Database Configuration: The OWS shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.

2. Controller Memory Download: Operators shall be able to download memory from the system database to each controller.

3. System Configuration: Operators shall be able to configure the system.

4. Online Help: Context-sensitive online help for each tool shall assist operators in operating and editing the system.

5. Security: System shall require a user name and password to view, edit, add, or delete data.

a. Operator Access: Each user name and password combination shall define accessible viewing, editing, adding, and deleting functions in each system application, editor, and object. Authorized operators shall be able to vary and deny each operator's accessible functions based on equipment or geographic location.

b. Automatic Log Out: Automatically log out each operator if no keyboard or mouse activity is detected. Operators shall be able to adjust automatic log out delay.
c. Encrypted Security Data: Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.

6. System Diagnostics: System shall automatically monitor controller and I/O point operation. System shall annunciate controller failure and I/O point locking (manual overriding to a fixed value).

7. Alarm Processing: System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as noted in the “BAS Point Function Schedule”. Alarms shall be BACnet alarm objects and shall use BACnet alarm services.

8. Alarm Messages: Alarm messages shall use an English language descriptor without acronyms or mnemonics to describe alarm source, location, and nature.

9. Alarm Reactions: Operator shall be able to configure (by object) actions the OWS shall initiate on receipt of each alarm. As a minimum, the OWS shall be able to log, print, start programs, display messages, send e-mail, text message, and audibly annunciate.

10. Alarm Maintenance. Operators shall be able to view system alarms and changes of state chronologically, to acknowledge and delete alarms, and to archive closed alarms to the workstation.

11. Trend Configuration: Operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk. Coordinate items to be trended and trend configurations with NC ANG maintenance personnel. Trends shall be BACnet trend objects. At a minimum, the operator shall be able to configure a 15 minute interval logging/trending for all essential BAS/DDC points (inputs, outputs and software numerics) for a two week period.

12. Object and Property Status and Control: Operator shall be able to view, and to edit if applicable, the status of each system object and property by menu, on graphics, or through custom programs.

13. Reports and Logs: Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.

14. Application Software:

   a. Objects: System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.
   
   b. Alarm Summary: Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.
   
   c. Logs: System shall log the following to a database or text file and shall retain data for an adjustable period:

      1) Alarm History.
      2) Trend Data: Operator shall be able to select trends to be logged.
      3) Operator Activity: At a minimum, system shall log operator log in and log out, control parameter changes, schedule changes, and alarm
acknowledgment and deletion. System shall date and time stamp logged activity.

15. Graphics Generation: Graphically based tools and documentation shall allow Operator to edit system graphics, to create graphics, and to integrate graphics into the system. Operator shall be able to add analog and binary values, dynamic text, static text, and animation files to a background graphic using a mouse.

16. Graphics Library: Complete library of standard HVAC equipment graphics shall include equipment such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. Library shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. Library graphic file format shall be compatible with graphics generation tools.

17. Custom Application Programming: Operator shall be able to create, edit, debug, and download custom programs. The system shall be fully operable while custom programs are edited, compiled, and downloaded.

2.8 NETWORK AND COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, switches and routers provided for this project shall comprise a BACnet network.

B. The Contractor shall provide and install communication cable, connectors, repeaters, bridges, routers, switches and hubs necessary for the BAS network. The Ethernet backbone and connection drop point for the major equipment controllers and OWS shall be provided by others. However, the contractor shall provide additional network hardware such as Ethernet routers and switches for the extension of BAS network or connection.

C. The time clocks in controllers shall be automatically synchronized daily. Time synchronization shall be implemented via BACnet time synchronization services. The BAS shall automatically adjust for daylight savings time.

D. Network operator interface and value passing shall be transparent to network architecture.

1. An operator interface connected to a controller shall allow the operator to interface with each network controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each network controller.

2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the network. Program and test all cross-controller links required to execute control strategies specified. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

E. A break in the communication path of the network shall be announced as an alarm and shall automatically initiate a network reconfiguration such that the resulting sections of the bus continue to function as separate networks. No loss of control shall result from such a break in the bus.
F. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

2.9 CONTROL PANELS

A. Local Control Panels: Unitized cabinet with suitable brackets for wall or floor mounting, located as indicated on drawings or adjacent to each system under automatic control if not indicated on drawings. Provide common keying for all panels.
   1. Construction: NEMA 1 as defined in ICS-6 "Enclosures for Industrial Control Systems", totally enclosed, with hinged doors and keyed lock, with manufacturer's standard shop-painted finish and color.
   4. Tags: Panels shall have an identification label on the front of the door, and labels shall identify components in the panel. Panels shall be permanently labeled with laminated plastic nameplates, black with white lettering, with minimum 1/4 inch lettering. Fasten nameplates to enclosures with a minimum of two sheet-metal screws or two rivets. Tag shall include device ID's as shown on as-built documentation and BAS software identification. Internal and external wires shall also be labeled.
   5. Panel Components: Enclosures shall include following:
      a. BC, AAC, ASC, hubs, switches, repeaters or routers.
      b. Provide pre-wired control cabinets containing:
         1) 120V power outlet;
         2) Terminal strips; and
         3) Electrical relays - latching or magnetically held.
      c. Provide electronic equipment in accordance with the requirements of FCC Regulation, 47 CFR Part 15, Subpart B Unintentional Radiators, governing radio frequency electromagnetic interference and be so labeled.
      d. Provide UL listed equipment.
      e. Raceway, wiring, terminations and mounting of equipment to present a fully functional integrated system.

2.10 CONTROL TRANSFORMERS

A. General: Provide high capacity step-down transformers where required to power control system components. The transformers shall have a secondary output rating that is at least 150 percent of the total load of the connected devices. Transformers shall be installed in a NEMA 1 rated enclosure. Transformers shall be UL Listed. The secondary output of the transformer shall be protected by an appropriately sized fuse.
2.11 INPUT AND OUTPUT SENSOR AND DEVICES

A. General: Input and output sensors and devices shall be closely matched to the requirements of the controller for accurate, responsive, noise free signal input and output. Control input sensitivity shall be matched to the control loop gain requirements for precise and responsive control. In no case shall computer inputs be derived from pneumatic sensors nor shall thermocouples be used.

1. Temperature Sensors: Temperature sensors shall be Thermistor or Resistance Temperature Detector (RTD) type.
   a. Space Temperature Sensors: Provide with blank institutional type locking white and/or beige covers to best match installed location and after-hours manual override push button or switch where required by application. Accuracy shall be plus or minus 0.5°F over range of 50 to 100°F.
   b. Space Temperature Sensors (VAV Box Application): Provide with blank institutional type locking white and/or beige covers to best match installed location and after-hours manual override push button or switch. Accuracy shall be plus or minus 0.5°F.
   c. Duct Temperature Sensors: Rigid stem or averaging type as specified in the sequence of operation or as shown on the control drawings. Accuracy shall be plus or minus 0.5°F over range of 30 to 130°F.
   d. Outside air wall mounted sensors: Provide with a sun shield and mount where effects of sun and mass of the building are minimized. Coordinate location with the NC ANG. Accuracy shall be plus or minus 0.5°F over a range of minus 30 to 130°F.

2. Differential pressure transmitter (Air): The differential pressure transmitter shall be calibrated for the appropriate operating range based on set point. The output signal shall be transmitted in an analog 4-20 mA format with an accuracy of plus or minus 1 percent of the calibrated span. The transmitter shall have a local span and zero. Transmitter shall be capable of withstanding pressures of up to 8 times the calibrated range without damage or re-calibration.

3. Photoionization Detector (PID): Provide wall mounted, fixed photoionization detector that measures a range of volatile organic compounds (VOCs) required for the application. The PID shall operate on 10 to 28 VDC and provide an analog (4-20mA) output signal for continuous monitoring of space VOC level by the BAS and a programmable alarm relay output for alarm notification to fire alarm system. It shall have local LCD display with an alarm indicator. Accuracy shall be of plus or minus 2 percent of the calibrated span. Operating temperature shall be -4°F to 131°F.

4. Equipment Operation Sensors;
   a. Current Switches: Current switches shall be sized for a current range appropriate to the fan, pump or compressor motor being monitored. The trip point shall be adjustable and set to 75 percent of rated motor current. The current switch shall be capable of withstanding a maximum continuous current of 150 Amps. Operating temperature shall be -58°F to 149°F. The current relay shall meet UL 94V-0 for flammability. A LED indicator shall be included which distinguishes between the following three conditions: tripped relay switch, current present but relay switch not tripped and no current present. The monitored frequency shall be 6 Hz.
minimum, allowing for accurate monitoring of variable frequency drives. The relay switch shall be rated for 1 to 135 VAC/DC at 0.3 Amps and shall not be polarity sensitive.

b. Filter Alarm: Differential pressure switch piped across filter with adjustable set point and a range of 0 to 5 inches wg, with maximum pressure rating of at least 10 inches wg.

2.12 MANUAL SWITCHES

A. General: Provide oil tight two or three position knob type switches as required by the application. Switches shall include screw terminals and contacts rated for the application, but not less than 10 amps at 120 VAC. Switches shall be rated both mechanically and electrically for minimum 500,000 operations. Include legend plate, which matches the application.

2.13 RELAYS

A. Relays: Provide relays with LED relay coil status indicator. Rated coil voltage shall match the application. Contacts shall be minimum DPDT rated for 10 amps resistive at 120 VAC. Panel mounted relays shall be plug-in blade type, with surface or snap track mounted relay bases and screw terminals. Field mounted relays shall be installed in an enclosure and provided with either screw terminals or pigtails. Provide relay with Hand-Off-Auto switch where controlled equipment does not already include a Hand-Off-Auto switch. Provide latching type relays for unit start/stop’s to fail in last commanded state

B. Time delay relay: Provide delay-on-make relay, with 0-60 second adjustable time delay, and separable relay base with screw terminals. Time adjustment shall be through a knob mounted on the relay. DPDT relay contacts shall be rated for a minimum of 5 amperes at 120 VAC. Time shall be adjusted as required to minimize spikes in facility power demand after a power failure.

2.14 DAMEPRS

A. Motorized Control Dampers:

1. Type: Opposed blade dampers for both modulating service and 2-position service.
2. Frames: Construct Frames of five inch by one inch extruded aluminum hat channel with a minimum of 0.125-inch wall thickness.
3. Blades: Blades not exceeding eight inches wide, and of heavy gage extruded aluminum airfoil shape to minimize pressure loss across the damper.
4. Bearings, shafts, and linkage: Bearings shall be of nylon or oil impregnated sintered bronze. Shafts made of heavy-duty steel shall be extended six inches beyond frame and is marked for damper blade position. Provide linkage of 1/8 inch by 1/2-inch aluminum tie bars located out of the airstream, concealed in the frame.
5. Seals: Provide replaceable resilient seals along top, bottom and sides of frame and along edge. Damper and seals shall comply with UL flame and smoke rating of 25/50.
6. Ratings: Rate damper for minimum 2000 fpm air velocity at 2.5 inches static pressure; damper leakage not exceeding 0.5 percent of total airflow (4.00 CFM/sq. ft.) based on 2000 fpm and one inch static pressure when tested per AMCA Publication 500. Damper
shall be rated for a temperature range of minus 70 to 200 deg F. Submit leakage and flow characteristics data with shop drawings.

7. **Maximum System Pressure:** Dampers shall be rated for no less than a maximum system pressure of 8.5” w.g. for a 36” blade length.

8. **Torque requirements:** Dampers shall require maximum 8 in-lb./square foot operating torque, based on 1 inch static pressure and 1000 FPM velocity. Submit actuator torque requirement with shop drawings.

9. **Known Acceptable Source:** Subject to compliance with requirements, manufacturers offering products that may be incorporated into the work include, but are not limited to, the following:
   
   a. Greenheck
   b. Nailor Industries Inc.
   c. Ruskin Company

B. **Damper Actuator:** Provide electric type, direct shaft mount damper actuators with bracket arrangement for location outside of the air stream. Actuators shall provide at least 125 percent of the required torque to effectively operate the damper. Actuator drive time for 90 deg rotation shall be 120 seconds maximum. Actuators shall be normally open, normally closed, or fail in position as required, to obtain the operation as described in the Sequence of Operation or as shown on the “BAS Point Function Schedule”. Normally open and normally closed dampers shall return to their normal position in the event of a power failure to the actuator. Provide auxiliary switches or damper position switches, rated as required, to provide specified Sequence of Operation. Provide transformers and accessories as required. Actuators requiring linkages, crank arms, connecting rods, or ball joints are not acceptable.

1. Damper actuator shall be securely attached to the damper shaft with a set screw or some other fastener to minimize slippage. When a U-Bolt is used to attach the actuator to the damper shaft, the shaft shall be modified with a file or a grinder to provide a flat side or a notch where the U-bolt is fastened to the shaft to minimize slippage.

C. **Damper Position Switch:** When required by the sequence of operation and the “BAS Point Function Schedule”, provide damper position switches. Switch may be part of the damper actuator.

2.15 **AIR FLOW MEASUREMENT**

A. **Air Flow Measuring Station (AFMS) and differential pressure transmitter** shall be provided under Division 23. AFMS sensing elements, which are provided by unit supplier but not installed at the factory, shall be field installed and wired to the AFMS transmitter by the controls contractor. Coordinate with unit supplier for installation and proper location of AFMS.

B. **If air flow measuring station is not provided by unit manufacturer, provide high performance, thermal dispersion type air flow measuring station (AFMS).** Pitot tubes, arrays, Piezo rings and other differential pressure based devices are not acceptable. AFMS shall contain an airflow straightener if required by the AFMS manufacturer's published installation instructions.
C. Resistance to airflow: The resistance to air flow through the AFMS, including the airflow straightener shall not exceed 0.08 inch water gauge at an air flow of 2,000 fpm. AFMS construction shall be suitable for operation at airflows of up to 5,000 fpm.

D. Outside air temperature: In outside air measurement or in low-temperature air delivery applications, the AFMS shall be certified by the manufacturer to be accurate as specified over a temperature range of -20°F to 120°F.

E. Sensing probe shall be constructed of extruded aluminum or of stainless steel tubes. The operating humidity range shall be 0 to 99% RH and direct exposure to water shall not damage the sensing elements. The sensing elements shall be distributed across the duct cross section in the quantity and pattern specified by the published application data of the AFMS manufacturer.

F. AFMS shall have an accuracy of +/- 2% of reading with air velocity range of 0 to 5,000 fpm.

G. The transmitter shall have local LCD display, continuously displaying airflow and temperature and be calibrated for the appropriate operating range based on the required operating range. The output signal shall be transmitted in an analog 4-20 mA, 0-10 VDC or 0-5 VDC format. The transmitter shall have a local span and zero with field configurable low and high limits and operating temperature range of -20°F to 120°F.

2.16 FILTER GAGES

A. General: Provide differential pressure switch/gage to sense the pressure drop across each air handling unit filter bank and separate filter banks as scheduled. Furnish gages with 0 to 4 inch w.c. range, 0.1 inch minor divisions, plus or minus 2 percent accuracy, and 5 inch diameter case. Switch shall include dry contacts rated for 0.5 amps at 125 VAC resistive, switch set point indicator on the gage, knob adjustment on the front of the unit. Surface mount gages on unit or ductwork near filter bank with high and low pressure connections installed according to manufacturer’s recommendations

2.17 DUCT SMOKE DETECTORS

A. Duct smoke detectors are specified in Division 28, “Fire Alarm.” Coordinate installation of duct smoke detectors with fire alarm and detection system work to provide the specified sequence of operation.

2.18 TAGS

A. Tags: All devices, control panels, input & output devices, control dampers, control valves relays, filter gages, duct smoke detectors, water leak detection devices and all other devices and sensors installed and not mentioned here shall be permanently labeled with laminated plastic nameplates, black with white lettering, with minimum 1/4 inch lettering. Tag shall include device ID’s as shown on as-built documentation and BAS software identification. Internal and external wires shall also be labeled with wire identification labels. Fasten nameplates to enclosures with a minimum of two sheet-metal screws or two rivets. Fasten nameplates to other devices with suitable adhesive.
2.19 UNINTERRUPTIBLE POWER SUPPLY (UPS)

A. Uninterruptible Power Supply: Provide UPS backup for each communication switch, router, repeater and OWS installed under this section. A battery backup UPS system shall have a nominal input/output voltage of 120 VAC sine wave and be rated for a minimum output of 420 VA and capacity of 260 Watts. The battery shall be maintenance-free, sealed, leak proof and lead-acid type. The battery shall be hot-swappable without disconnecting or disrupting the power to the attached load. The surge protection rating shall be at least 320 Joules, with zero clamping response time, full time multi-pole noise filtering and 0.7% IEEE surge let-through meeting UL 1449. The UPS shall have LED status displays with on line, on battery, replace battery, overload indicators and audible alarm. Each UPS shall be sized to provide a minimum of 4 hour of backup time to the equipment served.

2.20 CATEGORY 5E CABLE

A. General: Products listed in this section represent the minimum required features and level of quality to meet system operational requirements. Where BAS manufacturer’s recommendations exceed the specified minimum requirement, provide the cable recommended by the manufacturer.

B. Category 5e cables shall conform to or exceed EIA/TIA 568-B.2. Other standards supported shall include IEEE 802.3, 10BASE-T; and 100BASE-T. In addition, cables shall be capable of supporting evolving high-end applications. The cable shall be Underwriter's Laboratories (UL) listed type CMP.

C. Nonplenum Category 5e Unshielded Twisted Pair cables shall be composed of 24 AWG solid copper conductors, dual insulated with high density polyethylene (HDPE). The insulated conductors shall be twisted into pairs and jacketed with Polyvinyl Chloride (PVC) and shall meet or exceed the specifications listed below:

1. Maximum DC Resistance: 9.38A/100 m
2. Mutual Capacitance: @1.0 KHz – 4.59 nF/100 m
3. Mutual Capacitance Unbalance: 131.2 pF/100 m
4. Attenuation (db/305 m): @1.0 Mhz – 6.3 db; @4.0 Mhz – 13.0 db; @10.0 Mhz – 20.0 db; @16.0 Mhz – 25.0 db; @25.0 Mhz – 32.0 db; @100.0 Mhz – 67.0 db
5. Characteristic Impedance: @1.0 Mhz – 100.0 ± 15 ohm; @25.0 Mhz – 100.0 ± 15 ohm
6. Worst Pair Near-End Crosstalk (db/305 m): @1.0 Mhz – 68.0 db; @4.0 Mhz – 59.0 db; @10.0 Mhz – 53.0 db; @16.0 Mhz – 50.0 db; @25.0 MHz – 47.0 db; @100.0 MHz – 38.0 db

D. Plenum Category 5e Unshielded Twisted Pair cables shall be composed of 24 AWG bare solid-copper conductors, insulated with TEFLOMN. The insulated conductors shall be twisted into pairs and sheathed with a low smoke PVC jacket and shall meet or exceed the specifications listed below:

1. Maximum DC Resistance: 9.38A/100 m
2. Mutual Capacitance: @1.0 KHz – 4.59 nF/100 m
3. Mutual Capacitance Unbalance (pair to ground): 131.2 pF/100 m
4. Attenuation (dB/305 m): @1.0 Mhz – 6.3 db; @4.0 Mhz – 13.0 db; @10.0 Mhz – 20.0 db; @16.0 Mhz – 25.0 db; @25.0 Mhz – 32.0 db; @100.0 Mhz – 67.0 db
5. Characteristic Impedance: @1.0 Mhz – 100.0 ± 15 ohm; @25.0 Mhz – 100.0 ± 15 ohm
6. Worst Pair Near-End Crosstalk (db/305 m): @1.0 Mhz – 68.0 db; @4.0 Mhz – 59.0 db; @10.0 Mhz – 53.0 db; @16.0 Mhz – 50.0 db; @25.0 MHz – 47.0 db; @100.0 MHz – 38.0 db

E. Category 5e cables shall be run using a star topology format. The length of each individual run of horizontal copper cable shall not exceed 328 feet (100 meters).

2.21 CABLE AND WIRE

A. For Class 1 circuits, and power wiring provide 14 AWG minimum, Type THHN/THWN, solid wire in separate raceway.
B. For Class 2 and 3 circuits, provide 18 AWG minimum, power limited 300V, 140°F, type CM cable, which is so labeled. When recommend by the equipment manufacturer, or when required to comply with 47 CFR Part 15, Subpart B, “Unintentional Radiators,” provide shielded cables.
C. Cable and wire shall be non-halogenated low smoke producing cable tested in accordance with NFPA 262, “Standard Method of Test for Fire and Smoke Characteristics of Wires and Cables.” When burned, the cable shall produce a maximum peak optical smoke density of 0.5 and a maximum average optical smoke density of 0.15.

PART 3 - EXECUTION

3.1 EQUIPMENT INSTALLATION

A. Install equipment as indicated to comply with manufacturer's written instructions.
B. Connect and configure equipment and software to achieve the Sequence of Operation specified.
C. Verify location of temperature sensors, humidity sensors, and other exposed control sensors with plans and room details before installation.
D. Install damper actuators on outside of duct.
   1. When a U-Bolt is used to attach the actuator to the damper shaft, modify the shaft to provide a flat side or a notch with a file or a grinder, where the U-bolt is fastened to the shaft to minimize slippage.
E. Install labels and nameplates to identify control components according to Division 23, “Identification for HVAC Piping and Equipment.” Devices shall be permanently labeled with laminated plastic nameplates, black with white lettering, with minimum 1/4-inch lettering. Tag shall include device ID's as shown on as built documentation and BAS software identification. Internal and external wires shall also be labeled with wire identification labels. Fasten
nameplates to enclosures with a minimum of two sheet-metal screws or two rivets. Fasten nameplates to other devices with suitable adhesive.

F. Install software in control units and OWS. Implement all features of programs to specified requirements and appropriate to sequence of operation. Provide English listing of analog and digital points and alarm messages.

G. Provide a ¼ inch diameter hole in the duct adjacent to each duct temperature sensor to allow the insertion of a test probe for sensor calibration. Provide a removable plug to seal the hole.

H. Install hydronic instrument wells, valves, and other accessories according to Division 23, “Hydronic Piping.”

I. Color coding of Category 5e cable shall conform to requirements of EIA/TIA Standards.

J. Components of the network cabling system shall be labeled in accordance with EIA/TIA Standards.

3.2 ELECTRICAL INSTALLATION

A. Install raceways, boxes, and cabinets in accordance with Division 26 requirements.

B. Install building wire and cable in accordance with Division 26 requirements and those requirements described below.

1. Install wire and cable in raceways. EMT Conduit shall be at a minimum 3/4 inch in size.
2. Install communication LAN wiring and fiber between BC, AAC, ASC, and OWS in dedicated raceway separate from all other types of wire and cable.
3. For each sensor, input or output device, provide a single cable from the sensor or device directly to the BC, AAC or ASC. Each cable shall include the quantity of conductors required for the specific sensor or device. Sharing of conductors for multiple sensors shall not be permitted. Splices in the cable between the sensor or device and the BC, AAC or ASC shall not be allowed. Cables associated with analog signals shall be shielded. Drain wires from shielded cables (not including communication LAN cables) shall be grounded to the BC, AAC or ASC enclosure as close as possible to the point of entry.
4. Any wiring or communications LAN to be run on the roof or exterior of the building shall be run in Rigid Metal Conduit (RMC).
5. Install wire connectors and soldering lugs for use with copper conductors.
6. Fasten flexible conductors, which bridge cabinets and doors, neatly along the hinge side of the cabinet to protect against abrasion. Tie and support conductors neatly.
7. Number-code or color-code conductors, except local individual room controls, for future identification and servicing of control system.
8. Panels, junction boxes and raceway/conduit associated with the BAS shall be clearly identified as part of the BAS. Covers to BAS junction boxes shall be painted blue. Conduit and raceway shall be labeled with blue lettering.

C. Provide Hand-Off-Auto selector switches only for the equipment that does not have H-O-A switch to override automatic interlock controls when switch is in Hand position, except for safety interlocks such as freeze protection, smoke detectors or fire alarm interlocks. Manual
equipment start and stop control capabilities, such as motor starter hand-off-auto switches, shall remain fully operational. Do not provide Hand-Off-Auto selector switches for equipment operated through variable frequency drives.

3.3 COORDINATION

A. Install building wire and cable in accordance with Division 26 requirements and those requirements described below.

1. Provide Test and Balance Contractor a single set of necessary tools to interface to control system for testing and balancing.
2. Train Test and Balance Contractor to use control system interface tools.
3. Provide a qualified technician to assist with testing and balancing the first 10 terminal units.
4. Test and Balance Contractor shall return tools undamaged and in working condition at completion of testing and balancing.

3.4 COMMISSIONING

A. Manufacturer's Field Services: Provide the services of a factory-authorized service representative to start control systems and provide the commissioning coordination/support required under Division 1, Sections "General Commissioning Requirements" and “HVAC Commissioning Requirements”.

1. Verify that equipment installation complies with contract documents, NEC, and manufacturer’s written installation requirements. Correct deficiencies before proceeding.
2. Install DDCP, software and data for new equipment.
3. Test and adjust controls and safeties.
4. Replace damaged or malfunctioning controls and equipment.
5. Start, test, and adjust control systems.
6. Adjust, calibrate, and fine tune circuits and equipment to achieve sequence of operation specified and to provide safe, efficient operation.

3.5 CONNECTIONS

A. Ground equipment in accordance with Division 26 requirements.

1. Connect electrical components to wiring systems and to ground as indicated and instructed by manufacturer. Tighten electrical connectors and terminals according to manufacturer’s published torque-tightening values. If manufacturer’s torque values are not indicated, use those specified in UL 486A and UL 486B.

3.6 TRAINING

A. General: Skilled and efficient use of the system requires operators trained to a level of proficiency that allows the facility to be independent from the BAS supplier and assures the
facility that the capabilities of the BAS can be used to operate the facility safely and efficiently. Facility support personnel shall be trained on the system software after the completion of this project. Submit factory course description with outline, and conduct the sessions with factory instructors and training material after commissioning is complete and before acceptance of the system. Equipment installers are not acceptable instructors. Provide the following training:

B. BAS Training: The BAS training course shall be conducted at the project site and the NC ANG reserves the right to require the contractor to videotape the training sessions for later use. Emphasis shall be on maintenance training, which shall provide in-depth knowledge on how to conduct complete troubleshooting, maintenance and repair of the installed equipment. Training shall include both diagnostics software and hardware maintenance. Provide review of menu driven operator's training of data display, alarm and status descriptors, data requesting, execution of commands, insertion and deletion of a point and development of software maintenance. Preventive maintenance training shall also be provided to determine software, firmware, or hardware failures. Training shall include local OWS functionality, OWS functionality through the BAS server and functionality of the BAS server itself.

1. Operator Training: Provide 20 hours of operator training on site, for two shifts of maintenance staff, with a total of six (6) students. Training shall encompass:

   a. Installation, wiring, calibration and troubleshooting of sensors, BC, AAC, ASC, and control devices;
   b. Repair and replacement of sensors, BC, AAC, ASC, and control devices;
   c. Preventative maintenance;
   d. Sequence of operation review;
   e. Sign on - Sign off;
   f. Selection of all displays and reports;
   g. Commanding of points, keyboard and mouse mode;
   h. Modifying English text;
   i. Use of all dialogue boxes and menus;
   j. Modifying warning limits, alarm limits and start and stop times;
   k. System initialization;
   l. Download and initialization of remote panels;
   m. Purge and dump of historical data;
   n. Use of OWS;
   o. Password assignment and modification;
   p. Operator assignment and modification;
   q. Operator authority assignment and modification;
   r. Point disable and enable;
   s. Terminal and data segregation and modification; and
   t. Use of spreadsheet package with system data.

2. Programming Training: Provide 20 hours of programming training at a sanctioned training facility, owned and operated by the control system manufacturer, for a total of four (4) students. Programmer training shall be scheduled by the NC ANG with two weeks advance notice anytime during the warranty period. Training shall encompass:

   a. Software review of Sequence of Operation and flowcharts;
   b. Modification of control programs;
   c. Add-Delete-Modify data points;
d. Use of diagnostics;
e. System maintenance procedures;
f. Review of initialization;
g. Upload and download and off line archiving of all system software; and
h. Graphic creation.

3. Training Aids: Provide all training aids, equipment and training manuals. Provide one copy of the training manual for each student. Submit materials for NC ANG approval.

4. Student Education Level: The training for the various courses shall be structured for electrical/electronic technicians with experience in operating computers, but little experience in programming. The students’ education level shall be high school plus approximately two years technical training in math, sciences, and electrical and mechanical equipment.

3.7 START-UP

A. Manufacturers Field Services: Provide the services of a factory-authorized service representative to start the control systems.

1. Verify that equipment installation complies with the contract documents, NEC, and manufacturers written installation requirements and that equipment is functional. Correct deficiencies before proceeding.
2. Install BC, AAC, ASC and OWS with the latest software revision available. Confirm proper operation before proceeding.
3. Calibrate devices, make final settings, and thoroughly test control system and safeties under actual operating conditions for satisfactory performance before notifying the NC ANG that the BAS is operational.
4. Replace damaged or malfunctioning controls and equipment.
5. Start, test, and adjust control systems in accordance with the detailed requirements of the “Field Quality Control” section of this specification. This section details the following tasks, which shall be performed by the contractor.

a. Test Plan
b. Display demonstration
c. Functional Demonstration
d. Operator Programming Demonstration
e. Validation
f. Testing
g. Installation Inspection Report

6. Adjust, calibrate, and fine tune circuits and equipment to achieve Sequence of Operation specified and to provide safe, efficient operation. Provide “Installation Inspection Report” to the NC ANG as described below under “Field Quality Control.”

7. Commissioning: Provide “Contractor Commissioning Document” to the commissioning agent prior to the commissioning. Refer to Section 019113 “General Commissioning Requirements” for “Contractor Commissioning Document” and requirements of the commissioning process.
3.8 FIELD QUALITY CONTROL

A. Test Plan: Submit test plan at least 30 calendar days prior to conducting the acceptance tests. Develop a detailed testing plan, which consists of step-by-step procedures for entering nominal values into the system to simulate environmental conditions to be expected. Each test shall fully demonstrate the system operation capability as required by this specification section and as described below. Testing shall include local OWS functionality, OWS functionality through the BAS server and functionality of the BAS server itself.

1. Display demonstration: Perform a complete demonstration and readout of the capabilities of monitoring and control system in both textual and graphical format. This demonstration shall include an all points log to validate operation of 100 percent of the data points. Successful demonstration, including installation and training, constitutes a partial acceptance of the delivered system for online operation. The demonstration shall include the basic operation of 100 percent of the connected points and shall show, in accordance with the I/O summary:

   a. Analog display;
   b. Digital display;
   c. Start/Stop display;
   d. Command of selected start/stop points; and
   e. Selected Set Point Adjustment (SPA) action, both automatically and manually initiated.

2. Functional Demonstration: The following functions shall be demonstrated:

   a. Analog alarm and return to normal;
   b. Digital alarm and return to normal;
   c. Start/Stop alarm and return to normal;
   d. Off line memory access, including modification of at least two addressable memory locations;
   e. Software driven functions, including energy management application programs, event initiated programs, alarm limits and analog alarm lockout;
   f. That OWS and BAS server are capable of full system control;
   g. That single points and groups of points can be added or deleted in the program through keyboard entry;
   h. Sequential start up after simulated power interruption;
   i. Fail safe operation;
   j. Alarms and other functions;
   k. Simulated failure of all main equipment and auto transfer to standby;
   l. Simulated power failure and automatic restarting of main equipment;
   m. Simulated failure of BACnet transmission bus; and
   n. BC, AAC and ASC failure (enunciate at BAS server and OWS)

3. Operator Programming Demonstration: The following programming capabilities shall be demonstrated:

   a. Assigning of high and low analog alarm limits;
   b. Modifying analog alarm value;
c. Displaying group condition showing group detected, point within group off normal, ground fault and AC power off;
d. Modifying time based program by setting and resetting time assignment;
e. Dumping and reloading data;
f. Adding a point (the point type shall be selected by the NC ANG at time of acceptance);
g. Deleting a point, and
h. Adding a new group of points.

4. Validation: Completely check out, calibrate and test connected hardware and software to insure that the system performs in accordance with the specified requirements and approved sequences of operation. Validation shall be witnessed by the NC ANG.

a. Running each specified report;
b. Displaying and demonstrating each data entry to show site specific customizing capability and demonstrating parameter changes;
c. Step through penetration tree, displaying graphics, demonstrating dynamic update and direct access to graphics;
d. Executing digital and analog commands in graphic mode;
e. Demonstrating BC, AAC and ASC loop precision and stability through trend logs of inputs and outputs (6 loops minimum) by continuous operation of 7 days testing;
f. Demonstrating BAS performance through trend logs and command trace;
g. Demonstrating scan, update, and alarm responsiveness;
h. Demonstrating spreadsheet and curve plot software and its integration with the database;
i. Demonstrating on line user guide and help function and mail facility;
j. Demonstrating digital system configuration graphics with interactive up-line and down-line load, and demonstrating specified diagnostics;
k. Demonstrating multitasking by showing dynamic curve plot and graphic construction operating simultaneously through split screen;
l. Demonstrating class programming with point options of beep duration, beep rate, alarm archiving and color banding;
m. Demonstrate BC, AAC and ASC stand alone execution, remote control interface, upload and download data from remote controller, and Microsoft Windows compatibility;
n. Time and Event Application Control: Demonstrate that the system is capable of start/stop of controlled devices based on time and date setting, occupancy schedules, holiday schedules, activity defined schedules, lead/lag time and schedules changes, and rotational schedules; and
o. Network Strategies: A trend on one panel shall be set up for a point from another panel. This point shall also be trended in its own panel for the same intervals. Comparison of the two trends shall indicate if communication problems occurred during the 7 days testing period. Provide a historical communication error summary for the 7-day period as an alternative.

B. Testing: Perform complete tests, as indicated. Confirm test date in writing at least ten working days prior to test. The written test date confirmation shall identify changed conditions, which
may affect the test results. Provide equipment and personnel required to perform the test. Perform tests of the BAS, in accordance with the approved test plan, in presence of the NC ANG. The test shall not cause interruption of building activities in any manner.

C. Installation Inspection Report: Upon completion of tests, a list shall be provided by the NC ANG, showing each outstanding item. The Contractor shall provide a schedule detailing items to be corrected and date for completion. As each item is approved, an appropriate notation shall be entered at the time of correction on the inspection report, with counter signature of the NC ANG and date. A copy of this report shall be provided to the NC ANG.

3.9 ACCEPTANCE

A. As Built documentation: Submit complete set of as built data which shall identify the equipment supplied and the interconnecting wiring along with identification of components by part number or by ordering number. Record actual locations of control components, including control units, thermostats, and sensors. Revise Shop Drawings to reflect actual installation and operating sequences. Shop Drawings shall include floor plan drawings that show the actual location and complete identification of all sensors and control devices that are not mounted directly on the HVAC equipment. Data shall also include final set points, alarm limits, time schedules, and other BAS software information specific to this installation.

1. BAS Database: Maintain diskette copies of data files and application software for reload use in the event of a system crash or memory failure. Deliver one copy to the NC ANG during training session, and archive one copy in a local software vault to be provided by the control manufacturer.
2. Design drawings: Deliver one copy of CAD generated system design drawings in DXF format to the COTR during training session, and archive one copy in a local software vault to be provided by the control manufacturer.
3. Revised Control Drawings: Laminated version of As-built control drawings for each system shall be placed in a respective control panel.

B. Software, Firmware and Hardware Documentation Rights: The NC ANG shall have the right to reproduce (for internal use), copy, alter, use (within the scope of this project) data and software submitted. In return for this right the NC ANG agrees to maintain this data in a reasonably secure manner and agrees not to divulge the data to competitors or use the data for alternate purposes.

C. Warranty: The Warranty shall include a service and parts guarantee for two years from the date of acceptance of the installation, without charge to the NC ANG. After completion of the original installation, provide service incidental to the proper performance of the control system under the warranty for the period of two years. Calibrate and adjust the control system, including controllers, sensors, relays, control valves, motors, and other equipment provided under this contract. Place them in complete operating condition subject to the approval of the NC ANG.

D. Acceptance: The contractor shall be responsible for the system until acceptance of the BAS by the NC ANG and will be required to respond to BAS trouble calls within less than one day. The acceptance date of the system shall be that date the NC ANG and the Contractor jointly agree that the system meets the requirements of this specification. This date shall be the effective date.
of the start of the two year maintenance contract and shall constitute formal acceptance by the NC ANG.

3.10 MAINTENANCE SERVICE

A. Provide maintenance service for a two year period after the acceptance. A single source at the contractor’s facility shall be identified for maintenance type items during this time period. Failures under two year maintenance period shall be corrected by the contractor at his expense. Such occurrences shall not void acceptance. Appropriate logs, schedules, and reports shall be maintained to reflect those items and their redress. Service shall extend for a period of two years after system acceptance and shall include the following provisions:

1. Establish and maintain a telephone line, which may be used by field facilities to obtain factory support of the installed system. The telephone number shall be made available to the facility at the time of installation. The telephone shall be staffed by an on-call factory trained equipment specialist and programmer. The telephone shall be answered during normal plant hours. During nights, weekends, and holidays, an answering machine shall be provided to receive trouble calls. The factory shall return trouble calls within 14 hours of receipt of the call on night, weekend, and holiday calls, and within two hours if the call is received during normal plant hours.

2. Ship LRUs and requested parts upon request by the facility requiring maintenance parts and assistance, within three hours during normal plant hours and within 15 hours during nights, holidays, and weekends. Shipping costs to the facility shall be borne by the contractor. Shipping shall be UPS or similar fast door-to-door service.

3. Repair all returned parts at the contractor’s expense. The only exception is for neglect or abuse such as damage by liquids, breakage or power anomalies.

4. Contractor maintenance support applies to software as well as equipment.

5. Facility personnel shall perform required preventative maintenance tasks in accordance with periodic maintenance tasks and procedures specified in the Contractor’s periodic maintenance requirements handbook.

6. Provide to the NC ANG a local existing commercial source (within the local metropolitan commuting area) where parts, LRUs and circuit boards, and trained technical support can be obtained. The NC ANG at its discretion has the right to procure parts and service on a local basis to restore the system to an operating configuration on an emergency basis and such action shall not void the guarantees. Costs for local support shall be borne by the NC ANG.

END OF SECTION 23 09 23