SECTION 23 05 13 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes general requirements for polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on ac power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation.

1.2 COORDINATION

A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:

1. Motor controllers.
2. Torque, speed, and horsepower requirements of the load.
3. Ratings and characteristics of supply circuit and required control sequence.
4. Ambient and environmental conditions of installation location.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

A. Comply with requirements in this Section except when stricter requirements are specified in HVAC equipment schedules or Sections.

B. Comply with NEMA MG 1 unless otherwise indicated.

2.2 MOTOR CHARACTERISTICS

A. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet above sea level.

B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

2.3 POLYPHASE MOTORS

A. Description: NEMA MG 1, Design B, medium induction motor.

B. Efficiency: Premium Energy efficient, as defined in NEMA MG 1.

C. Service Factor: 1.15.

D. Multispeed Motors: Variable torque.

1. For motors with 2:1 speed ratio, consequent pole, single winding.
2. For motors with other than 2:1 speed ratio, separate winding for each speed.

E. Multispeed Motors: Separate winding for each speed.

F. Rotor: Random-wound, squirrel cage.

G. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.

H. Temperature Rise: Match insulation rating.

I. Insulation: Class F.

J. Code Letter Designation:

1. Motors 15 HP and Larger: NEMA starting Code F or Code G.
2. Motors Smaller than 15 HP: Manufacturer's standard starting characteristic.

K. Enclosure Material: Cast iron for motor frame sizes 324T and larger; rolled steel for motor frame sizes smaller than 324T.

2.4 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

A. Motors Used with Reduced-Voltage and Multispeed Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals in motor terminal box, suited to control method.

B. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.

1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.
2. Premium-Efficient Motors: Class B temperature rise; Class F insulation.
3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.
5. Shaft Static Ground Ring(s) similar to Aegis SGR.

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 23 05 13

SECTION 23 05 93 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Balancing Air Systems:

    a. Constant-volume air systems.

2. Balancing Hydronic Piping Systems:

    a. Variable-flow hydronic systems.

3. Balancing Hydronic Cooling Coils:

    a. Air Handling Units.

4. HVAC equipment quantitative-performance settings.
5. Reporting results of activities and procedures specified in this Section.
6. Coordinate with Commissioning.

1.2 DEFINITIONS

A. AABC: Associated Air Balance Council.

B. NEBB: National Environmental Balancing Bureau.

C. TAB: Testing, adjusting, and balancing.

D. TABB: Testing, Adjusting, and Balancing Bureau.

E. TAB Specialist: An entity engaged to perform TAB Work.

F. Adjust: To regulate fluid flow rate and air patterns at the terminal equipment, such as to reduce fan speed or adjust a damper.

G. Balance: To proportion flows within the distribution system, including submains, branches, and terminals, according to indicated quantities.

H. Barrier or Boundary: Construction, either vertical or horizontal, such as walls, floors, and ceilings that are designed and constructed to restrict the movement of airflow, smoke, odors, and other pollutants.

I. Draft: A current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person's skin than is normally dissipated.

J. NC: Noise criteria.

K. Procedure: An approach to and execution of a sequence of work operations to yield repeatable results.

L. RC: Room criteria.

M. Report Forms: Test data sheets for recording test data in logical order.

N. Static Head: The pressure due to the weight of the fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.

O. Suction Head: The height of fluid surface above the centerline of the pump on the suction side.

P. System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

Q. System Effect Factors: Allowances used to calculate a reduction of the performance ratings of a fan when installed under conditions different from those presented when the fan was performance tested.

R. Terminal: A point where the controlled medium, such as fluid or energy, enters or leaves the distribution system.

S. Test: A procedure to determine quantitative performance of systems or equipment.

T. Testing, Adjusting, and Balancing (TAB) Firm: The entity responsible for performing and reporting TAB procedures.

1.3 SUBMITTALS

A. Qualification Data: Within 45 days of Contractor's Notice to Proceed, submit documentation that the TAB contractor and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.

B. Contract Documents Examination Report: Within 45 days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.

C. Strategies and Procedures Plan: Within 90 days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.

D. Certified TAB reports.

E. Sample report forms.

F. Instrument calibration reports, to include the following:

1. Instrument type and make.
2. Serial number.
3. Application.
4. Dates of use.
5. Dates of calibration.

1.4 QUALITY ASSURANCE

A. TAB Contractor Qualifications: Engage a TAB entity certified by AABC NEBB or TABB.

1. TAB Field Supervisor: Employee of the TAB contractor and certified by AABC NEBB or TABB.
2. TAB Technician: Employee of the TAB contractor and who is certified by AABC NEBB or TABB as a TAB technician.

B. TAB Conference: Meet with FAA**,** COTR and Commissioning Authority on approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Require the participation of the TAB field supervisor and technicians. Provide seven days' advance notice of scheduled meeting time and location.

1. Agenda Items:

a. The Contract Documents examination report.
b. The TAB plan.
c. Coordination and cooperation of trades and subcontractors.
d. Coordination of documentation and communication flow.

C. Certify TAB field data reports and perform the following:

1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
2. Certify that the TAB team complied with the approved TAB plan and the procedures specified and referenced in this Specification.

D. TAB Report Forms: Use standard TAB contractor's forms approved by FAA, COTR and Commissioning Authority.

E. Instrumentation Type, Quantity, Accuracy, and Calibration: As described in ASHRAE 111, Section 5, "Instrumentation."

1.5 PROJECT CONDITIONS

A. Full FAA Occupancy: FAA will occupy the site and existing building during entire TAB period. Cooperate with FAA during TAB operations to minimize conflicts with FAA's operations.

1.6 COORDINATION

A. Notice: Provide seven days' advance notice for each test. Include scheduled test dates and times.

B. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment.

B. Examine systems for installed balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are accessible.

C. Examine the approved submittals for HVAC systems and equipment.

D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine equipment performance data including fan and pump curves.

1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

F. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.

G. Examine test reports specified in individual system and equipment Sections.

H. Examine HVAC equipment and filters and verify that bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

I. Examine strainers. Verify that startup screens are replaced by permanent screens with indicated perforations.

J. Examine three-way valves for proper installation for their intended function of diverting or mixing fluid flows.

K. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

L. Examine system pumps to ensure absence of entrained air in the suction piping.

M. Examine operating safety interlocks and controls on HVAC equipment.

N. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.2 PREPARATION

A. Prepare a TAB plan that includes strategies and step-by-step procedures.

B. Complete system-readiness checks and prepare reports. Verify the following:

1. Permanent electrical-power wiring is complete.
2. Hydronic systems are filled, clean, and free of air.
3. Automatic temperature-control systems are operational.
4. Equipment and duct access doors are securely closed.
5. Balance, smoke, and fire dampers are open.
6. Isolating and balancing valves are open and control valves are operational.
7. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
8. Windows and doors can be closed so indicated conditions for system operations can be met.

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Total System Balance" ASHRAE 111 NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" or SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing" and in this Section.

1. Comply with requirements in ASHRAE 62.1-2004, Section 7.2.2, "Air Balancing."

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.

1. After testing and balancing, install test ports and duct access doors.
2. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Section 23 07 13 "HVAC Insulation."

C. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.

D. Take and report testing and balancing measurements in inch-pound (IP) units.

3.4 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.

B. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.

C. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

D. Verify that motor starters are equipped with properly sized thermal protection.

E. Check dampers for proper position to achieve desired airflow path.

F. Check for airflow blockages.

G. Check condensate drains for proper connections and functioning.

H. Check for proper sealing of air-handling-unit components.

3.5 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure total airflow.

    a. Where sufficient space in ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow.

2. Measure fan static pressures as follows to determine actual static pressure:
    a. Measure static pressure directly at the fan outlet or through the flexible connection.
    b. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.
    c. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

3. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.

    a. Report the cleanliness status of filters and the time static pressures are measured.

4. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
5. Obtain approval from FAA COTR and Commissioning Authority for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in Division 23 Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
6. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

3.6 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports with pertinent design data, and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against the approved pump flow rate

B. Prepare schematic diagrams of systems' "as-built" piping layouts.

C. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:

1. Open all manual valves for maximum flow.
2. Check liquid level in expansion tank.
3. Check makeup water-station pressure gage for adequate pressure for highest vent.
4. Check flow-control valves for specified sequence of operation, and set at indicated flow.
5. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type unless several terminal valves are kept open.
6. Set system controls so automatic valves are wide open to heat exchangers.
7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.7 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

A. Balance systems with automatic two-way and three-way control valves by setting systems at maximum flow through heat-exchange terminals and proceed as specified above for hydronic systems.

3.8 PROCEDURES FOR MOTORS

A. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:

1. Manufacturer's name, model number, and serial number.
2. Motor horsepower rating.
3. Motor rpm.
4. Efficiency rating.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter thermal-protection-element rating.

B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass of the controller to prove proper operation. Record observations including name of controller manufacturer, model number, serial number, and nameplate data.

3.9 PROCEDURES FOR HEAT-TRANSFER COILS

A. Water Coils: Measure the following data for each coil:

1. Entering- and leaving-water temperature.
2. Water flow rate.
3. Water pressure drop.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.
7. Air pressure drop.

3.10 PROCEDURES FOR TEMPERATURE MEASUREMENTS

A. During TAB, report the need for adjustment in temperature regulation within the automatic temperature-control system.

B. Measure indoor wet- and dry-bulb temperatures every other hour for a period of one eight-hour day, on first floor, to prove correctness of final temperature settings.

C. Measure outside-air, wet- and dry-bulb temperatures.

3.11 TEMPERATURE-CONTROL VERIFICATION

A. Coordinate with commissioning work required to verify temperature control system operation.

3.12 TOLERANCES

A. Set HVAC system airflow and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans: minus 5 to plus 10 percent.
2. Air Outlets and Inlets: minus 5 to plus 10 percent.
3. Cooling-Water Flow Rate: minus 5 to plus 10 percent.

3.13 REPORTING

A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems' balancing devices. Recommend changes and additions to systems' balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Status Reports: Prepare monthly progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.14 FINAL REPORT

A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
2. Include a list of instruments used for procedures, along with proof of calibration.

B. Final Report Contents: In addition to certified field-report data, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance; do not include Shop Drawings and product data.

C. General Report Data: In addition to form titles and entries, include the following data:

1. Title page.
2. Name and address of the TAB contractor.
3. Project name.
4. Project location.
5. FAA's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.

9. Signature of TAB supervisor who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:

    a. Indicated versus final performance.
    b. Notable characteristics of systems.
    c. Description of system operation sequence if it varies from the Contract Documents.

12. Nomenclature sheets for each item of equipment.
13. Data for terminal units, including manufacturer's name, type, size, and fittings.
14. Notes to explain why certain final data in the body of reports vary from indicated values.
15. Test conditions for fans and pump performance forms including the following:

    a. Settings for outdoor-, return-, and exhaust-air dampers.
    b. Conditions of filters.
    c. Cooling coil, wet- and dry-bulb conditions.
    d. Face and bypass damper settings at coils.
    e. Fan drive settings including settings and percentage of maximum pitch diameter.
    f. Settings for supply-air, static-pressure controller.
    g. Other system operating conditions that affect performance.

D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:

1. Quantities of outdoor, supply, return, and exhaust airflows.
2. Water and steam flow rates.
3. Duct, outlet, and inlet sizes.
4. Pipe and valve sizes and locations.
5. Terminal units.
6. Balancing stations.
7. Position of balancing devices.

E. Air-Handling Unit Test Reports: For air-handling units with coils, include the following:

1. Unit Data: Include the following:

    a. Unit identification.
    b. Location.
    c. Make and type.
    d. Model number and unit size.
    e. Manufacturer's serial number.
    f. Unit arrangement and class.
    g. Discharge arrangement.
    h. Sheave make, size in inches, and bore.
    i. Sheave dimensions, center-to-center, and amount of adjustments in inches.
    j. Number of belts, make, and size.
    k. Number of filters, type, and size.

2. Motor Data:

    a. Make and frame type and size.
    b. Horsepower and rpm.
    c. Volts, phase, and hertz.
    d. Full-load amperage and service factor.
    e. Sheave make, size in inches, and bore.
    f. Sheave dimensions, center-to-center, and amount of adjustments in inches.

3. Test Data (Indicated and Actual Values):

    a. Total airflow rate in cfm.
    b. Total system static pressure in inches wg.
    c. Fan rpm.
    d. Discharge static pressure in inches wg.
    e. Filter static-pressure differential in inches wg.
    f. Preheat coil static-pressure differential in inches wg.
    g. Cooling coil static-pressure differential in inches wg.
    h. Heating coil static-pressure differential in inches wg.
    i. Outside airflow in cfm.
    j. Return airflow in cfm.
    k. Outside-air damper position.
    l. Return-air damper position.

F. Apparatus-Coil Test Reports:

1. Coil Data:

    a. System identification.
    b. Location.
    c. Coil type.
    d. Number of rows.
    e. Fin spacing in fins per inch o.c.
    f. Make and model number.
    g. Face area in sq. ft..
    h. Tube size in NPS.
    i. Tube and fin materials.
    j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):

    a. Air flow rate in cfm.
    b. Average face velocity in fpm.
    c. Air pressure drop in inches wg.
    d. Outdoor-air, wet- and dry-bulb temperatures in deg F.
    e. Return-air, wet- and dry-bulb temperatures in deg F.
    f. Entering-air, wet- and dry-bulb temperatures in deg F.
    g. Leaving-air, wet- and dry-bulb temperatures in deg F.
    h. Water flow rate in gpm.

i. Water pressure differential in feet of head or psig.
j. Entering-water temperature in deg F.
k. Leaving-water temperature in deg F.
l. Refrigerant expansion valve and refrigerant types.
m. Refrigerant suction pressure in psig.
n. Refrigerant suction temperature in deg F.
o. Inlet steam pressure in psig.

G. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and size.
e. Manufacturer's serial number.
f. Arrangement and class.
g. Sheave make, size in inches, and bore.
h. Center-to-center dimensions of sheave, and amount of adjustments in inches.

2. Motor Data:

a. Motor make, and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches, and bore.
f. Center-to-center dimensions of sheave, and amount of adjustments in inches.
g. Number, make, and size of belts.

3. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Suction static pressure in inches wg.

H. Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

a. System and air-handling unit number.
b. Location and zone.
c. Traverse air temperature in deg F.
d. Duct static pressure in inches wg.
e. Duct size in inches.

f. Duct area in sq. ft.
g. Indicated airflow rate in cfm.
h. Indicated velocity in fpm.
i. Actual airflow rate in cfm.
j. Actual average velocity in fpm.
k. Barometric pressure in psig.

I. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:

a. System and air-handling-unit identification.
b. Location and zone.
c. Room or riser served.
d. Coil make and size.
e. Flowmeter type.

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm.
b. Entering-water temperature in deg F.
c. Leaving-water temperature in deg F.
d. Water pressure drop in feet of head or psig.
e. Entering-air temperature in deg F.
f. Leaving-air temperature in deg F.

J. Instrument Calibration Reports:

1. Report Data:

a. Instrument type and make.
b. Serial number.
c. Application.
d. Dates of use.
e. Dates of calibration.

3.15 INSPECTIONS

A. Initial Inspection:

1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the final report.
2. Check the following for each system:

a. Measure airflow of at least 10 percent of air outlets.
b. Measure water flow of at least 5 percent of terminals.
c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.

d. Verify that balancing devices are marked with final balance position.
e. Note deviations from the Contract Documents in the final report.

B. Final Inspection:

1. After initial inspection is complete and documentation by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by COTR and Commissioning Authority.
2. The TAB contractor's test and balance engineer shall conduct the inspection in the presence of COTR and Commissioning Authority.
3. COTR and Commissioning Authority shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.
4. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
5. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

C. TAB Work will be considered defective if it does not pass final inspections. If TAB Work fails, proceed as follows:

1. Recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
2. If the second final inspection also fails, FAA may contract the services of another TAB contractor to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB contractor's final payment.

D. Prepare test and inspection reports.

3.16 ADDITIONAL TESTS

A. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

END OF SECTION 23 05 93

SECTION 23 09 00 - INSTRUMENTATION AND CONTROLS FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. Provide control valves, control valve actuators, wiring and cable as necessary, dampers, damper actuators, damper end switches, network connection from VFDs to control system, new inputs/outputs and input/output control modules as necessary to complete control system installation, and sequence of operation changes.

1.2 AIR TRAFFIC CONTROL EQUIPMENT RESTRICTIONS

A. Job Conditions: Do not permit interference with the air traffic control function at the Center. Schedule and plan work to permit normal facility operations to continue with minimum of disruption. Access to the facility shall be kept unobstructed at all times. If interference with the existing facility operations seems to be unavoidable, advise the COTR 10 days prior to such interference. Proceed as directed by the COTR.

B. Equipment Shutdown: Each ARTCC maintains air traffic control continuously without shutdown. Various techniques are employed to achieve maximum system availability. Mechanical and electrical systems in direct support of air traffic operation and environmental systems have redundant configurations. Shutdown of equipment shall be scheduled with the COTR at least 10 days prior to the DDCS installer’s need. The reliability of mechanical and electrical systems is compromised when redundant equipment is not available. Every effort will be made by the FAA to allow work to be accomplished during the installer’s normal working hours; however, the COTR may require that certain equipment be shut down during off normal hours and be restored to service immediately after this period. Shutdown shall be accomplished by FAA personnel.

C. Equipment Testing: Since equipment failures or unexpected shut downs may occur during new equipment start up and testing, this work shall be scheduled with the COTR to take place during off normal hours. If power transfers are required during equipment testing, a sufficient amount of off normal hours shall be scheduled to assure that systems recover and perform properly after the power transfer occurs.

1.3 RELATED SECTIONS

A. Division 01, "General Requirements" contains requirements that relate to this Section.

B. The entirety of the Division 23 Specifications contains requirements which relate to this Section.

C. The entirety of the Division 26 Specifications contains requirements which relate to this Section.

1.4 REFERENCE STANDARDS

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

1. 135-2004: 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-232: Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Exchange.
2. EIA/TIA-485: Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multi-point Systems.
3. EIA/TIA-568: Commercial Building Telecommunications Wiring Standard.
4. EIA/TIA-606: Administration Standard for the Telecommunications Infrastructure of Commercial Buildings.

C. Institute of Electrical and Electronics Engineers (IEEE)

1. IEEE-802.3: Standards for Local Area Networks - Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications.

D. International Organization for Standardization (ISO)
1. ISO-8802: Telecommunications and Information Exchange Between Systems

E. National Fire Protection Association (NFPA)

1. 70: National Electric Code
2. 72: National Fire Alarm Code
3. 90A: Standard for the Installation of Air Conditioning and Ventilating Systems
4. 262: Standard Method of Test for Fire and Smoke Characteristics of Wires and Cables

F. Underwriters Laboratories (UL)

1. 94: Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
2. 268: Smoke Detectors for Fire Protective Signaling Systems
3. 268A: Smoke Detectors for Duct Applications
4. 486A: Wire Connectors and Soldering Lugs for Use With Copper Conductors
5. 916: Energy Management Equipment Listing
6. 1449: Surge Protective Devices

G. Federal Communications Commission (FCC)

1. 47CFR Part 15, Subpart B - Unintentional Radiators

H. National Electrical Manufacturer's Association (NEMA)

1. ICS6: Enclosures for Industrial Control Systems.

1.5 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 BACnet/IP 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 DDCS. 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. Human-Machine Interface (HMI): Method by which operator communicates with HVAC control system. Allows operator to command, monitor, and program control system.

J. Direct Digital Control Panel (DDCP): An enclosure with hinged doors, back panel and keyed lock to mount Direct Digital Control (DDC) components, panel devices and other control devices.

K. Last Commanded State (L.C.S.): A failure condition where, upon loss of control signal or power to a controlled device, the device continues to maintain the state or position of that device as it was last commanded by the DDCS.

L. 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.

M. PICS - Protocol Implementation Conformance Statement: A written document, created by the manufacturer of a device, which identifies the particular options specified by ANSI/ASHRAE Standard 135–2004, BACnet, that are implemented in the device.

1.6 SYSTEM DESCRIPTION

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

B. Existing 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.

1.7 SEQUENCE OF OPERATION

A. Point Listing: See the DDCS Point Function Schedule shown on the drawings for a list of required hardware points and associated software functions. Points 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. DDCS 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 set as shown on the DDCS Point Function Schedule on the mechanical plans. The alarm limits may be changed during start-up, if required, to meet actual operating conditions.

D. Alarm Monitoring: Alarms identified on the DDCS Point Function Schedule shall be enunciated on the display of the OWS and on the alarm printer.

E. Air Handling Unit 201,202,203,204,210,211,214A,214B and 214C

1. Supply Fan Hand-Off-Auto Operation: Hand-Off-Auto settings shall be provided as part of the variable frequency drive through the drive's keypad. In the Hand mode, the fan shall start and run continuously. In the Off mode, the fan shall be stopped. In the Auto mode, the fan shall be started and stopped as described under "Automatic Mode Start/Stop Control". Program a time delay into the VFD, in both the Hand and Auto modes, to stagger the restart of each fan after a power failure to prevent creating a spike in the facility electrical demand.
2. Supply Fan Drive-Off-Bypass Operation: A Drive-Off-Bypass selector switch shall be provided as part of the variable frequency drive. The Bypass shall consist of an across the line starter which will allow the fan to be operated at full speed when the variable frequency drive is not available for operation. When the switch is placed in the Drive position, the variable frequency drive shall operate as described under "Supply Fan Hand-Off-Auto Operation". When the switch is placed in the Off position, the fan shall stop. When the switch is placed in the Bypass position, the fan shall start and the fan motor shall run at full speed using line voltage. Bypass functionality described shall occur regardless of the current Hand-Off-Auto selected mode or the start/stop command from the DDCS.
3. Supply Fan Local-Remote Speed Control: Local-Remote settings shall be provided as part of the variable frequency drive through the drive's keypad. In the Local mode, the fan speed shall be controlled through a manual speed control located at the VFD control panel. In the Remote mode, the fan speed shall be controlled by the DDCS.
4. Automatic Mode Start/Stop Control: The DDCS shall start and stop the supply fan. To start the fan, the DDCS shall send a signal to the VFD which will start the supply fan. To stop the supply fan, the DDCS shall send a signal to the VFD, which will stop the supply fan.

5. Supply Fan VFD Speed Control: When the supply fan VFD is started, the DDCS shall control the speed of the VFD to maintain the room air temperature.

6. Safety Device Interlocks: Upon activation, safety devices shall stop the unit in the Hand, Auto and Bypass modes.
   a. Safety interlocks shall be hardwired; utilizing the safety circuitry built into the VFD; and provided independent of the DDCS.

   b. Power for the safety circuit shall be provided from the VFD. No other power source is acceptable. If the VFD cannot directly provide a power source, an appropriately sized transformer shall be added at the VFD for this purpose.

      1) Loss of power to the DDCS shall not interfere with the ability to start the supply fan in either the Hand or Bypass modes of operation.

2) Loss of power to the DDCS shall not interfere with the ability of safety devices to disable the supply fan in either the Hand or Bypass modes of operation.

F. Control Wing Attic – AHU- 201,202,203,204 (Sequence Of Operations):

1. General: The air handling units serve the control room and run 24 hours a day, 7 days a week. Each unit shall be controlled by a separate controller to perform the sequence of operation as described below. The BAS shall sequentially start the equipment with 10 seconds (adj.) time delay between start commands to minimize inrush current during start-up or after power failure. The time delay shall not prevent the unit controller from immediately starting equipment in response to an equipment failure.
2. Supply Fan Hand-Off-Auto Operation: In the Hand mode, the supply fan shall start and run continuously. In the Off mode, the fan shall be de-energized. In the Auto mode, the fan shall be started and stopped as described under "Automatic Mode Start/Stop Control".
3. Automatic Mode Start/Stop Control: The BAS shall start and stop the unit. To start the unit, the BAS shall send a signal to the unit controller which shall energize the EC drive supply fan and operate as describe under "Supply Fan Automatic Speed Control". If the unit does not start after a 60 second (adjustable) time delay, a unit failure alarm shall be issued and the unit start command shall be canceled. To stop the unit, the BAS shall send a stop command to the unit controller which shall de-energize the supply fan.
4. Supply Fan Automatic Speed Control: When the supply fan is started, the BAS shall send a speed command to the unit controller which shall control the speed of EC drive to maintain the supply air flow rate at set point. When the fan is stopped, the unit controller shall return the EC drive to a speed of zero. If the BAS senses that one of the unit fans has failed through loss of run status or through a loss of air flow sensed by the supply fan air flow measuring station AFM-1, the fans on the remaining fans shall automatically speed up the fans to deliver the required operating CFM until the failed fan is operating again. When the failed fan has returned to normal operation the fans on the other fans shall return back to normal operation.
5. Damper Control: When the unit is commanded to start in Hand or Auto Mode, the isolation dampers shall be commanded open.
6. Cooling Control: The unit controller shall modulate the chilled water valve V201-C to maintain the discharge air temperature, as sensed by supply air temperature sensor TS-1. The set point shall be adjustable and initially set at 60°F and reset based on the return air temperature as sensed by TS-2. When the return temperature rises, proportionally decrease the discharge air set point. When the return air temperature falls, the discharge air set point will be proportionally increased. The discharge air set point shall never be more than +/- 2°F (adjustable) of the base set point. When the unit supply fan is off, the cooling control valve V201-C shall close.
7. Fire Alarm Shutdown:
    a. When particles of combustion are sensed by the supply and return air duct smoke detector SD201-1 and SD201-2, the smoke detectors shall close the fire and smoke dampers via a hardwire interlock and stop the respective AHU, in either the Automatic or Hand Mode. An alarm signal shall be sent to the BAS and the Building Fire Alarm Panel. When the smoke alarm condition has been cleared 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 filter.
9. Fan Status: The fan status contacts on the EC drive 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, after a 60 second time delay (adjustable), an alarm shall be generated and sent to the BAS.

10. Failure Mode: Upon loss of control signal or electrical power, the control devices shall fail in the manner, as follows:

a. Supply fan start/stop: Off
b. Cooling coil control valve: Open
c. Return air damper: Open

G. Building B Attic – AHU- 210/211 (Sequence Of Operations):

A) The return and supply dampers associated with each unit shall be Opened/Closed through the DDCP. The damper limit switches shall start the respective fan after the return and supply dampers have proven at least 90% open and shall stop the fan after the dampers close past 80%.
B) An Auto/Open switch shall be capable of overriding the ACD to manually open the dampers after they have been closed. The Auto/Open switch shall be monitored by the DDCP and shall initiate an alarm at the OWS if the switch is placed in the Open position.
C) AHU-210 and AHU-211 shall be alternated as primary and standby unit every 1 to 31 days, initially set at 7 days (adjustable). The primary unit shall run continuously 24 hours, 7 days a week.
D) When the primary unit is enabled by the DDCP, the supply and return air dampers shall be commanded open through the Field Relay. When the supply and return dampers are proven open, the Fan drive shall start the fan thought the Run Permissive Relay and ramp up to normal operating speed.
E) Upon a Run Status from the Fan drive, the chilled water valve shall modulate to maintain a set point of 75 F (adjustable) return air temperature. The supply air temperature sensor shall function as a low and high limit control and shall override the return air sensor in order to maintain a maximum of 62 F (adjustable) and a minimum of 58 F (adjustable) supply temperature.
F) The Coyote drive shall modulate the supply fan speed to maintain a static pressure set point of 0.05 “WC (adjustable) as sensed by the static pressure sensor in the raised access floor.
G) When the damper limit switches indicate that the dampers are closing, the supply fan shall be disabled through the Run Permissive Relay.
H) Upon a Off Status from the Fan drive, the chilled water valve shall close.
I) In the event that the primary unit should fail, the DDCS shall automatically start the standby unit and generate an alarm at the OWS.
J) A differential pressure switch shall monitor the pressure drop at the stage two filter. When the pressure exceeds an adjustable limit, an alarm shall be sent to the OWS.

Dilution Ventilation Mode

A) The "Dilution Ventilation Mode" of operation shall be initiated either through a momentary push button switch or through the OWS.
B) If the space temperature in control room 151 rises above 85 F (adjustable) or drops below 65 F (adjustable), the dilution ventilation mode shall be disabled. If the space humidity in control room 151 rises above 70% relative humidity (adjustable) or falls below 30% relative humidity (adjustable), the dilution ventilation mode shall be disabled. The primary unit shall be disabled. Refer to the damper matrix for the dilution ventilation position. Once the control dampers have proven through the dampers position switches, the primary unit shall be enabled.

AHU-214A, AHU-214B, AHU-214C Damper Matrix				
Damper Name	Damper ID	Normal	Dilution	Failure
AHU-214A OA	CD-1	OPEN (MIN)	OPEN	CLOSED
AHU-214B OA	CD-12	CLOSED	OPEN	CLOSED
AHU-214C OA	CD-2	OPEN (MIN)	OPEN	CLOSED
AHU-214C RA	CD-3	OPEN	CLOSED	CLOSED
ATTIC SUPPLY	CD-4	OPEN	CLOSED	CLOSED
AHU-214A RA	CD-5A	OPEN	OPEN	CLOSED
AHU-214B RA	CD-5B	CLOSED	OPEN	CLOSED
AHU-214C RA	CD-5C	OPEN	OPEN	CLOSED
AHU-214A SA	CD-6C	OPEN	OPEN	CLOSED
AHU-214B SA	CD-6B	CLOSED	OPEN	CLOSED
AHU-214C SA	CD-6C	OPEN	OPEN	CLOSED
AHU-210/211 SA	CD-7	CLOSED	OPEN	CLOSED
AHU-214B SA	CD-8	CLOSED	CLOSED	OPEN
AHU-214C SA	CD-9	OPEN	OPEN	CLOSED
RM 151/151 A SA	CD-10	OPEN	CLOSED	OPEN
RM 151A SA	CD-11	CLOSED	OPEN	CLOSED
AHU-214A RA	CD-13	OPEN	CLOSED	OPEN
AHU-214A/B RA	CD-14	OPEN	CLOSED	OPEN
RM 151 SA	CD-15	OPEN	CLOSED	OPEN

H. Building B Attic – AHU- 214A,B,&C (Sequence Of Operations):

A) Hand Mode: The return and supply dampers associated with each unit shall be opened. The damper limit switches shall start the respective fan after the return and supply dampers have proven open at least 90%.
B) Off Mode: The dampers shall be closed and the fan shall be off.
C) Auto Mode: The return and supply dampers associated with each unit shall be Opened/Closed through the Enable Relay. The damper limit switches shall start the respective fan after the return and supply dampers have proven open at least 90% and shall stop the fan after the dampers close past 80%.
D) An Override switch shall be capable of overriding the ACD to manually start the fan after it has been shut off by

the ACD. The Override switch shall be monitored by the DDCP and shall initiate an alarm at the OWS if the switch is placed in the Override position.
E) AHU-214A, AHU-214B and AHU-214C shall be alternated as primary and standby unit every 1 to 31 days, initially set at 7 days (adjustable). The primary unit shall run continuously 24 hours, 7 days a week.
F) When the primary unit is enabled by the DDCP, the supply and return air dampers shall be commanded open through the Enable Relay. When the supply and return dampers are proven open, the VFD shall start the fan thought the Run Permissive Relay and ramp up to normal operating speed.
G) Upon a Run Status from the Fan drive, the outdoor air damper shall open to a minimum position and the chilled water and hot water valves shall modulate to maintain supply air temperature based on a reset of a space temperature of 72 F (adjustable). The supply air temperature sensor shall function as a low and high limit control in order to maintain a maximum of 60 F (adjustable) and a minimum of 55 F (adjustable) supply temperature as the space temperature in Room 151 fluctuates between 76 F and 70 F.
H) Upon a Run Status from the Fan drive, the humidifier (HU214A & B) shall be modulated to maintain a, return air humidity of 45% relative humidity. If the supply air humidity exceeds a high limit of 90% relative humidity, the humidifier shall be disabled.
I) The VFD shall modulate the supply fan speed to maintain a supply air flow of 8,650 CFM (adjustable), as measured by the associated air flow measuring station.
J) When the damper limit switches indicate that the dampers are closing, the supply fan shall be disabled through the Run Permissive Relay.
K) Upon a Off Status from the Fan drive, the chilled water valve, hot water pre-heat and re-heat valves shall close. The outdoor air damper shall close and the humidifier shall be disabled.
L) In the event that the primary unit should fail, the DDCS shall automatically start the standby unit and generate an alarm at the OWS.
M) In the event of a freeze condition as indicated by the low limit switch, the associated unit shall shutdown, the outdoor air, return air and supply air dampers shall be closed and the chilled water and hot water valves shall open fully.
N) A differential pressure switch shall monitor the pressure drop at the AHU Filter, (DP-1A). When the pressure exceeds an adjustable limit, an alarm shall be sent to the OWS.
O) A differential pressure switch shall monitor the pressure drop at the stage one, (DP-2), and another differential pressure switch shall monitor both Filter two and Filter three (DP-3). When the pressure exceeds an adjustable limit, an alarm shall be sent to the OWS.
P) If during operation of either AHU-214A, AHU-214B or AHU-214C dilution ventilation outdoor air damper limit switches indicates that the dilution ventilation outdoor air damper (CD-1, CD-2 or CD-12) is fully open, an alarm shall be generated and sent to the OWS.

Dilution Ventilation Mode

A) The “Dilution Ventilation Mode” of operation shall be initiated either through a momentary push button switch or through the OWS.
B) If the space temperature in control room 151 rises above 85 F (adjustable) or drops below 65 F (adjustable), the dilution ventilation mode shall be disabled. If the space humidity in control room 151 rises above 70% relative humidity (adjustable) or falls below 30% relative humidity (adjustable), the dilution ventilation mode shall be disabled.
C) The primary unit shall be disabled. Refer to the damper matrix for the dilution ventilation position. Once the control dampers have proven through the dampers position switches, the primary unit shall be enabled.
D) The supply air flow set point shall be adjusted to 5,400 CFM as measured by the air flow station.
* With AHU-214B shutdown in Stand-By Mode. When AHU-214B is operating in conjunction with AHU-214A or AHU-214C, respective unit dampers must be positioned to isolate unit that is shut down.
** Open when AHU-214B is operating in conjunction with AHU-214A or AHU-214C.

Exhaust Fan

A) The supply dampers associated with each unit shall be Opened/Closed through the DDCP. The damper limit switches shall start the respective exhaust fan after the supply dampers have proven open and shall stop the fan after the dampers close past 80%.
B) Current Sensing Relays shall monitor power to the exhaust fan and indicate a Run Status to the DDCP when the fan is running.
C) EF-408 has an associated FSD interlocked to the Start/Stop. The Fan will not be energized until the damper status has proven open. An Open/Auto switch shall override the damper.
D) EF-408 Shall switch from Low speed Fan to high speed Fan and each EF shall operate as follows:

EF		Normal Dilution
EF-403	ON	OFF
EF-404	ON	OFF
EF-405	ON	OFF
EF-406	OFF	ON
EF-407	OFF	ON
EF-408	LOW	HIGH

AHU-214A, AHU-214B, AHU-214C Damper Matrix				
Damper Name	Damper ID	Normal	Dilution	Failure
AHU-214A OA	CD-1	OPEN (MIN)	OPEN	CLOSED
AHU-214B OA	CD-12	CLOSED	OPEN	CLOSED
AHU-214C OA	CD-2	OPEN (MIN)	OPEN	CLOSED
AHU-214C RA	CD-3	OPEN	CLOSED	CLOSED
ATTIC SUPPLY	CD-4	OPEN	CLOSED	CLOSED
AHU-214A RA	CD-5A	OPEN	OPEN	CLOSED
AHU-214B RA	CD-5B	CLOSED	OPEN	CLOSED
AHU-214C RA	CD-5C	OPEN	OPEN	CLOSED
AHU-214A SA	CD-6C	OPEN	OPEN	CLOSED
AHU-214B SA	CD-6B	CLOSED	OPEN	CLOSED
AHU-214C SA	CD-6C	OPEN	OPEN	CLOSED
AHU-210/211 SA	CD-7	CLOSED	OPEN	CLOSED
AHU-214B SA	CD-8	CLOSED	CLOSED	OPEN
AHU-214C SA	CD-9	OPEN	OPEN	CLOSED
RM 151/151 A SA	CD-10	OPEN	CLOSED	OPEN
RM 151A SA	CD-11	CLOSED	OPEN	CLOSED
AHU-214A RA	CD-13	OPEN	CLOSED	OPEN
AHU-214A/B RA	CD-14	OPEN	CLOSED	OPEN
RM 151 SA	CD-15	OPEN	CLOSED	OPEN

1.8 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 inch by 17 inch drawings. Upon successful installation, as-built drawings shall be delivered to the Government on CD ROM in Visio compatible electronic format, as well as on 22 inch by 34 inch reproducible drawings. Drawings prepared for or used for this work shall become the property of the Government. The Government reserves the right to reproduce, in part or whole, the delivered drawings for internal Government purposes.

B. Control Diagrams: Submit a control diagram 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 DDCS point schedules 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.
3. In addition to the system network architecture diagram required in the paragraph above, submit a network architecture diagram to show how the new Ethernet cable will be installed to replace the serial network topology of the existing I/Net system. The diagram shall show how the new network cable will be connected to the Operator Workstations and all the existing DDCS controllers in the existing I/Net system. This diagram shall also show the Netplus routers that will replace the existing tap devices.
4. Communication cable installation plans and network architecture diagram showing OWS location, controller locations, network router and switch locations (if applicable) and communication cable conductors and routing, distinguishing between different forms of media (i.e. 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.
5. 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/duplication of the sequences presented in this specification is not acceptable.
6. Device Tag Schedule and Point List: Device Tag Schedule and Point List shall be the national standard developed by the SE ARTCC Program Office. Provide device tag schedule that at a minimum indicates device type, tag identifier, terminal connection points for wiring on the controller, DDCS software point name and complete DDCS

point address. A separate listing shall be provided for each BC, AAC and ASC. DDCS software point names and associated DDCS expanded point descriptors shall incorporate the device tags used.

7. 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.
8. Sample Graphical Displays: Provide samples of OWS graphical displays that will be provided for each system. Graphical Displays provided for all HVAC equipment and other system controlled by new control system shall be the national standard developed by the SE ARTCC Program Office.
9. Provide complete description and documentation of any proprietary (non-BACnet) services and/or objects used in the system.

C. Technical Specification Data Sheets: Documents 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 manufacturer's 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. BACnet Capability Certification: Submit Protocol Implementation Conformance Statement (PICS) for every BACnet compliant hardware and software component to be installed as part to the Building Automation System. All devices conforming to the BACnet Protocol of ANSI/ASHRAE BACnet Standard 135-2004 are to have a PICS, created by the device manufacturer. The PICS describes the BACnet capabilities of a particular BACnet implementation for the device.

E. Software Documentation: Include 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.

F. Installer Qualifications: Submit resume listing installer's qualifications including manufacturer's certification as an approved system installer and a list of recently completed projects demonstrating 2 years of system installation experience in BACnet based systems. Provide name(s), address, and telephone numbers for installer supervisory personnel.

G. Startup Personnel Qualifications: Submit resume listing startup personnel qualifications including manufacturer's certification as an approved system technician and a list of recently completed projects demonstrating 2 years of system startup experience in BACnet based systems. Provide name(s), address, and telephone numbers for supervisory personnel.

H. Graphical Displays: Coordinate the final graphical displays and other functions with the COTR. Prior to the commissioning of this project, submit printed copies of all graphical displays that will be installed in 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 "DDCS 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 "DDCS 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. 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.

I. Operation and Maintenance Manual: Provide operation and maintenance manual for control systems equipment as specified in Division 1, "Operation and Maintenance Manual Data," which includes 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;
6. Keyboard illustrations and step-by-step procedures indexed for each operator function;
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; and
9. Sequence of operation in computer flow chart format. The flow chart shall show how each control action is derived.
10. As-built communication cable installation plans and as-built network architecture diagram.

J. Test plans and inspection reports specified in Part 3 of this Section.

K. As built drawing requirements specified in Part 3 of this Section.

1.9 QUALITY ASSURANCE

A. Installer Qualifications: Engage an Installer specializing in BACnet based control system installations with a minimum of 5 years of experience installing systems of similar type, size and complexity. The SE ARTCC Program Office, as a representative of the control system manufacturer, shall certify that the installer has been authorized and trained on the proper installation of the specified system and that the firm is approved for the ARTCC control system replacement program.

B. Startup Personnel Qualifications: Engage specially trained personnel in BACnet based control system with a minimum of 2 years of experience programming, testing and commissioning systems of similar size and complexity. The SE ARTCC Program Office, as a representative of the control system manufacturer, shall certify that the startup personnel have been authorized and trained on the proper installation, programming, testing, and commissioning of the specified system and that the firm is approved for the ARTCC control system replacement program.

C. Contractor Qualifications: The controls contractor shall be a local branch office; a representative; or a qualified dealer of Schneider Electric. The contractor shall be regularly engaged in the installation and maintenance of BACnet based DDCS and shall have demonstrated technical expertise and experience in the fabrication, manufacture, installation, and maintenance of BACnet based DDCS. Materials and equipment shall be the latest standard design of Schneider Electric and/or the instrument and control device manufacturer that comply with the requirements specified in this Section. The contractor or the manufacturer must maintain, within 100 miles of the project site, a local service center or a qualified local dealer/representative office which is capable of providing training, parts, service/emergency maintenance and repairs.

D. Software Quality Assurance Plan: Provide a software quality assurance plan.

1. Standards and Procedures: Describe the contractor's standards and procedures (e.g., documentation, work, coding, testing) which will be used to support the software programming, controller programming and computer graphic screen development and associated documentation such as Operation & Maintenance Manuals required for this project. The standards and procedures shall specify criteria for use, and shall have controlled conditions for release and change. As a minimum, the plan shall address those standards and procedures necessary for the requirements, design, implementation, test, and documentation of the software, controller programming and computer graphic screens provided.
2. Corrective Action, Reporting and Control: Describe the corrective action process used to assure the prompt reporting, tracking, analysis, and correction of problems and defects for all software, controller programming and computer graphic screens and related documentation such as Operation & Maintenance Manuals required for this project. Include those procedures and controls which shall assure that deficiencies are promptly documented and corrected and that appropriate action is taken to prevent repetition. The deficiency documentation shall identify problems or defects by severity (critical, major, minor), and by function (test, coding, programming, graphics, documentation).

1.10 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.

1.11 EXTRA MATERIALS

A. Re-procurement Package: Submit a re-procurement package that 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. Historical failure rate; and
5. Schematics and board drawings.

PART 2 - PRODUCTS

2.1 MANUFACTURER

A. The Direct Digital Control System (DDCS) shall be StruxureWare Andover Continuum BACnet system by Schneider Electric, Inc.

2.2 BUILDING AUTOMATION SYSTEM PERFORMANCE **(EXISTING CONDITION**)

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

1. Graphic Display: The DDCS shall display a graphic with 20 dynamic points/objects with all current data within 10 seconds;
2. Graphic Refresh: The DDCS 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 2 seconds. Analog objects should start to adjust within 2 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 2 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. Multiple Alarm Annunciation: OWS on the network must receive alarms within 5 seconds of each other; and
9. The DDCS shall be capable of being expanded through either the use of additional controllers or expansion cards to provide complete control of future HVAC equipment.

B. DDCS Components: Control system shall include the following:

1. OWS and software functioning as the primary operator interfaces for the DDCS;
2. BC, AAC and ASC;
3. Control panels;
4. Native BACnet communication buses to serve OWS, BC, AAC and ASC;
5. Data communication between the BC, AAC, ASC, and OWS shall be carried in a dedicated raceway;
6. BACnet communication gateways between non-DDCS systems and the DDCS (computer room unit's manufacturer's controllers and Chillers);
7. Data shall be digitally displayed with properly located decimal point and two or three alphabetic characters on the display of the OWS;
8. Provide necessary devices for proper operation of control system, i.e. transmitters, sensors, temperature controllers and indicators, motors, linkages, flow control valves, relays and gages;
9. 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;
10. Provide UL listed equipment; and
11. Raceway, wiring, terminations and mounting of equipment to present a fully functional integrated system.

2.3 BUILDING CONTROLLER (BC) **(EXISTING CONDITION**)

A. General: Each BC shall conform to the BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L.

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 monitor and control all input and output sensors and devices using shielded twisted pair cable. 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 field proven and shall be listed in UL 916 PAZX.
3. Inputs and Outputs:

    a. Analog Input: Analog inputs shall be compatible with RTD 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.
e. Prioritization: The command prioritization mechanism in Clause 19.2 of ASNI/ASHRAE 135-2004 shall be used including the priority assignments of Clause. If the contractor needs to define a priority level that is indicated as "Available" in Clause 19.2.2, then these assignments must be submitted to and approved by the COTR in advance.
f. I/O Point Distribution: All I/O points specified for a piece of equipment shall be integral to a single controller. Except where it is otherwise permitted, a single controller may be used to control more than one piece of equipment.
g. 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. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing (ANSI/ASHRAE 135-2004, BACnet Annex J).
b. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
c. 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.
d. 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.
e. 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 OWS.

5. The property support indicated below shall be provided if the object is required to be present in order to meet the application requirements.

a. Analog Input, Analog Output and Analog Value: These objects shall have the following writeable properties: Object Name; Object Value; Description; COV Increment; Out of Service and Units. In addition, these objects shall support the properties: Device type; Reliability; Min./Max. Values; Update Interval and Resolution.

b. Binary Input, Binary Output And Binary Value: These objects shall have the following writeable properties: Object Name; Object Value; Description; Polarity; Default Value; Min On/Off and Out of Service. In addition, these objects shall support the properties: Device Type; Reliability; Active/Inactive Texts; Update Interval; Resolution; Change-of-State Time; Count Times and Time Reset.
c. Calendar: This object shall have the following writeable properties: Object Name; Object Value; Description; and Date List.
d. Device: This object shall have the following writeable properties: Object Name; Description; Location; and UTC Offset.
e. Event Enrollment: This object shall have the following writeable properties: Object Name; Object Value; Description; Out-of-Service; Event & Notify Types; Parameters; Property Ref; Enable; and Notification Class.
f. File: This object shall have the following writeable properties: Object Name; Description; File Type; and File Access.
g. Loop (PID): This object shall have the following writeable properties: Object Name; Object Value; Description; Polarity; Output and Input Refs.; Input Value & Units; Setpoint Value; PID Values; Bias; Write Priority and COV Increment. In addition, this object shall support the properties: Reliability; Update Interval; Proportional Constant & Units; Derivative Constant & Units.
h. Notification Class: This object shall have the following writeable properties: Object Name; Object Value; Description; Priority and Ack Required.
i. Program: This object shall have the following writeable properties: Object Name; Object Value and Description. In addition, this object shall support the property Reliability.
j. Schedule: This object shall have the following writeable properties: Object Name; Object Value and Description; Effective period; Schedule; Exception; Controlled Properties and Write Properties.
k. Trend Log: This object shall have the following writeable properties: Object Name; Description; Log Enable; Start/stop Times; Log Device Object Property; Log Interval; Stop When Full; Buffer Size; and Record Count.

6. BC Reliability: The mean time between failure (MTBF) of the BC shall not be less than 6,000 hours for the installed systems. System failure shall be defined as single malfunction that causes loss of data or failure to function as specified.
7. Corrective Maintenance Time: Mean Time To Repair (MTTR) is defined as the elapsed time starting with BC failure or malfunction until the BC is again available for service, including checkout and warm up time required. The MTTR of the BC shall not be greater than two hours. Maximum repair time for failures shall not be greater than six hours. Corrective maintenance times are dependent on spare parts availability at the site.
8. Data Control (D/C): The requirements below are associated with the hardware devices to be connected to the BC and the standard control software modules to be implemented. Provide additional software required to accomplish the detailed Sequence of Operations.

a. Each analog point shall have unique controller resident dual high and dual low limit alarm thresholds set in engineering units. The first set of limits shall be warning limits, which provide a normal band around the temperature set point. If the analog point exceeds these limits a warning shall be issued at the OWS indicating that the analog value is out of its normal range. An alarm shall be

generated at the OWS if the analog point value exceeds the second set of limits. See "DDCS Point Function Schedule" for list of alarm limits.

b. Where digital outputs have an associated monitored input, if the monitored input does not track its associated command output within a programmable time interval, a command-failed alarm shall be reported.

c. Unless otherwise indicated, the primary analog input and the analog output of each control loop shall be resident in a single controller containing the control algorithm, and shall function independently of BACnet communication links. Secondary, reset type, analog inputs may be received from the network, but approved default values and procedures shall be substituted in the control algorithm for this secondary input if network communications fail or if the secondary input becomes erroneous or invalid.

9. 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.

a. Changing program or application package parameters, adding data points, or deleting data points, shall not interfere with data processing or other application programs being executed.

b. Each BC in the system shall contain its own microprocessor and memory. Each BC in the system shall be completely independent with its own hardware clock, calendar, firmware and software to maintain control on an independent basis.

c. Each BC shall be capable of storing and executing demand forecast programs, duty cycle programs, calculation point programs, and include the following capabilities:

1) Acquire, process, and transfer information to the OWS or other controllers on the same BACnet network.
2) Accept, process, and execute commands from the other controllers on the same BACnet network or OWS on the network.
3) Allow access to both data base and control functions by multiple workstations on the BACnet network at the same time. Provide plug-in connections for programmable terminals.
4) Record, evaluate, and report the changes of state and values that occur among points associated with the BC.

d. Each BC panel shall continuously perform self-diagnostics, communication diagnosis and diagnosis of subsidiary equipment. The BC shall provide both local and remote annunciation of detected component failures; or repeated failure to establish communication. Indication of the diagnostic results shall be provided at each BC and shall not require the connection of an operator interface device.

e. BC software shall provide equipment cycling protection. Control shall include a provision for limiting the number of times each piece of equipment may be cycled within any one hour period.

f. BC shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads.
g. Provide software to execute and observe diagnostics of remote devices connected to the BACnet LAN and the ability to deactivate and restart the device.

10. 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.
11. Control Algorithms: A control application package shall be provided to permit nonstandard control algorithms to be provided as part of the initial installation or added at a later date. The control algorithms shall permit interlocks, calculations of BTUs, flows, and outputs; and provide hysteresis, scaling, offset, linearization, summation, multiplication, division, and other functions. Default modes, start up and check out tests, interlocks, demand control and other functions shall be provided utilizing these algorithms.
12. 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; a user control and calculation application package; and the following:

a. EPROM or RAM resident operating system (OS), operating independently of central computers. The operating system shall control BACnet communications between the operator's terminal, controllers and the input/output (I/O) modules; accept analog and digital inputs; produce analog and digital outputs; provide alarm monitoring; control application packages; and interface the necessary sensor and actuators. The controller OS shall also contain built-in diagnostic routines as indicated.
b. Allow for scaling and for calibration of sensor lead length variations to insure instrument accuracy, and provide for automatic restart of equipment based on current program time without operator intervention.
c. Provide a system advisory and alarm any time there is a loss of communication between the I/O microprocessor and the OWS. In the event of I/O microprocessor failure, provide a means for local or remote alarm. Also provide an override of selected output functions.
d. Built in safeguards to prevent the BC microprocessor from becoming captured by one control loop resident in the BC. These built-in software safeguards shall be resident in nonvolatile memory.
e. Power Fail-automatic Restart-interrupt: If power is removed and then restored, an interrupt shall be generated at one of the highest possible priority levels. This interrupt shall automatically cause a bootstrap operation to occur, which in turn shall call the automatic restart routines.

f. Data Base Manager: A menu data base manager shall be provided that manages data on an integrated, non-redundant basis. The data base manager shall allow additions and deletions to the database without detriment to existing data.
g. Timer Routine: A timer routine shall be provided that executes at the lowest foreground priority level. If a command fails to execute after a predetermined amount of time, a message shall be reported to the OWS.
h. Error Messages: Executing and operating system errors shall be reported to the OWS.
i. Recovery from Fatal Errors: The BC shall indicate an error at the OWS after an error occurs that halts operation of active programming in the controller.

13. Control Groups: User control groups shall be provided to allow selected points to assume a control state based on the reception of a pre-defined initiator. The groups shall be logically constructed without regard to their physical location in the system. Each group shall have a sufficient number of points so that each point state to be assumed shall be individually assignable. The set or reset initiators may be calendar or elapsed time event occurrences, such as alarms, or inputs from an authorized operator. A control group sequence initiator shall override other action until a reset initiator is received or a manual operator request is made.
14. 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 DDCS, 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 Annex M. Notification classes shall be configured in a manner that distinguishes between the facilities involved and to meet any other operational needs requested by the FAA.

15. 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.

16. BC Global Communications: Global data values required by the installation shall be updated using change-of-value notifications.
17. BC Variable Execution Timer: It shall be possible to independently set the execution speed for each point in the BC to an operator selected time from 1 to 60 seconds.
18. BC Upload and Download Capability: Each BC shall support backup and restore functionality as defined in Clause 19.1 of ANSI/ASHRAE 135-2004.
19. Test Mode Operation: Each BC shall have the ability to place input/output points in a test mode. The test mode shall allow control algorithms to be tested and developed on line without disrupting the field hardware and controlled environment. This shall be accomplished by making Out-Of-Service properties writable and outputs commandable.
20. 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.
21. 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 "DDCS Point Function Schedule". For such items as remote temperature adjustment, the reset signal shall maintain its last setting. Manual equipment start and stop control capabilities, such as motor starter hand-off-auto switches, shall remain fully operational. 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.
22. Real Time Clock: Routines shall be provided to maintain time of day, date and interval timers.

2.4 NETWORK AND COMMUNICATION

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

B. The Contractor shall provide and install communication cable, connectors, repeaters, bridges, routers, switches and hubs necessary for the DDCS network. The contractor shall provide additional network hardware such as Ethernet routers and switches for the extension of DDCS 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 DDCS 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.

2.5 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. Provide NEMA 3R type panels where required by the application.
2. Panel-Mounted Equipment: Temperature and humidity controllers, relays, switches and automatic switches; except safety devices. Mount devices with adjustments accessible through front of panel.
3. Door-Mounted Equipment: Flush-mount (on hinged door) manual switches, keyed switches, alarm horns, pushbuttons, changeover switches, digital displays and indicator lights.
4. Tags: 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 DDCS 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.

2.6 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. Each transformer shall be enclosed in a metal box with conduit knockouts. The transformers shall be UL Listed. The secondary output of the transformer shall be protected by an appropriately sized fuse.

2.7 HAND-OFF-AUTO AND OVERRIDE 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.

2.8 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 DDCS 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 TEFLON. 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).

2.9 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.

2.10 TAGS

A. Tags: Devices shall be permanently labeled with phenolic resin nameplates, black with white lettering, with minimum 1/4 inch lettering. Tag shall include device ID's, as shown on as-built documentation and software identification, affixed to the unit identification. Internal and external wires shall also be labeled.

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. Locate room sensors 60 inches above the finished floor.

D. Install labels and nameplates to identify control components according to the national standard developed by the SE ARTCC Program Office. Devices shall be permanently labeled with phenolic resin nameplates, black with white lettering, with minimum 1/4-inch lettering. Tag shall include device ID's as shown on as built documentation and DDCS software identification. Internal and external wires shall also be labeled using computer printed wire tags. These tags shall include description and termination locations in the panel. Submit a complete list of nameplates prior to ordering.

E. 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/digital points and alarm messages.

F. 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.

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

H. Components of the network cabling system shall be labeled in accordance with EIA/TIA-606.

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.

1. Install wire and cable in raceways. 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. Install wire connectors and soldering lugs for use with copper conductors.
4. Fasten flexible conductors, bridging cabinets and doors, neatly along hinge side; protect against abrasion. Tie and support conductors neatly.
5. Number-code or color-code conductors, except local individual room controls, for future identification and servicing of control system.
6. Panels, junction boxes and raceway/conduit associated with the DDCS shall be clearly identified as part of the DDCS.

C. Provide Hand-Off-Auto selector switches for motor starters and disconnect switches 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. Do not provide Hand-Off-Auto selector switches for equipment operated through variable frequency drives.

3.3 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.

3.4 COORDINATION

A. Test and Balance

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. Test and Balance Contractor shall return tools undamaged and in working condition at completion of testing and balancing.

3.5 COMMISSIONING

A. Manufacturer's Field Services: Provide the services of a Schneider Electric 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 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 COTR that the DDCS 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 COTR as described below under "Field Quality Control".

3.6 FIELD QUALITY CONTROL

A. Test Plan: Submit test plan at least 60 calendar days prior to conducting the acceptance tests. Develop a detailed testing plan that 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 described below. Testing shall include local OWS functionality.

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 on line 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 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 OWS), with controlled devices positioned as required in the fail mode section of the DDCS Point Function Schedule

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 COTR at time of acceptance);
g. Deleting a point;
h. Adding a new group of points; and
i. Uploading and downloading of BC, AAC and ASC configuration programs.

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 COTR.

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 DDC loop precision and stability through trend logs of inputs and outputs (6 loops minimum) by continuous operation of 7 days testing;
f. Demonstrating DDCS 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 Windows XP 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 a panel shall be set up for a point from a different 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. Schedule test date with COTR and confirm date in writing at least ten working days prior to test. The written test date confirmation shall identify changed conditions that may affect the test results. Provide equipment and personnel required to perform the test. Perform tests of the DDCS, in accordance with the approved test plan, in presence of the COTR.

C. Installation Inspection Report: Upon completion of tests, a list shall be provided by the COTR, 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 COTR and date. A copy of this report shall be provided to the COTR. If the system fails acceptance tests, the Contractor shall operate his system off line during corrective procedures.

3.7 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. Data shall also include final set points, alarm limits, time schedules, and other DDCS software information specific to this installation.

1. DDCS Database: Maintain CD or DVD copies of data files and application software for reload and use in the event of a system crash or memory failure. Deliver two (2) hard copies to the COTR during training session, and archive one soft copy in an external hard disk to be provided by the controls contractor for storage in the facility.
2. Design Drawings: Deliver two hard copies of CAD generated system design drawings in DXF/DWG format to the COTR during training session, and archive one soft copy in an external hard disk to be provided by the controls contractor for storage in the facility.
3. Provide electronic copies of As-built shop drawings, DDC logic diagrams and Operation and Maintenance Manual. The drawings, logic diagrams and O&M manual shall be generated in PDF or JPEG file format and be located in the OWS, so the user can access the diagrams and manuals without using a special software or tool. Panel layout diagram shall consist of a scale drawing showing all control devices installed in the panel. Wiring diagram shall consist of a complete schematic drawing showing the termination between the field/control devices and controller.

B. Software, Firmware and Hardware Documentation Rights: The system described shall be used to control environmental parameters at the ARTCC. As such, it is essential that the Government

have full and complete rights to system software, and to system firmware and hardware documentation supplied for this project. The Government 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 Government 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. The DDCS manufacturer shall be required to license the Government to use the OWS and DDCS software.

C. Guarantee: The Guarantee shall include a service and parts guarantee for one year from the date of acceptance of the installation, without charge to the Government. After completion of the original installation, provide service incidental to the proper performance of the control system under the guarantee for the period of one year. 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 COTR.

D. Acceptance: The acceptance date of the system shall be that date the COTR 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 first year maintenance contract and shall constitute formal acceptance by the FAA at the facility.

END OF SECTION 23 09 00

SECTION 26 29 23 - VARIABLE-FREQUENCY DRIVE

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes separately enclosed, preassembled, combination VFDs, rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.

1.2 DEFINITIONS

A. BAS: Building automation system.

B. CE: Conformite Europeene (European Compliance).

C. CPT: Control power transformer.

D. EMI: Electromagnetic interference.

E. IGBT: Insulated-gate bipolar transmission.

F. LAN: Local Area Network.

G. LED: Light-emitting diode.

H. MCP: Motor-circuit protector.

I. NC: Normally closed.

J. NO: Normally open.

K. OCPD: Overcurrent protective device.

L. PCC: Point of common coupling.

M. PID: Control action, proportional plus integral plus derivative.

N. PWM: Pulse-width modulated.

O. RFI: Radio-frequency interference.

P. TDD: Total demand (harmonic current) distortion.

Q. THD(V): Total harmonic voltage demand.

R. VFD: Variable-frequency drive.

1.3 ACTION SUBMITTALS

A. Product Data: For each type and rating of VFD indicated. Include features, performance, electrical ratings, operating characteristics, shipping and operating weights, and furnished specialties and accessories.

B. Shop Drawings: For each VFD indicated. Include dimensioned plans, elevations, and sections; and conduit entry locations and sizes, mounting arrangements, and details, including required clearances and service space around equipment.

1. Show tabulations of installed devices, equipment features, and ratings. Include the following:

a. Each installed unit's type and details.
b. Factory-installed devices.
c. Enclosure types and details.
d. Nameplate legends.
e. Short-circuit current (withstand) rating of enclosed unit.
f. Features, characteristics, ratings, and factory settings of each VFD and installed devices.
g. Specified modifications.

2. Schematic and Connection Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Required working clearances and required area above and around VFDs.
2. Show VFD layout and relationships between electrical components and adjacent structural and mechanical elements.
3. Show support locations, type of support, and weight on each support.
4. Indicate field measurements.

B. Qualification Data: For qualified testing agency.

C. Seismic Qualification Certificates: For each VFD, accessories, and components, from manufacturer.

1. Certificate of compliance.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based, and their installation requirements.

D. Product Certificates: For each VFD from manufacturer.

E. Source quality-control reports.

F. Field quality-control reports.

G. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate, full-load currents.

H. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For VFDs to include in emergency, operation, and maintenance manuals.

1. In addition to items specified in Section 01782 "Operation and Maintenance Manual Data," include the following:

a. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and motor-circuit protector trip settings.
b. Manufacturer's written instructions for setting field-adjustable overload relays.
c. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
d. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.
e. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate, full-load currents.
f. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed, and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
2. Control Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than two of each size and type.
3. Indicating Lights: Two of each type and color installed.
4. Auxiliary Contacts: Furnish one spare(s) for each size and type of magnetic controller installed.
5. Power Contacts: Furnish three spares for each size and type of magnetic contactor installed.

1.7 QUALITY ASSURANCE

A. Testing Agency Qualifications: Member Company of NETA or an NRTL.

1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.

1.8 DELIVERY, STORAGE, AND HANDLING

A. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside controllers and connect factory-installed space heaters to temporary electrical service.

B. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFDs, including clearances between VFDs, and adjacent surfaces and other items.

1.9 PROJECT CONDITIONS

A. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by FAA or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:

1. Notify Resident Engineer no fewer than 14 days in advance of proposed interruption of electrical systems.
2. Indicate method of providing temporary electrical service.
3. Do not proceed with interruption of electrical systems without FAA’s written permission.
4. Comply with NFPA 70E.

1.10 WARRANTY

A. Special Warranty: Manufacturer agrees to repair or replace VFDs that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Danfoss Inc; Danfoss Drives Div.
2. Eaton Electrical Sector; Eaton Corporation; Cutler-Hammer Business Unit.
3. Square D; a brand of Schneider Electric USA, Inc.
4. ABB Group; Industry Specific Drives

2.2 SYSTEM DESCRIPTION

A. General Requirements for VFDs:

1. VFDs and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508C.

B. Application: Constant torque and variable torque.

C. VFD Description: Variable-frequency motor controller, consisting of power converter that employs pulse-width-modulated inverter, factory built and tested in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.

1. Units suitable for operation of NEMA MG 1, Design A and Design B motors, as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."
2. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
3. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

D. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

E. Output Rating: Three phase; 10 to 60 Hz, with voltage proportional to frequency throughout voltage range; maximum voltage equals input voltage.

F. Unit Operating Requirements:

1. Input AC Voltage Tolerance: Plus 10 and minus 10 percent of VFD input voltage rating.
2. Input AC Voltage Unbalance: Not exceeding 3 percent.
3. Input Frequency Tolerance: Plus or minus 3 percent of VFD frequency rating.
4. Minimum Efficiency: 96 percent at 60 Hz, full load.
5. Minimum Displacement Primary-Side Power Factor: 96 percent under any load or speed condition.
6. Minimum Short-Circuit Current (Withstand) Rating: 25 kA.
7. Ambient Temperature Rating: Not less than 32 deg F and not exceeding 104 deg F.
8. Ambient Storage Temperature Rating: Not less than minus 4 deg F and not exceeding 140 deg F.
9. Humidity Rating: Less than 95 percent (noncondensing).
10. Altitude Rating: Not exceeding 3300 feet.
11. Vibration Withstand: Comply with NEMA ICS 61800-2.
12. Overload Capability: 1.1 times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.
13. Starting Torque: Minimum 100 percent of rated torque from 3 to 60 Hz.
14. Speed Regulation: Plus or minus 5 percent.
15. Output Carrier Frequency: Selectable; 0.5 to 15 kHz.
16. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.

G. Inverter Logic: Microprocessor based, 16 bit, isolated from all power circuits.

H. Isolated Control Interface: Allows VFDs to follow remote-control signal over a minimum 40:1 speed range.

1. Signal: Electrical.

I. Internal Adjustability Capabilities:

1. Minimum Speed: 5 to 25 percent of maximum rpm.
2. Maximum Speed: 80 to 100 percent of maximum rpm.
3. Acceleration: 0.1 to 999.9 seconds.
4. Deceleration: 0.1 to 999.9 seconds.
5. Current Limit: 30 to minimum of 150 percent of maximum rating.

J. Self-Protection and Reliability Features:

1. Surge Suppression: Factory installed as an integral part of the VFD, complying with UL 1449 SPD, Type 1 or Type 2.
2. Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
3. Under- and overvoltage trips.
4. Inverter overcurrent trips.
5. VFD and Motor-Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFDs and motor thermal characteristics, and for providing VFD overtemperature and motor-overload alarm and trip; settings selectable via the keypad.
6. Critical frequency rejection, with three selectable, adjustable deadbands.
7. Instantaneous line-to-line and line-to-ground overcurrent trips.
8. Loss-of-phase protection.
9. Reverse-phase protection.
10. Short-circuit protection.
11. Motor-overtemperature fault.

K. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.

L. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Autospeed Search" feature is available and engaged.

M. Bidirectional Autospeed Search: Capable of starting VFD into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.

N. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.

O. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

P. Integral Input Disconnecting Means and OCPD: UL 489, instantaneous-trip circuit breaker with pad-lockable, door-mounted handle mechanism.

1. Disconnect Rating: Not less than 115 percent of VFD input current rating.
2. Disconnect Rating: Not less than 115 percent of NFPA 70 motor full-load current rating or VFD input current rating, whichever is larger.
3. Auxiliary Contacts: NO or NC, arranged to activate before switch blades open.
4. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
5. NO alarm contact that operates only when circuit breaker has tripped.

2.3 PERFORMANCE REQUIREMENTS

A. Seismic Performance: VFDs shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified."

2.4 CONTROLS AND INDICATION

A. Status Lights: Door-mounted LED indicators displaying the following conditions:

1. Power on.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
6. External fault.

B. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English-language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.

1. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
2. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.

a. Control Authority: Supports at least four conditions: Off, local manual control at VFD, local automatic control at VFD, and automatic control through a remote source.

C. Historical Logging Information and Displays:

1. Real-time clock with current time and date.
2. Running log of total power versus time.
3. Total run time.
4. Fault log, maintaining last four faults with time and date stamp for each.

D. Indicating Devices: Digital display and additional readout devices as required, mounted flush in VFD door and connected to display VFD parameters including, but not limited to:

1. Output frequency (Hz).
2. Motor speed (rpm).
3. Motor status (running, stop, fault).
4. Motor current (amperes).
5. Motor torque (percent).
6. Fault or alarming status (code).
7. PID feedback signal (percent).
8. DC-link voltage (V dc).
9. Set point frequency (Hz).
10. Motor output voltage (V ac).

E. Control Signal Interfaces:

1. Electric Input Signal Interface:

   a. A minimum of two programmable analog inputs: 0- to 10-V dc.
   b. A minimum of six multifunction programmable digital inputs.

2. Pneumatic Input Signal Interface: 3 to 15 psig.
3. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:

   a. 0- to 10-V dc.
   b. 4- to 20-mA dc.
   c. Potentiometer using up/down digital inputs.
   d. Fixed frequencies using digital inputs.

4. Output Signal Interface: A minimum of one programmable analog output signal(s) (0- to 10-V dc), which can be configured for any of the following:

   a. Output frequency (Hz).
   b. Output current (load).
   c. DC-link voltage (V dc).
   d. Motor torque (percent).
   e. Motor speed (rpm).
   f. Set point frequency (Hz).

5. Remote Indication Interface: A minimum of two programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:

   a. Motor running.
   b. Set point speed reached.
   c. Fault and warning indication (overtemperature or overcurrent).
   d. PID high- or low-speed limits reached.

F. PID Control Interface: Provides closed-loop set point, differential feedback control in response to dual feedback signals. Allows for closed-loop control of fans and pumps for pressure, flow, or temperature regulation.

1. Number of Loops: One.

G. BAS Interface: Factory-installed hardware and software shall interface with BAS to monitor, control, display, and record data for use in processing reports. VFD settings shall be retained within VFD's nonvolatile memory.

1. Network Communications Ports: Ethernet and RS-422/485.
2. Network Communications: Provide BACnet compatible network interface card or embedded network module for future communication with the BAS. Interface shall be factory-installed and integral to the drive and it shall communicate using either BACnet protocol via BACnet MS/TP or BACnet/IP.

2.5 LINE CONDITIONING AND FILTERING

A. Input Line Conditioning: Based on harmonic analysis study and report, provide input filtering, as required, to limit total demand (harmonic current) distortion and total harmonic voltage demand at the defined point of common coupling to meet IEEE 519 recommendations.

B. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for Category C2.

2.6 BYPASS SYSTEMS

A. Bypass Operation: Safely transfers motor between power converter output and bypass circuit, manually, automatically, or both. Selector switches set modes and indicator lights indicate mode selected. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter.

B. Bypass Mode: Manual operation only; requires local operator selection at VFD. Transfer between power converter and bypass contactor, and retransfer shall only be allowed with the motor at zero speed.

C. Bypass Mode: Field-selectable automatic or manual, allows local and remote transfer between power converter and bypass contactor and retransfer, either via manual operator interface or automatic control system feedback.

D. Bypass Controller: Two-contactor-style bypass allows motor operation via the power converter or the bypass controller.

E. Bypass Controller: Three-contactor-style bypass allows motor operation via the power converter or the bypass controller arranged to isolate the power converter input and output and permit safe testing and troubleshooting of the power converter, both energized and de-energized, while motor is operating in bypass mode.

1. Bypass Contactor: Load-break, NEMA-rated contactor.

2. Input and Output Isolating Contactors: Non-load-break, NEMA-rated contactors.
3. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

F. Bypass Contactor Configuration: Full-voltage (across-the-line) type.

1. NORMAL/BYPASS selector switch.

2. HAND/OFF/AUTO selector switch.
3. NORMAL/TEST Selector Switch: Allows testing and adjusting of VFD while the motor is running in the bypass mode.
4. Contactor Coils: Pressure-encapsulated type with coil transient suppressors.

    a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
    b. Power Contacts: Totally enclosed, double break, and silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.

5. Control Circuits: 120-V ac; obtained from integral CPT, with primary and secondary fuses, with control power source of sufficient capacity to operate all integral devices and remotely located pilot, indicating, and control devices.

    a. CPT Spare Capacity: 150 VA.

6. Overload Relays: NEMA ICS 2.

    a. Melting-Alloy Overload Relays:

        1) Inverse-time-current characteristic.
        2) Class 10 tripping characteristic.
        3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

    b. Bimetallic Overload Relays:

        1) Inverse-time-current characteristic.
        2) Class 10 tripping characteristic.
        3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
        4) Ambient compensated.
        5) Automatic resetting.

    c. Solid-State Overload Relays:

        1) Switch or dial selectable for motor-running overload protection.
        2) Sensors in each phase.
        3) Class 10 tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

4) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
5) Analog communication module.

d. NO isolated overload alarm contact.
e. External overload, reset push button.

2.7 OPTIONAL FEATURES

A. Multiple-Motor Capability: VFD suitable for variable-speed service to multiple motors. Overload protection shuts down VFD and motors served by it, and generates fault indications when overload protection activates.

1. Configure to allow two or more motors to operate simultaneously at the same speed; separate overload relay for each controlled motor.
2. Configure to allow two motors to operate separately; operator selectable via local or remote switch or contact closures; single overload relay for both motors; separate output magnetic contactors for each motor.
3. Configure to allow two motors to operate simultaneously and in a lead/lag mode, with one motor operated at variable speed via the power converter and the other at constant speed via the bypass controller; separate overload relay for each controlled motor.

B. Damper control circuit with end-of-travel feedback capability.

C. Sleep Function: Senses a minimal deviation of a feedback signal and stops the motor. On an increase in speed-command signal deviation, VFD resumes normal operation.

D. Motor Preheat Function: Preheats motor when idle to prevent moisture accumulation in the motor.

E. Firefighter's Override (Smoke Purge) Input: On a remote contact closure from the firefighter's control station, this password-protected input:

1. Overrides all other local and external inputs (analog/digital, serial communication, and all keypad commands).
2. Forces VFD to operate motor, without any other run or speed command, at a field-adjustable, preset speed.
3. Forces VFD to transfer to bypass mode and operate motor at full speed.
4. Causes display of override mode on the VFD display.
5. Reset VFD to normal operation on removal of override signal automatically.

F. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.

G. Remote digital operator kit.

H. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer.

2.8 ENCLOSURES

A. VFD Enclosures: NEMA 250, to comply with environmental conditions at installed location.

1. Dry and Clean Indoor Locations: Type 1.
2. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.

B. Plenum Rating: UL 1995; NRTL certification label on enclosure, clearly identifying VFD as "Plenum Rated."

2.9 ACCESSORIES

A. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in VFD enclosure cover unless otherwise indicated.

1. Push Buttons: Covered.
2. Pilot Lights: Push to test.
3. Selector Switches: Rotary type.
4. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.

B. Control Relays: Auxiliary and adjustable solid-state time-delay relays.

C. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.

1. Current Transformers: Continuous current rating, basic impulse insulating level (BIL) rating, burden, and accuracy class suitable for connected circuitry. Comply with IEEE C57.13.

D. Supplemental Digital Meters:

1. Elapsed-time meter.
2. Kilowatt meter.
3. Kilowatt-hour meter.

E. Breather and drain assemblies, to maintain interior pressure and release condensation in NEMA 250, Type 4X enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.

F. Space heaters, with NC auxiliary contacts, to mitigate condensation in NEMA 250, Type 4X enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.

G. Cooling Fan and Exhaust System: For NEMA 250, Type 1; UL 508 component recognized: Supply fan, with stainless steel intake and exhaust grills; 120-V ac; obtained from integral CPT.

H. Spare control-wiring terminal blocks; unwired.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas, surfaces, and substrates to receive VFDs, with Installer present, for compliance with requirements for installation tolerances, and other conditions affecting performance of the Work.

B. Examine VFD before installation. Reject VFDs that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFD installation.

D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work

E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Floor-Mounting Controllers: Install VFDs on existing unistrut. Modify unistrut as necessary for mounting VFDs.

B. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

C. Install fuses in each fusible-switch VFD.

D. Install fuses in control circuits if not factory installed.

E. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors are installed.

F. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.

G. Comply with NECA 1.

3.3 CONTROL WIRING INSTALLATION

A. Install wiring between VFDs and remote devices.

B. Bundle, train, and support wiring in enclosures.

C. Connect selector switches and other automatic-control devices where applicable.

1. Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switches are in manual-control position.

2. Connect selector switches with control circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor-overload protectors.

3.4 IDENTIFICATION

A. Identify VFDs, components, and control wiring. Comply with requirements for identification specified in Section 26 05 53 "Identification For Electrical Systems"

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label each VFD with engraved nameplate.
3. Label each enclosure-mounted control and pilot device.

B. Operating Instructions: Frame printed operating instructions for VFDs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFD units.

3.5 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

B. Acceptance Testing Preparation:

1. Test insulation resistance for each VFD element, bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

C. Tests and Inspections:

1. Inspect VFD, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
2. Test insulation resistance for each VFD element, component, connecting motor supply, feeder, and control circuits.
3. Test continuity of each circuit.
4. Verify that voltages at VFD locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify FAA before starting the motor(s).
5. Test each motor for proper phase rotation.
6. Perform tests according to the Inspection and Test Procedures for Adjustable Speed Drives stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
8. Perform the following infrared (thermographic) scan tests and inspections, and prepare reports:

a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each VFD. Remove front panels so joints and connections are accessible to portable scanner.
b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFD 11 months after date of Substantial Completion.
c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

9. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

D. VFDs will be considered defective if they do not pass tests and inspections.

E. Prepare test and inspection reports, including a certified report that identifies the VFD and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.6 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.

3.7 ADJUSTING

A. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.

B. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.

C. Adjust the trip settings of instantaneous-only circuit breakers and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to 6 times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed 8 times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify FAA before increasing settings.

D. Set the taps on reduced-voltage autotransformer controllers.

E. Set field-adjustable circuit-breaker trip ranges as specified in Overcurrent Protective Device Coordination Study.

F. Set field-adjustable pressure switches.

3.8 PROTECTION

A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until controllers are ready to be energized and placed into service.

B. Replace VFDs whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.9 DEMONSTRATION

A. Engage a factory-authorized service representative to train maintenance personnel. Provide two 4-hour sessions of training and training material to train FAA maintenance personnel to adjust, operate, reprogram, and maintain VFDs.

END OF SECTION 26 29 23