SECTION 250000

BUILDING AUTOMATION SYSTEMS

PART 1   GENERAL

1.1   SUMMARY

A. Furnish Building Automation Systems upgrades specified herein.

1. Software upgrade from RC-Studio 2 to RC-Studio 3

2. New BACnet gateway point mapping for AC-1 through AC-4. BACnet interface will be provided with AC units. Existing Reliable Controls hardware, including thermostats, will be reused.

3. Sequence of operation changes

1.2   CONTRACTOR PROPOSALS

A. Where requirements are unclear, the contractor shall clarify the requirements with the Engineer before the bid due date. Where requirements continue to be unclear, the contractor's proposal must accurately describe what is included and excluded.

B. By submitting a proposal, contractor guarantees that their proposal is in full compliance with these specifications except as specifically excluded in their proposal.

1.3   REFERENCE STANDARDS

A. Nothing in Contract Documents shall be construed to permit Work not conforming to applicable laws, ordinances, rules, and regulations. When Contract Documents differ from requirements of applicable laws, ordinances, rules and regulations, comply with documents establishing the more stringent requirement.

B. The latest published or effective editions, including approved addenda or amendments, of the following codes and standard shall apply to the BAS design and installation as applicable.

C. State, Local, and City Codes

1. CBC − California Building Code

2. CMC − California Mechanical Code

3. CEC – California Electrical Code

4. Local City and County Codes

D. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)

1. ANSI/ASHRAE 135 – BACnet - A Data Communication Protocol for Building Automation and Control Networks

2. ANSI/ASHRAE Standard 135.1− Method of Test for Conformance to BACnet

3. ANSI/ASHRAE Standard 15 – Safety Standard for Refrigeration Systems

E. Electronics Industries Alliance

1. EIA-232 – Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.

2. EIA-458 – Standard Optical Fiber Material Classes and Preferred Sizes.

3. EIA-485 – Standard for Electrical Characteristics of Generator and Receivers for use in Balanced Digital Multipoint Systems.

4. EIA-472 – General and Sectional Specifications for Fiber Optic Cable.

5. EIA-475 – Generic and Sectional Specifications for Fiber Optic Connectors and all Sectional Specifications.

6. EIA-573 – Generic and Sectional Specifications for Field Portable Polishing Device for Preparation Optical Fiber and all Sectional Specifications.

7. EIA-590 – Standard for Physical Location and Protection of Below-Ground Fiber Optic Cable Plant and all Sectional Specifications.

F. Underwriters Laboratories

1. UL 916 – Energy Management Systems.

G. National Electrical Manufacturers Association

1. NEMA 250 – Enclosure for Electrical Equipment.

H. Institute of Electrical and Electronics Engineers (IEEE)

1. IEEE 142 – Recommended Practice for Grounding of Industrial and Commercial Power Systems.

2. IEEE 802.3 – CSMA/CD (Ethernet – Based) LAN.

3. IEEE 802.4 – Token Bus Working Group (ARCNET – Based) LAN.

1.4 QUALITY ASSURANCE

A. Installer

1. BAS Contractor's Project Manager Qualifications: Individual shall specialize in and be experienced with direct digital control system installation for not less than 3 years. Project Manager shall have experience with the installation of the proposed direct digital control equipment product line for not less than 2 projects of similar size and complexity. Project Manager must have proof of having successfully completed the most advanced training offered by the manufacturer of the proposed product line.

2. BAS Contractor's Programmer Qualifications: Individual(s) shall specialize in and be experienced with direct digital control system programming for not less than 3 years and with the proposed direct digital control equipment product line for not less than 1.5 years. Programmers must show proof of having successfully completed the most advanced programming training offered by the vendor of the programming application on the proposed product line.

3. BAS Contractor's Lead Installation Technician Qualifications: Individual(s) shall specialize in and be experienced with direct digital control system installation for not less than 3 years and with the proposed direct digital control equipment product line for not less than 1.5 years. Installers must show proof of having successfully completed the installation certification training offered by the vendor of the proposed product line.

4. BAS Contractor's Service Qualifications: The installer must be experienced in control system operation, maintenance and service. BAS Contractor must document a minimum 5-year history of servicing installations of similar size and complexity. Installer must also document at least a 1-year history of servicing the proposed product line.

5. Installer's Response Time and Proximity

    a. Installer must maintain a fully capable service facility within 50 miles of the subject Project. Service facility shall manage the emergency service dispatches and maintain the inventory of spare parts.

    b. Installer must demonstrate the ability to meet the emergency response times listed in Paragraph 1.10B.1.

6. Electrical installation shall be by manufacturer-trained electricians

    a. Exception: Roughing in wiring and conduit and mounting panels may be subcontracted to any licensed electrician.

1.5   SUBMITTALS

A. No work may begin on any segment of this Project until the related submittals have been reviewed for conformity with the design intent and the Contractor has responded to all comments to the satisfaction of the Owner's Representative.

B. Submit drawings and product data as hereinafter specified. Conditions in this Section take precedence over conditions in Division 1.

C. Submittal Schedule: Submittal schedule shall be as follows unless otherwise directed by the Owner's Representative:

1. Allow 10 working days for approval, unless Owner's Representative agrees to accelerated schedule.

2. Submittal Package 1 (Programming) and shall be submitted no less than 30 days before software is to be installed in field devices.

3. Submittal Package 2 (Post-Construction Trend Points List) shall be submitted 14 days prior to the start of the trend collection period.

4. Submittal Package 3 (Functional Test Report) shall be submitted no more than 7 days after conducting tests.

5. Submittal Package 4 (Post-Construction Trend Logs) shall be submitted after demonstration tests are accepted and systems are in full automatic operation.

D. Submission and Resubmission Procedure

1. Each submittal shall have a unique serial number that includes the associated specification section followed by a number for each sub-part of the submittal for that specification section, such as SUBMITTAL 250000-01.

2. Each resubmittal shall have the original unique serial number plus unique revision number such as SUBMITTAL 250000-01 REVISION 1.

3. Submit one copy of submittal in electronic format specified under each submittal package below. Submissions made in the wrong format will be returned without action.

4. Submittals shall have bookmarks for each subsection (e.g. Materials, Drawings) and for each drawing including drawing number and name.

5. Owner's Representative will return a memo or mark-up of submittal with comments and corrections noted where required.

6. Make corrections

    a. Revise initial submittal to resolve review comments and corrections.

    b. Clearly identify resubmittal by original submittal number and revision number.

    c. The cover page of resubmittals shall include a summary of prior comments and how they were resolved in the resubmittal.

    d. Indicate any changes that have been made other than those requested.

7. Resubmit revised submittals until no exceptions are taken.

    a. The cost of Taylor Engineering's review of submittals after first resubmittal will be borne by Contractor at Taylor Engineering standard billing rates.

8. Once submittals are accepted with no exceptions taken, provide

    a. Complete submittal of all accepted drawings and products in a single electronic file.

    b. Photocopies or electronic copies for coordination with other trades, if and as required by the General Contractor or Owner's Representative.

E. Submittals Packages

1. Submittal Package 1 (Programming)

a. A list of all hardware and software points identifying their full text names, device addresses and descriptions.

b. Control Logic Documentation

1) Include a MS Word file of the specified English-language Sequences of Operation of each control sequence updated to reflect any suggested changes made by the Contractor to clarify or improve the sequences. Changes shall be clearly marked. Also merge Guideline 36 sequences, where referenced, verbatim into the file; see Section 259000 Building Automation Sequences of Operation. SOO shall be fully consistent with the graphical programming.

2) Include control settings, setpoints, throttling ranges, reset schedules, adjustable parameters and limits.

3) Submit one complete set of programming and operating manuals for all digital controllers concurrently with control logic documentation.

c. Format

1) Points list: Word-searchable format per Paragraph 1.7C.3.

2) Programming: None required

3) Control sequences: MS Word

4) Programming and operating manual: Word-searchable format per Paragraph 1.7C.3.

2. Submittal Package 2 (Post-Construction Trend Points List)

a. Provide a list of points being trended along with trend interval or change-of-value per Paragraph 3.10G.2.d.

3. Submittal Package 3 (Functional Test Report)

a. Provide completed functional test forms as required by Paragraph 3.10E.4.

b. Format: Word-searchable format per Paragraph 1.7C.3.

4. Submittal Package 4 (Post-Construction Trend Logs)

a. Provide trend logs as required by Paragraph 3.10G.

1.6 USE OF PREMISES

A. See Section 010000.

1.7 COMPLETION REQUIREMENTS

A. Procedure

1. Until the documents required in this Section are submitted and approved, the system will not be considered accepted and final payment to Contractor will not be made.

2. Before requesting acceptance of Work, submit one set of completion documents for review and approval of Owner.

3. After review, furnish quantity of sets indicated below to Owner.

B. Completion Documents

1. Operation and Maintenance (O & M) Manuals. Provide in both paper and electronic format per Paragraph 1.7C.

   a. Include the as-built version of all submittals (product data, shop drawings, control logic documentation, hardware manuals, software manuals, installation guides or manuals, maintenance instructions and spare parts lists) in maintenance manual. Submittal data shall be located in tabs along with associated maintenance information.

   b. Engineering, Installation, and Maintenance Manual(s) that explain how to design and install new points, panels, and other hardware; preventive maintenance and calibration procedures; how to debug hardware problems; and how to repair or replace hardware.

   c. Complete original issue documentation, installation, and maintenance information for all third-party hardware and software provided, including computer equipment and sensors.

   d. A list of recommended spare parts with part numbers and suppliers.

   e. Operators Manual with procedures for operating the control systems, including logging on/off, alarm handling, producing point reports, trending data, overriding computer control, and changing set points and other variables.

   f. Programming Manuals with a description of the programming language, control block descriptions (including algorithms and calculations used), point database creation and modification, program creation and modification, and use of the programming editor.

   g. Recommended preventive maintenance procedures for all system components, including a schedule of tasks (inspection, cleaning, calibration, etc.), time between tasks, and task descriptions.

   h. A listing and documentation of all custom software for the Project created using the programming language, including the set points, tuning parameters, and point and object database.

   i. English language control sequences updated to reflect final programming installed in the BAS at the time of system acceptance. See Section 259000 Building Automation Sequences of Operation.

2. Complete original issue electronic copy for all software provided, including operating systems, programming language, operator workstation software, and graphics software.

3. Complete electronic copy of updated BAS database, user screens, setpoints and all configuration settings necessary to allow re-installation of system after crash or replacement of server, and resume operations with the BAS in the same configuration as during owner sign-off.

4. Commissioning Reports. Completed versions of all Pre-functional, Functional, and Demonstration Commissioning Test reports, calibration logs, etc., per Paragraph 3.10A.8.

5. Copy of inspection certificates provided by the local code authorities.

6. Written guarantee and warranty documents for all equipment and systems, including the start and end date for each.

7. Training materials.

8. Contact information. Names, addresses, and 24-hour telephone numbers of contractors installing equipment, and the control systems and service representatives of each.

C. Format of Completion Documents

1. Provide the type and quantity of media listed in table below.

2. Project database, programming source files, and all other files required to modify, maintain, or enhance the installed system shall be provided in their source format and compiled format (where applicable).

3. Where electronic copies are specified, comply with the following:

a. Provide in word-searchable electronic format; acceptable formats are MS Word, Adobe Acrobat (pdf), and HTML; submit other formats for review and approval prior to submission; scanned paper documents not acceptable.

b. For submittals, provide separate file for each type of equipment.

c. Control sequences shall be in MS Word.

	Document	Paper (binder or bound)	Electronic	
			Loaded onto Flash Drive	Loaded onto CSS
1.	O&M Manual	2	1	1
2.	Original issue software	–	1 per workstation	1
3.	Project database including all source files	–	1 per workstation	1
4.	Control sequences	1	1	1
5.	Commissioning Reports	2	1	1
6.	Inspection Certificates	1	–	–

	Document	Paper (binder or bound)	Electronic	
			Loaded onto Flash Drive	Loaded onto CSS
7.	Warranty documents	1	–	–
8.	Training materials	1 per trainee	1	1
9.	Contact information	1	–	1

D. Permanent On-site Documentation

1. In each panel, provide the following stored in clear plastic sleeve taped to the back of the panel door:

a. 8.5x11 printout of as-built points list

b. 21 inch x 15 inch or 17 inch x 11 inch set of as-built shop drawings for devices in panel

1.8   OWNERSHIP OF PROPRIETARY MATERIAL

A. All project-developed software and documentation shall become the property of the Owner. These include, but are not limited to:

1. Record drawings

2. Project database

3. Project-specific application programming code

4. All documentation

1.9   WARRANTY

A. At the successful completion of the final testing, commissioning, and demonstration phase in accordance with the terms of this specification, if equipment and systems are operating satisfactorily to the Owner and if all completion requirements per Paragraph 1.7B have been fulfilled, the Owner shall certify in writing that the control system has been accepted. The date of acceptance shall be the start of the warranty period.

B. Guarantee all materials, equipment, apparatus and workmanship (including programming) to be free of defective materials and faulty workmanship for the following periods from date of acceptance:

1. One year

C. Provide new materials, equipment, apparatus and labor to replace that determined by Owner to be defective or faulty.

D. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the Owner. Contractor shall respond to the Owner's request for warranty service within 24 hours during normal business hours.

E. Operator workstation software, project-specific software, graphic software, database software, and firmware updates that resolve known software deficiencies shall be provided at no cost to the Owner during the warranty period.

F. Sequence of operation programming bugs (both due to programming misinterpretations and sequence errors) shall be corrected and any reasonable control sequence changes required to provide proper system operation shall be provided at no additional cost to the Owner during this period.

1.10   WARRANTY MAINTENANCE

A. The Owner reserves the right to make changes to the BAS during the warranty period. Such changes do not constitute a waiver of warranty. The Contractor shall warrant parts and installation work regardless of any such changes made by the Owner, unless the Contractor provides clear and convincing evidence that a specific problem is the result of such changes to the BAS.

B. At no cost to the Owner, provide maintenance services for software and hardware components during the warranty period as specified below:

1. Emergency Service: Any malfunction, failure, or defect in any hardware component or failure of any control programming that would result in property damage or loss of comfort control shall be corrected and repaired following notification by the Owner to the Contractor.

   a. Response by telephone or via internet connection to the BAS to any request for service shall be provided within two hours of the Owner's initial request for service.

   b. In the event that the malfunction, failure, or defect is not corrected, at least one technician, trained in the system to be serviced, shall be dispatched to the Owner's site within eight hours of the Owner's initial request for such services.

2. Normal Service: Any malfunction, failure, or defect in any hardware component or failure of any control programming that would not result in property damage or loss of comfort control shall be corrected and repaired following notification by the Owner to the Contractor.

   a. Response by telephone to any request for service shall be provided within eight working hours (contractor specified 40 hr. per week normal working period) of the Owner's initial request for service.

   b. In the event that the malfunction, failure, or defect is not, at least one technician, trained in the system to be serviced, shall be dispatched to the Owner's site within three working days of the Owner's initial request for such services, as specified.

3. Owner's Telephonic Request for Service: Contractor shall specify a maximum of three telephone numbers for Owner to call in the event of a need for service. At least one of

the lines shall be attended continuously (24/7). Alternatively, pagers/SMS can be used for technicians trained in system to be serviced. One of the three paged/texted technicians shall respond to every call within 15 minutes.

4. Technical Support: Contractor shall provide technical support by telephone throughout the warranty period.

5. Documentation: Record drawings and software documentation shall be updated as required to reflect any and all changes made to the system or programming during the warranty period.

PART 2   PRODUCTS

2.1   ELECTRIC WIRING AND DEVICES

A. Communication Wiring

1. Provide all communication wiring if needed to connect replacement AC units to existing BAS network.

2. Ethernet LAN: Use Fiber or Category 5e or 6 of standard TIA/EIA 68 (10baseT). Network shall be run with no splices and separate from any wiring over 30 volts.

3. ARCnet and MS/TP LAN: Communication wiring shall be individually 100% shielded pairs per manufacturers recommendations for distances installed, with overall PVC cover, Class 2, plenum-rated run with no splices and separate from any wiring over 30 volts. Shield shall be terminated and wiring shall be grounded as recommended by BC manufacturer.

B. Analog Signal Wiring

1. Input and output signal wiring to all field devices, including, but not limited to, all sensors, transducers, transmitters, switches, current or voltage analog outputs, etc. shall be twisted pair, 100% shielded if recommended or required by controller manufacturer, with PVC cover. Gauge shall be as recommended by controller manufacturer.

2.2   CONTROL POINTS

A. Table Column Definitions

1. Point description

2. Type (number in point schedule after each type refers to tag on schematics)

a. AO: analog output

b. AI: analog input

c. DO: digital or binary output

d. DI: digital or binary input

3. Trend Logging

   a. Commissioning: Where listed, point is to be trended at the basis listed for commissioning and performance verification purposes.

   b. Continuous: Where listed, point is to be trended at the basis listed continuously, initiated after system acceptance, for the purpose of future diagnostics.

   c. Trend Basis

      1) Where range of engineering units is listed, trend on a change of value (COV) basis (in other words record time stamp and value when point value changes by engineering unit listed).

      2) Where time interval is listed, trend on a time basis (in other words record time stamp and value at interval listed). All points relating to a specific piece of equipment shall be trended at the same initiation time of day so data can be compared in text format.

4. Calibration

   a. F = factory calibration only is required (no field calibration)

   b. HH = field calibrate with handheld device. See Paragraph 3.10C.5.a.2)

B. Note that points lists below are for each system of like kind. Refer to drawings for quantity of each.

C. Points mapped through gateways and network interfaces

   1. Heat Pump Unit Controllers (Points may differ depending on manufacturer chosen. Submittal to provide full available gateway points list)

Description	Type	Device	Trend Logging		Calibra-tion
			Comm-issioning	Contin-uous	
Unit state	AI	Through network	COV	COV	–
Cooling status	AI	Through network	COV	COV	–
Heating status	AI	Through network	COV	COV	–
Economizer status	AI	Through network	COV	COV	–
Cooling percent	AI	Through network	5 min	15 min	–
Heating percent	AI	Through network	5 min	15 min	–
Electric heating percent	AI	Through network	5 min	15 min	–
Electric heating status	AI	Through network	COV	COV	–
Supply air temperature setpoint	AO	Through network	±0.5°F	±1°F	–
Outdoor airflow setpoint	AO	Through network	5 min	15 min	–
Outdoor airflow	AI	Through network	5 min	15 min	HH
General trouble alarm	DI	Through network	COV	COV	–
Compressor #x status	DI	Through network, typical of each compressor	COV	COV	–

Description	Type	Device	Trend Logging		Calibra-tion
			Comm-issioning	Contin-uous	
Supply fan status	DI	Through network	COV	COV	–
Communications alarm	DI	Through network	COV	COV	–
Supply air temperature	AI	Through network	5 min	15 min	F
Mixed air temperature	AI	Through network	5 min	15 min	F
Return air temperature	AI	Through network	5 min	15 min	F
Outdoor air temperature	AI	Through network	5 min	15 min	F
Supply fan speed	AI	Through network	5 min	15 min	F
Economizer damper position	AI	Through network	5 min	15 min	F

1. Single Zone Packaged AC units (AC-4)

Description	Type	Device	Trend Logging		Calibra-tion
			Comm-issioning	Contin-uous	
Space temperature	AI	Through network	1 min	15 min	F
Discharge-air temperature	AI	Through network	1 min	15 min	F
Space temperature cooling setpoint	AO	Through network	±1°F	±1°F	–
Cooling status	DI	Through network	COV	COV	–
Low temperature sensor alarm	DI	Through network	COV	COV	–
Low pressure sensor alarm	DI	Through network	COV	COV	–
High pressure switch alarm	DI	Through network	COV	COV	–
Condensate sensor alarm	DI	Through network	COV	COV	–
High/low voltage alarm	DI	Through network	COV	COV	–
Unoccupied/occupied command	DO	Through network	COV	COV	–
Cooling command	DO	Through network	COV	COV	–
Fan "ON/AUTO" command	DO	Through network	COV	COV	–
Fault reset command	DO	Through network	COV	COV	–
Itemized fault code revealing reason for specific shutdown fault	AI	Through network	COV	COV	–

D. Hardwired Points

1. None

PART 3   EXECUTION

3.1   INSTALLATION - GENERAL

A. Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details indicated on Drawings.

B. Coordinate Work and Work schedule with other trades prior to construction.

C. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.2 DELIVERY, STORAGE, AND HANDLING

A. Provide factory-shipping cartons for each piece of equipment and control device. Maintain cartons during shipping, storage and handling as required to prevent equipment damage, and to eliminate dirt and moisture from equipment.

B. Store equipment and materials inside and protect from weather.

3.3 IDENTIFICATION

A. General

1. Manufacturers' nameplates and UL or CSA labels to be visible and legible after equipment is installed.

2. Identifiers shall match record documents.

3. All plug-in components shall be labeled such that removal of the component does not remove the label.

B. Wiring and Tubing

1. All wiring and cabling, including that within factory-fabricated panels, shall be labeled at each end within 2 inches of termination with the BAS address or termination number.

2. Permanently label or code each point of field terminal strips to show the instrument or item served.

3. All pneumatic tubing shall be labeled at each end within 2 inches of termination with a descriptive identifier.

C. Equipment and Devices

1. Valve and damper actuators: None required.

2. Sensors: Provide 1 inch x 3 inches x 1/8 inches black micarta or lamacoid labels with engraved white lettering, ¼ inches high. Indicate sensor identifier and function (for example "AC-x Building Pressure").

3.4 CUTTING, CORING, PATCHING AND PAINTING

A. Penetrations through rated walls or floors shall be filled with a listed material to provide a code compliant fire-stop.

B. All damage to and openings in ductwork, piping insulation, and other materials and equipment resulting from Work in this Section shall be properly sealed, repaired, or re-insulated by experienced mechanics of the trade involved. Repair insulation to maintain integrity of insulation and vapor barrier jacket. Use hydraulic insulating cement to fill voids and finish with material matching or compatible with adjacent jacket material.

C. At the completion of Work, all equipment furnished under this Section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired and repainted to original finish.

3.5   CLEANING

A. Clean up all debris resulting from its activities daily. Remove all cartons, containers, crates, and other debris generated by Work in this Section as soon as their contents have been removed. Waste shall be collected and legally disposed of.

B. Materials stored on-site shall be protected from weather and stored in an orderly manner, neatly stacked, or piled in the designated area assigned by the Owner's Representative.

C. At the completion of work in any area, clean all work and equipment of dust, dirt, and debris.

D. Use only cleaning materials recommended by the manufacturer of the surfaces to be cleaned and on surfaces recommended by the cleaning material manufacturer.

3.6   COMMUNICATION DEVICES

A. General

1. Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details indicated on Drawings.

2. Provide all interface devices and software to provide an integrated system.

B. Gateways and Routers to Equipment Controllers

1. Wire to networks on both sides of device.

2. Map across all monitoring and control points listed in Paragraph 2.2C.

3. Thoroughly test each point to ensure that mapping is accurate.

4. Initiate trends of points as indication in Paragraph 2.2C.

3.7   CONTROL AND COMMUNICATION WIRING

A. Control and Signal Wiring

1. Low Voltage Wiring

a. All low-voltage wiring shall meet NEC Class 2 requirements. (Low-voltage power circuits shall be sub-fused when required to meet Class 2 current-limit.)

    b. Class 2 wiring shall be installed in UL Listed approved raceway as follows:

        1) Where located in unconcealed or inaccessible locations, such as:

            a) Equipment rooms

            b) Exposed to weather

            c) Exposed to occupant view

            d) Inaccessible locations such as concealed shafts and above inaccessible ceilings

        2) Class 2 wiring shall not be installed in raceway containing Class 1 wiring.

    c. Class 2 wiring need not be installed in raceway as follows:

        1) Where located in concealed and easily accessible locations, such as:

            a) Inside mechanical equipment enclosures and control panels

            b) Above suspended accessible ceilings (e.g. lay-in and spline)

            c) Above suspended drywall ceilings within reach of access panels throughout

            d) In shafts within reach of access panels throughout

            e) Nonrated wall cavities

        2) Wiring shall be UL Listed for the intended application. For example, cables used in floor or ceiling plenums used for air transport shall be UL Listed specifically for that purpose.

        3) Wiring shall be supported from or anchored to structural members neatly tied at 10 foot intervals and at least 1 foot above ceiling tiles and light fixtures. Support or anchoring from straps or rods that support ductwork or piping is also acceptable. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceilings.

        4) Install wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.

    d. Boxes and panels containing high-voltage wiring and equipment shall not be used for low-voltage wiring except for the purpose of interfacing the two (for example relays and transformers).

2. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.

3. All field wiring shall be properly labeled at each end, with self-laminating typed labels indicating device address, for easy reference to the identification schematic. All power wiring shall be neatly labeled to indicate service, voltage, and breaker source.

4. Use coded conductors throughout with different colored conductors.

5. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.

6. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the Contractor shall provide step-down transformers.

7. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.

8. Size of raceway and size and type of wire shall be the responsibility of the Contractor, in keeping with the manufacturer's recommendation and NEC requirements.

9. Include one pull string in each raceway 1 inch or larger.

10. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.

11. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 6 inches from high-temperature equipment (for example steam pipes or flues).

12. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.

13. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.

14. Terminate all control or interlock wiring.

15. Maintain updated as-built wiring diagrams with terminations identified at the jobsite.

16. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 3 feet in length and shall be supported at each end. Flexible metal raceway less than ½ inches electrical trade size shall not be used. In areas exposed to moisture liquid-tight, flexible metal raceways shall be used.

17. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings per code. Terminations must be made with fittings at boxes and ends not terminating in boxes shall have bushings installed.

18. Wire digital outputs to either the normally-closed or normally-open contacts of binary output depending on desired action in case of system failure. Unless otherwise indicated herein, wire to the NO contact except the following shall be wired to the NC contact.

19. Shielded cable shield shall be grounded only at one end. Signal wiring shield shall be grounded at controller end only unless otherwise recommended by the controller manufacturer.

B. Communication Wiring

1. Adhere to the requirements of Paragraph 3.7A in addition to this Paragraph.

2. Communication and signal wiring may be run without conduit in concealed, accessible locations as permitted by Paragraph 3.7A only if noise immunity is ensured. Contractor is fully responsible for noise immunity and rewire in conduit if electrical or RF noise affects performance.

3. All cabling shall be installed in a neat and workmanlike manner. Follow all manufacturers' installation recommendations for all communication cabling.

4. Do not install communication wiring in raceway and enclosures containing Class 1 or other Class 2 wiring.

5. Maximum pulling, tension, and bend radius for cable installation as specified by the cable manufacturer shall not be exceeded during installation.

6. Verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.

7. All runs of communication wiring shall be unspliced length when that length is commercially available.

8. All communication wiring shall be labeled to indicate origination and destination data.

9. Grounding of coaxial cable shall be in accordance with NEC regulations Article on Communications Circuits, Cable and Protector Grounding.

10. Power-line carrier signal communication or transmission is not acceptable.

3.8   SOFTWARE INSTALLATION

A. Point Structuring and Naming

1. The intent of this Paragraph is to require a consistent means of naming points across the BAS. The following requirement establishes a standard for naming points and addressing Buildings, Networks, Devices, Instances, etc.

2. Point Naming Convention

   a. All point names shall adhere to the format as established below, unless otherwise agreed to by the Owner. New categories and descriptors may be created with approval of the Owner.

   b. Format:

      1) EquipmentTag.Component.Property, where

         a) EquipmentTag is the unique ID of the equipment from drawings, e.g. AC1.

    b) Component is an identifiable part of the device/system, e.g., a compressor, fan, secondary loop, etc.

    c) Property is a characteristic of the component, e.g. status, command, speed, temperature, etc.

   2) Example: AC1.Compressor1.Status

  3. Device Addressing Convention

   a. BACnet network numbers and Device Object IDs shall be unique throughout the network.

   b. All assignment of network numbers and Device Object IDs shall be coordinated with the Owner to ensure there are no duplicate BACnet device instance numbers.

   c. Each Network number shall be unique throughout all facilities and shall be assigned in the following manner: VVVNN, where: VVV = 0-999 for BACnet Vendor ID, NN = 00 - 99 for building network.

   d. Each Device Object Identifier property shall be unique throughout the system and shall be assigned in the following manner: VVVNNDD , where: VVV = number 0 to 999 for BACnet Vendor ID , NN = 00 - 99 for building network, DD = 01-99 for device address on a network.

   e. Coordinate with the Owner or a designated representative to ensure that no duplicate Device Object IDs occur.

   f. Alternative Device ID schemes or cross-project Device ID duplication if allowed shall be approved before Project commencement by the Owner.

  4. I/O Point Physical Description

   a. Each point associated with a hardware device shall have its BACnet long-name point description field filled out with:

    1) The device manufacturer and model number. Include range of device if model number does not so identify.

    2) For space sensors, include room number in which sensor is located.

 B. Point Parameters

  1. Provide the following minimum programming for each analog input

   a. Name

   b. Address

   c. Scanning frequency or COV threshold

   d. Engineering units

e. Offset calibration and scaling factor for engineering units

f. High and low value reporting limits (reasonableness values), which shall prevent control logic from using shorted or open circuit values.

g. Default value to be used when the actual measured value is not reporting. This is required only for points that are transferred across the primary or secondary controlling networks and used in control programs residing in control units other than the one in which the point resides. Events causing the default value to be used shall include failure of the control unit in which the point resides or failure of any network over which the point value is transferred.

2. Provide the following minimum programming for each analog output

a. Name

b. Address

c. Engineering units

d. Offset calibration and scaling factor for engineering units

e. Output Range

f. Default value to be used when the normal controlling value is not reporting.

3. Provide the following minimum programming for each digital input

a. Name

b. Address

c. Engineering units (on/off, open/closed, freeze/normal, etc.)

d. Debounce time delay

e. Message and alarm reporting as specified

f. Reporting of each change of state, and memory storage of the time of the last change of state

g. Totalization of on-time (for all motorized equipment status points), and accumulated number of off-to-on transitions.

4. Provide the following minimum programming for each digital output

a. Name

b. Address

c. Output updating frequency

    d.   Engineering units (on/off, open/closed, freeze/normal, etc.)

    e.   Direct or Reverse action selection

    f.   Minimum on-time

    g.   Minimum off-time

    h.   Status association with a DI and failure alarming (as applicable)

    i.   Reporting of each change of state, and memory storage of the time of the last change of state.

    j.   Totalization of on-time (for all motorized equipment status points), and accumulated number of off-to-on transitions.

    k.   Default value to be used when the normal controlling value is not reporting.

C. Site-Specific Application Programming

    1.   All site specific application programming shall be written in a manner that will ensure programming quality and uniformity. Contractor shall ensure:

        a.   Programs are developed by one programmer, or a small group of programmers with rigid programming standards, to ensure a uniform style.

        b.   Programs for like functions are identical, to reduce debugging time and to ease maintainability.

        c.   Programs are thoroughly debugged before they are installed in the field.

    2.   Massage and tune application programming for a fully functioning system. It is the Contractor's responsibility to request clarification on sequences of operation that require such clarification.

    3.   All site-specific programming shall be fully documented and submitted for review and approval

        a.   Prior to downloading into the panel (see Submittal Package 2, Paragraph 1.5.)

        b.   At the completion of functional performance testing, and

        c.   At the end of the warranty period (see Warranty Maintenance, Paragraph 1.10).

    4.   All programming, graphics and data files must be maintained in a logical system of directories with self-explanatory file names. All files developed for the Project will be the property of the Owner and shall remain on the workstations/servers at the completion of the Project.

D. Alarm Configuration

    1.   Program alarms and alarm levels per Sequence of Operations.

3.9   SEQUENCES OF OPERATION

A. Packaged Single Zone VAV Heat Pump Units serving Thermafusers, AC-1 and AC-3

1. Each of the AC units operates independently through its factory installed controller.

2. All setpoints and scheduling shall be written from the BAS to the AC unit controller via the BACnet interface.

3. Supply fan speed control

    a. Fan speed shall be controlled by the units internal controls in order to maintain duct static pressure setpoint (match existing).

4. Minimum outdoor air control

    a. AC unit internal controls shall modulate the OA damper position to achieve measured OA airflow (using included OA AFMS or other included method) between the scheduled absolute minimum and the occupied minimum to maintain space CO_2 at setpoint of 1000 ppm.

5. Supply air temperature

    a. Supply air temperature shall be controlled by the AC unit internal controls to sequence the economizer, compressors, and electric heat (heating and cooling).

    b. Supply air temperature shall be controlled by the AC unit internal controls to maintain space temperature setpoint.

    c. Zone thermostat associated with AC unit shall be used for heating and cooling setpoints and to determine if the unit shall be in cooling or heating mode.

    d. The electric auxiliary heat shall be enabled when the outdoor air temperature is below 43°F and the heat pump compressor shall be disabled. There is not sufficient electrical capacity to run both the compressor and the electric heat.

6. Economizer Lockout

    a. The normal sequencing of the economizer dampers shall be disabled when OAT is ≥ 75°F

    b. Once the economizer is disabled, it shall not be re-enabled within 10 minutes and vice versa.

7. Night Ventilation

    a. Not required (disable existing sequence)

8. Alarms:

    a. Cooling compressors operate when the outdoor air is below 55°F. Level 4.

b. Maintenance interval alarm when fan has operated for more than 1500 hours: Level 5. Reset interval counter when alarm is acknowledged.

c. Fan alarm is indicated by the status input being different from the output command after a period of 15 seconds after a change in output status.

1) Commanded on, status off: Level 2.

2) Commanded off, status on: Level 4.

d. Level 3 alarms

1) Heating outputs are on and supply air fan is proven on and supply air temperature is below 80°F for more than 3 minutes indicating heating system failure.

2) Cooling outputs are on and supply air fan is proven on and supply air temperature is above 65°F for more than 3 minutes indicating cooling system failure.

B. Packaged Single Zone VAV Heat Pump Unit without Thermafusers, AC-2

1. Each of the AC units operates independently through its factory installed controller.

2. All setpoints and scheduling shall be written from the BAS to the AC unit controller via the BACnet interface.

3. Supply fan speed control

a. Fan speed shall be controlled by the units internal controls in order to maintain space temperature setpoint.

4. Minimum outdoor air control

a. AC unit internal controls shall modulate the OA damper position to achieve measured OA airflow (using included OA AFMS or other included method) between the scheduled absolute minimum and the occupied minimum to maintain space CO_2 at setpoint of 1000 ppm.

5. Supply air temperature

a. Supply air temperature shall be controlled by the AC unit internal controls to sequence the economizer, compressors, and electric heat (heating and cooling).

b. Supply air temperature shall be controlled by the AC unit internal controls.

c. Zone thermostat associated with AC unit shall be used for heating and cooling setpoints and to determine if the unit shall be in cooling or heating mode.

d. The electric auxiliary heat shall be enabled when the outdoor air temperature is below 43°F and the heat pump compressor shall be disabled. There is not sufficient electrical capacity to run both the compressor and the electric heat.

6. Economizer Lockout

      a.   The normal sequencing of the economizer dampers shall be disabled when OAT is ≥ 75°F

      b.   Once the economizer is disabled, it shall not be re-enabled within 10 minutes and vice versa.

   7.   Night Ventilation

      a.   Not required (disable existing sequence)

   8.   Alarms:

      a.   Cooling compressors operate when the outdoor air is below 55°F. Level 4.

      b.   Maintenance interval alarm when fan has operated for more than 1500 hours: Level 5. Reset interval counter when alarm is acknowledged.

      c.   Fan alarm is indicated by the status input being different from the output command after a period of 15 seconds after a change in output status.

         1)   Commanded on, status off: Level 2.

         2)   Commanded off, status on: Level 4.

      d.   Level 3 alarms

         1)   Heating outputs are on and supply air fan is proven on and supply air temperature is below 80°F for more than 3 minutes indicating heating system failure.

         2)   Cooling outputs are on and supply air fan is proven on and supply air temperature is above 65°F for more than 3 minutes indicating cooling system failure.

C.   Packaged Single Zone Cooling Only Unit, AC-4

   1.   Each of the AC units operates independently through its factory installed controller.

   2.   All setpoints and scheduling shall be written from the BAS to the AC unit controller via the BACnet interface.

   3.   Unit shall use internal controls to control to space temperature setpoint.

D.   Alarms

   1.   Maintenance interval alarm when fan has operated for more than 1500 hours: Level 5. Reset interval counter when alarm is acknowledged.

   2.   AC unit alarm: Level 2 to 4 based on severity.

3.10   SYSTEM COMMISSIONING

A.   Sequencing. The following list outlines the general sequence of events for submittals and commissioning:

1. Submit Submittal Package 1 (Hardware and Shop Drawings) and receive approval.

2. Initiate installation of BAS hardware, devices and wiring.

3. Develop point database and application software.

4. Simulate sequencing and debug programming off-line to the extent practical.

5. Submit Submittal Package 2 (Programming and Graphics) and receive approval.

6. Install point database and application software in field panels.

7. Ship controllers to AC unit vendor for installation within units and complete installation of field devices and wiring.

8. Field test application programs prior to functional testing.

9. Submit Package 3 (Post-Construction Trend Points List) in format specified for review and approval.

10. Receive approval of successful Trend Log configuration, or reconfigure as required.

11. Prepare and initiate commissioning Trend Logs.

12. Perform and record functional tests and submit Submittal Package 4 (Functional Test Report) for approval.

13. Assist in TAB tests and determining setpoints as specified in Section 230000.

14. Assist in Title 24 Acceptance Testing as specified in Section 230000.

15. Receive BAS Functional Test Report approval and approval to schedule Demonstration Tests.

16. Perform Demonstration Tests to Commissioning Provider and Owner's Representatives and submit Demonstration Test Report.

17. Receive acceptance of Demonstration Tests.

18. Train Owner personnel on BAS operation and maintenance.

19. Substantial Completion

20. Submit Package 5 (Post-Construction Trend Logs) in format specified for review and approval.

21. Receive approval of successful Trend Log tests, or retest as required.

22. Complete all items in Completion Requirements per Paragraph 1.7B.

23. Final Acceptance

24. Begin Warranty Period.

25. Prepare and initiate continuous Trend Logs per Paragraph 2.2A.3.

26. Update all software as specified.

27. End of Warranty Period

B. Coordinate with Commissioning Work specified in Section 230000.

C. Pre-functional tests

1. General

    a. Inspect the installation of all devices. Review the manufacturer's installation instructions and validate that the device is installed in accordance with them.

    b. Verify proper electrical voltages and amperages, and verify that all circuits are free from faults.

    c. Verify integrity/safety of all electrical connections.

    d. Verify that shielded cables are grounded only at one end.

    e. Verify that all sensor locations are as indicated on drawings and are away from causes of erratic operation.

2. Digital Outputs

    a. Verify that all digital output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.

3. Digital Inputs

    a. Adjust setpoints, where applicable.

        1) For current switches used as status on fans, adjust current setpoint so that fan status is OFF when fan discharge damper (if present) is fully closed and when belt is broken (temporarily remove belt).

        2) For current switches used as status on pumps, adjust current setpoint so that pump status is OFF when pump is dead-headed (temporarily close discharge valve).

        3) For differential pressure sensors on pumps and fans, set so that status is on when pump operating with all valves open (out on its curve).

4. Analog Outputs

    a. Verify start and span are correct and control action is correct.

b. Check all control valves and automatic dampers to ensure proper action and closure. Make any necessary adjustments to valve stem and damper blade travel.

c. Check all normal positions of fail-safe actuators.

d. For outputs to reset other manufacturer's devices (for example, chiller setpoint) and for feedback from them, calibrate ranges to establish proper parameters.

5. Analog Input Calibration

a. Sensors shall be calibrated as specified on the points list. Calibration methods shall be one of the following:

1) Factory: Calibration by factory, to standard factory specifications. Field calibration is not required.

2) Handheld: Field calibrate using a handheld device with accuracy meeting the requirements of Paragraph **Error! Reference source not found.**.

b. The calibrating parameters in software (such as slope and intercept) shall be adjusted as required. A calibration log shall be kept and initialed by the technician indicating date and time, sensor and hand-held readings, and calibration constant adjustments and included in the Pre-functional Test Report.

c. Inaccurate sensors must be replaced if calibration is not possible.

6. Alarms and Interlocks

a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.

b. Coordinate with Division 26 to test fire and life safety systems alarm contacts.

7. Variable Frequency Drive Minimum Speed

a. Minimum speed for VFD-driven fans shall be determined in accordance with this Paragraph. Tests shall be done for each piece of equipment, except that for multiple pieces of identical equipment used for identical applications, only one piece of equipment need be tested with results applied to all. Note that for fans and pumps, there is no minimum speed required for motor cooling. Power drops with cube of speed, causing motor losses to be minimal at low speeds.

b. This work shall be done only after fan/pump system is fully installed and operational.

c. Determine minimum speed setpoint as follows:

1) Start the fan or pump.

2) Manually set speed to 6 Hz (10%) unless otherwise indicated in control sequences. For cooling towers with gear boxes, use 20% or whatever minimum speed is recommended by tower manufacturer.

3) Observe fan/pump in field to ensure it is visibly rotating.

    a) If not, gradually increase speed until it is.

4) The speed at this point shall be the minimum speed setpoint for this piece of equipment.

5) Record minimum speeds in log and store in software point as indicated in ASHRAE Guideline 36.

8. Tuning

a. Tune all control loops to obtain the fastest stable response without hunting, offset or overshoot. Record tuning parameters and response test results for each control loop in the Pre-functional Test Report. Except from a startup, maximum allowable variance from set point for controlled variables under normal load fluctuations shall be as follows. Within 3 minutes of any upset (for which the system has the capability to respond) in the control loop, tolerances shall be maintained (exceptions noted)

Controlled Variable	Control Accuracy
Duct Pressure	±0.1 inches w.g.
Building and relief plenum	±0.01 inches w.g.
Duct Temperature	±2°F

9. Interface and Control Panels

a. Ensure devices are properly installed with adequate clearance for maintenance and with clear labels in accordance with the Record Drawings.

b. Ensure that terminations are safe, secure and labeled in accordance with the Record Drawings.

c. Check power supplies for proper voltage ranges and loading.

d. Ensure that wiring and tubing are run in a neat and workman-like manner, either bound or enclosed in trough.

e. Check for adequate signal strength on communication networks.

f. Check for standalone performance of controllers by disconnecting the controller from the LAN. Verify the event is annunciated at Operator Interfaces. Verify that the controlling LAN reconfigures as specified in the event of a LAN disconnection.

g. Ensure that buffered or volatile information is held through power outage.

h. With all system and communications operating normally, sample and record update and annunciation times for critical alarms fed from the panel to the Operator Interface.

i. Check for adequate grounding of all BAS panels and devices.

10. Operator Interfaces

a. Verify that all elements on the graphics are functional and are properly bound to physical devices or virtual points, and that hot links or page jumps are functional and logical.

b. Verify that the alarm logging, paging, emailing etc. are functional and per requirements.

D. Testing, Adjusting, and Balancing (TAB) Coordination

1. Coordinate with Work performed under Section 230000. Some balancing procedures require the BAS to be operational and require Contractor time and assistance.

2. Setpoint Determination

a. Perform pre-functional tests described in Paragraph 3.10C before assisting in setpoint determination.

b. Coordinate with Work performed under Section 230000 to determine fan static pressure setpoints, confirm AFMS calibration, etc. as indicated in Section 230000.

E. Functional Tests

1. Test schedule shall be coordinated with the Commissioning Provider, Commissioning Coordinator, and Owner's Representative.

2. Functional tests may be witnessed by Owner's Representative at the Owner's option.

3. All approved Functional Tests shall be conducted by the Contractor with results confirmed and signed by the Contractor's start-up technician.

4. Test documentation

a. Owner's Representatives will prepare functional testing forms after Submittal Package 2 has been reviewed and approved. Tests will be designed to test all sequences in a formal manner with simulations and expected outcomes.

b. Review tests and recommend changes that will improve ease of testing or avoid possible system damage, etc. and provide to Owner's Representative.

c. Complete work, document results on forms, and submit for approval as Submittal Package 4 Functional Test Report. Tutorials for using the functional test Excel workbook can be found here.

F. Demonstration Test

1. Demonstration tests consist of a small representative sample of functional tests and systems randomly selected by the Commissioning Provider. Tests will be designed to occur over no longer than 2working days.

2. Schedule the demonstration with the Commissioning Provider and Owner's Representative at least 1 week in advance. Demonstration shall not be scheduled until the Functional Test Report has been approved.

3. The Contractor shall supply all personnel and equipment for the demonstration, including, but not limited to, instruments, ladders, etc. Contractor-supplied personnel shall be those who conducted the Functional tests or who are otherwise competent with and knowledgeable of all project-specific hardware, software, and the HVAC systems.

4. The system will be demonstrated following procedures that are the same or similar to those used in the Pre-Functional and Functional Tests. The Commissioning Provider will supply the test forms at the site at the start of the tests.

5. Demonstration tests may be witnessed by Owner's Representative at the Owner's option.

6. Contractor shall conduct tests as directed by and in the presence of the Commissioning Provider and complete test forms. Commissioning Provider will document the test results as the Demonstration Test Report after tests are complete.

7. Demonstration Tests shall be successfully completed and approved prior to Substantial Completion.

G. Trend Log Tests

1. Trends shall be fully configured to record and store data to the server for the points and at the interval listed in Paragraph 2.2 as follows:

   a. Commissioning: Configure trends prior to functional testing phase. Retain configuration until post-construction commissioning trend review has been completed successfully and accepted by the Owner's representative. Trends shall be deactivated after acceptance.

   b. Continuous: After system acceptance, configure trends for the purpose of long term future diagnostics. Configure trends to overwrite the oldest trends at the longest interval possible without filling the server hard disk beyond 80%.

2. Post-Construction Trend Test

   a. Trend logging shall not commence until Demonstration Tests are successfully completed.

   b. Hardware Points. Contractor shall configure points to trend as indicated in the Commissioning Trend column listed in Paragraph 2.2 points.

   c. Software Points. Include the following in trends of systems and zones whose hardware points are being trended as called for above. Time interval shall be the same as associated hardware point.

      1) All setpoints and limits that are automatically reset, such as supply air temperature and fan static pressure setpoints, plus the points that are driving the reset, such as zone level cooling and static pressure requests

      2) All setpoints that are adjustable by occupants

      3) Outputs of all control loops, other than those driving a single AO point that is already being trended

4) System mode points (e.g. Warm-up, Occupied, etc.)

5) Global overrides such as demand shed signals

6) Calculated performance monitoring points, such as chiller efficiency

d. Submit for review and approval by the Commissioning Provider a table of points to be trended along with trend intervals or change-of-value a minimum of 14 days prior to trend collection period, as Submittal Package 5.

e. Trends shall be uploaded to the CSS.

f. Trend logs of all points indicated above shall be collected for a 3 week Trend Period.

g. At the completion of the Trend Period, data shall be reviewed by the Contractor to ensure that the system is operating properly. If so, data shall be submitted to the Owner in an electronic format agreed to by the Owner and Contractor (such as flash drive or via direct access to the CSS via the internet) as Submittal Package 8.

h. Data will be analyzed by the Commissioning Provider.

i. The system shall be accepted only if the trend review indicates proper system operation without malfunction, without alarm caused by control action or device failure, and with smooth and stable control of systems and equipment in conformance with these specifications. If any but very minor glitches are indicated in the trends, steps f to h above shall be repeated for the same Trend Period until there is a complete Trend Period of error free operation.

j. After successfully completing the Post-Construction Trend Tests, the Contractor shall configure all points to trend as indicated in the Continuous Trend column listed in Paragraph 2.2 points list.

H. Remedial Work

1. Repair or replace defective Work, as directed by Owner's Representative in writing, at no additional cost to the Owner.

2. Restore or replace damaged Work due to tests as directed by Owner's Representative in writing, at no additional cost to the Owner.

3. Restore or replace damaged Work of others, due to tests, as directed by Owner's Representative in writing, at no additional cost to the Owner.

4. Remedial Work identified by site reviews, review of submittals, demonstration test, trend reviews, etc. shall be performed to the satisfaction of the Owner's Representative, at no additional cost to the Owner.

5. Contractor shall compensate Owner's Representatives and Commissioning Provider on a time and material basis at standard billing rates for any additional time required to witness additional demonstration tests or to review additional BAS trends beyond the initial tests, at no additional cost to the Owner.

3.11   TRAINING

    A. Coordinate schedule and materials with Commissioning Provider.

        1. On-Site Training

            a. Include 2 hours total of on-site training to assist personnel in becoming familiar with the new AC units, control sequences, etc.

            b. Owner shall be permitted to videotape training sessions.

        2. During the warranty period, provide unlimited telephone support for all trained operators.

    B. The instructor(s) shall be factory-trained instructors experienced in presenting this material.

    C. The type and number of personnel for training shall include

        1. Day-to-day Operators: 1

<div align="center">END OF SECTION 250000</div>