UPGRADE ENERGY MANAGEMENT SYSTEM

626-15-106

FINAL SUBMITTAL SPECIFICATIONS

Prepared for:

Nashville VA Medical Center

Nashville, Tennessee

Prepared by:

Biagi, Chance, Cummins, London, Titzer, Inc.

Consulting Engineers

May 13, 2016

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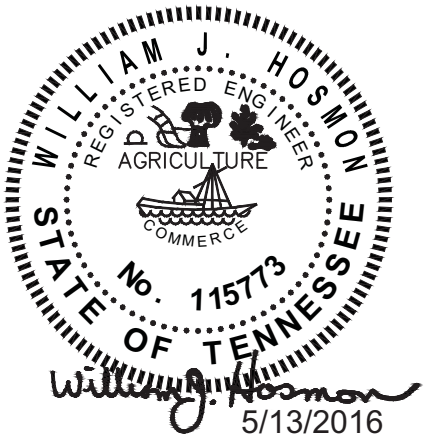

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SECTION 23 05 11
COMMON WORK RESULTS FOR HVAC

PART 1 - GENERAL

1.1 DESCRIPTION

A. The requirements of this Section apply to all sections of Division 23.

B. Definitions:

1. Exposed: Piping, ductwork, and equipment exposed to view in finished rooms.
2. Option or optional: Contractor's choice of an alternate material or method.
3. RE: Resident Engineer
4. COTR: Contracting Officer’s Technical Representative.

1.2 RELATED WORK

A. Section 00 72 00, GENERAL CONDITIONS

B. Section 01 00 00, GENERAL REQUIREMENTS

C. Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES

D. Section 07 84 00, FIRESTOPPING

E. Section 23 05 93, TESTING, ADJUSTING, and BALANCING FOR HVAC

F. Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS.

G. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

H. Section 26 05 19, LOW VOLTAGE ELECTRICAL POWER CONDUITS and CABLES.

1.3 QUALITY ASSURANCE

A. Mechanical, electrical and associated systems shall be safe, reliable, efficient, durable, easily and safely operable and maintainable, easily and safely accessible, and in compliance with applicable codes as specified. The systems shall be comprised of high quality institutional-class and industrial-class products of manufacturers that are experienced specialists in the required product lines. All construction firms and personnel shall be experienced and qualified specialists in industrial and institutional HVAC

B. Flow Rate Tolerance for HVAC Equipment: Section 23 05 93, TESTING, ADJUSTING, AND BALANCING FOR HVAC.

C. Products Criteria:

1. Standard Products: Material and equipment shall be the standard products of a manufacturer regularly engaged in the manufacture of the products for at least 3 years (or longer as specified elsewhere). The design, model and size of each item shall have been

in satisfactory and efficient operation on at least three installations for approximately three years. However, digital electronics devices, software and systems such as controls, instruments, computer work station, shall be the current generation of technology and basic design that has a proven satisfactory service record of at least three years. See other specification sections for any exceptions and/or additional requirements.

2. All items furnished shall be free from defects that would adversely affect the performance, maintainability and appearance of individual components and overall assembly.
3. Conform to codes and standards as required by the specifications. Conform to local codes, if required by local authorities, if the local codes are more stringent then those specified. Refer any conflicts to the Resident Engineer.
4. Multiple Units: When two or more units of materials or equipment of the same type or class are required, these units shall be products of one manufacturer.
5. Assembled Units: Manufacturers of equipment assemblies, which use components made by others, assume complete responsibility for the final assembled product.
6. Nameplates: Nameplate bearing manufacturer's name or identifiable trademark shall be securely affixed in a conspicuous place on equipment, or name or trademark cast integrally with equipment, stamped or otherwise permanently marked on each item of equipment.
7. Asbestos products or equipment or materials containing asbestos shall not be used.

D. Equipment Service Organizations:

1. HVAC: Products and systems shall be supported by service organizations that maintain a complete inventory of repair parts and are located within 50 miles to the site.

E. Execution (Installation, Construction) Quality:

1. Apply and install all items in accordance with manufacturer's written instructions. Refer conflicts between the manufacturer's instructions and the contract drawings and specifications to the Resident Engineer for resolution. Provide written hard copies or computer files of manufacturer’s installation instructions to the Resident Engineer at least two weeks prior to commencing

installation of any item. Installation of the item will not be allowed to proceed until the recommendations are received. Failure to furnish these recommendations is a cause for rejection of the material.

F. Upon request by Government, provide lists of previous installations for selected items of equipment. Include contact persons who will serve as references, with telephone numbers and e-mail addresses.

1.4 SUBMITTALS

A. Submit in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES, and with requirements in the individual specification sections.

B. Contractor shall make all necessary field measurements and investigations to assure that the equipment and assemblies will meet contract requirements.

C. If equipment is submitted which differs in arrangement from that shown, provide drawings that show the rearrangement of all associated systems. Approval will be given only if all features of the equipment and associated systems, including accessibility, are equivalent to that required by the contract.

D. Prior to submitting shop drawings for approval, contractor shall certify in writing that manufacturers of all major items of equipment have each reviewed drawings and specifications, and have jointly coordinated and properly integrated their equipment and controls to provide a complete and efficient installation.

E. Submittals and shop drawings for interdependent items, containing applicable descriptive information, shall be furnished together and complete in a group. Coordinate and properly integrate materials and equipment in each group to provide a completely compatible and efficient.

F. Manufacturer's Literature and Data: Submit under the pertinent section rather than under this section.

1. Submit variable speed drive data with the driven equipment.
2. Equipment and materials identification.
3. Fire-stopping materials.

G. HVAC Maintenance Data and Operating Instructions:

1. Maintenance and operating manuals in accordance with Section 01 00 00, GENERAL REQUIREMENTS, Article, INSTRUCTIONS, for systems and equipment.
2. Provide a listing of recommended replacement parts for keeping in stock supply, including sources of supply, for equipment.

1.5 APPLICABLE PUBLICATIONS

A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.

B. American National Standard Institute (ANSI):

B31.1-2007.....Power Piping

C. American Society of Mechanical Engineers (ASME):

Boiler and Pressure Vessel Code (BPVC):

Section I-2007.....Power Boilers

Section IX-2007.....Welding and Brazing Qualifications

Code for Pressure Piping:

B31.1-2007.....Power Piping

D. American Society for Testing and Materials (ASTM):

A36/A36M-08.....Standard Specification for Carbon Structural Steel

A575-96(2007).....Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades

E84-10.....Standard Test Method for Surface Burning Characteristics of Building Materials

E119-09c.....Standard Test Methods for Fire Tests of Building Construction and Materials

E. Manufacturers Standardization Society (MSS) of the Valve and Fittings Industry, Inc:

SP-58-2009.....Pipe Hangers and Supports-Materials, Design and Manufacture, Selection, Application, and Installation

SP 69-2003.....Pipe Hangers and Supports-Selection and Application

SP 127-2001.....Bracing for Piping Systems, Seismic – Wind – Dynamic, Design, Selection, Application

F. National Fire Protection Association (NFPA):

70-08.....National Electrical Code

90A-09.....Standard for the Installation of Air Conditioning and Ventilating Systems

101-09.....Life Safety Code

1.6 DELIVERY, STORAGE AND HANDLING

A. Protection of Equipment:

1. Equipment and material placed on the job site shall remain in the custody of the Contractor until phased acceptance, whether or not the Government has reimbursed the Contractor for the equipment and material. The Contractor is solely responsible for the protection of such equipment and material against any damage.
2. Place damaged equipment in first class, new operating condition; or, replace same as determined and directed by the Resident Engineer. Such repair or replacement shall be at no additional cost to the Government.
3. Protect interiors of new equipment and piping systems against entry of foreign matter. Clean both inside and outside before painting or placing equipment in operation.
4. Existing equipment and piping being worked on by the Contractor shall be under the custody and responsibility of the Contractor and shall be protected as required for new work.

B. Cleanliness of Piping and Equipment Systems:

1. Exercise care in storage and handling of equipment and piping material to be incorporated in the work. Remove debris arising from cutting, threading and welding of piping.
2. Piping systems shall be flushed, blown or pigged as necessary to deliver clean systems.
3. Contractor shall be fully responsible for all costs, damage, and delay arising from failure to provide clean systems.

1.7 JOB CONDITIONS – WORK IN EXISTING BUILDING

A. Building Operation: Government employees will be continuously operating and managing all facilities, that serve the medical center.

B. Maintenance of Service: Schedule all work to permit continuous service as required by the medical center.

C. Phasing of Work: Comply with all requirements shown on drawings or specified.

D. Building Working Environment: Maintain the architectural and structural integrity of the building and the working environment at all times. Maintain the interior of building at 18 degrees C (65 degrees F) minimum. Limit the opening of doors, windows or other access openings to brief periods as necessary for rigging purposes. No storm water or ground water leakage permitted. Provide daily clean-up of construction and demolition debris on all floor surfaces and on all equipment being operated by VA.

E. Acceptance of Work for Government Operation: As new facilities are made available for operation and these facilities are of beneficial use to the Government, inspections will be made and tests will be performed. Based on the inspections, a list of contract deficiencies will be issued to the Contractor. After correction of deficiencies as necessary for beneficial use, the Contracting Officer will process necessary acceptance and the equipment will then be under the control and operation of Government personnel.

PART 2 - PRODUCTS

2.1 FACTORY-ASSEMBLED PRODUCTS

A. Provide maximum standardization of components to reduce spare part requirements.

B. Manufacturers of equipment assemblies that include components made by others shall assume complete responsibility for final assembled unit.

1. All components of an assembled unit need not be products of same manufacturer.
2. Constituent parts that are alike shall be products of a single manufacturer.
3. Components shall be compatible with each other and with the total assembly for intended service.
4. Contractor shall guarantee performance of assemblies of components, and shall repair or replace elements of the assemblies as required to deliver specified performance of the complete assembly.

C. Components of equipment shall bear manufacturer's name and trademark, model number, serial number and performance data on a name plate securely affixed in a conspicuous place, or cast integral with, stamped or otherwise permanently marked upon the components of the equipment.

D. Major items of equipment, which serve the same function, must be the same make and model. Exceptions will be permitted if performance requirements cannot be met.

2.2 COMPATIBILITY OF RELATED EQUIPMENT

Equipment and materials installed shall be compatible in all respects with other items being furnished and with existing items so that the result will be a complete and fully operational plant that conforms to contract requirements.

2.3 EQUIPMENT AND MATERIALS IDENTIFICATION

A. Use symbols, nomenclature and equipment numbers specified, shown on the drawings and shown in the maintenance manuals. Identification for piping is specified in Section 09 91 00, PAINTING.

B. Interior (Indoor) Equipment: Engraved nameplates, with letters not less than 48 mm (3/16-inch) high of brass with black-filled letters, or rigid black plastic with white letters specified in Section 09 91 00, PAINTING permanently fastened to the equipment. Identify unit components such as controls, components, etc.

C. Control Items: Label all temperature and humidity sensors, controllers and control dampers. Identify and label each item as they appear on the control diagrams.

2.4 FIRESTOPPING

Section 07 84 00, FIRESTOPPING specifies an effective barrier against the spread of fire, smoke and gases where penetrations occur for piping and ductwork.

2.5 GALVANIZED REPAIR COMPOUND

Mil. Spec. DOD-P-21035B, paint form.

2.6 HVAC PIPE AND EQUIPMENT SUPPORTS AND RESTRAINTS

A. Attachment to existing structure: Support from existing floor/roof frame.

2.7 PIPE PENETRATIONS

A. To prevent accidental liquid spills from passing to a lower level, provide the following:

1. For drilled penetrations: Provide 40 mm (1-1/2 inch) angle ring or square set in silicone adhesive around penetration.

B. Penetrations are not allowed through beams or ribs, but may be installed in concrete beam flanges. Any deviation from these requirements must receive prior approval of Resident Engineer.

C. Sheet Metal, Plastic, or Moisture-resistant Fiber Sleeves: Provide for pipe passing through floors, interior walls, and partitions, unless brass or steel pipe sleeves are specifically called for below.

D. Galvanized Steel or an alternate Black Iron Pipe with asphalt coating Sleeves: Provide for pipe passing through concrete beam flanges, except where brass pipe sleeves are called for. Provide sleeve for pipe passing through floor of mechanical rooms. Except in mechanical rooms, connect sleeve with floor plate.

E. Sleeves are not required in drywall construction.

F. Sleeve Clearance: Sleeve through floors, walls, partitions, and beam flanges shall be one inch greater in diameter than external diameter of pipe. Interior openings shall be caulked tight with fire stopping material and sealant to prevent the spread of fire, smoke, and gases.

G. Sealant and Adhesives: Shall be as specified in Section 07 92 00, JOINT SEALANTS.

2.8 ASBESTOS

Materials containing asbestos are not permitted.

PART 3 - EXECUTION

3.1 ARRANGEMENT AND INSTALLATION OF EQUIPMENT AND PIPING

A. Operating Personnel Access and Observation Provisions: Select and arrange all equipment and systems to provide clear view and easy access, without use of portable ladders, for maintenance and operation of all devices including, but not limited to: all equipment items, valves, filters, transmitters, sensors, control devices. All gages and indicators shall be clearly visible by personnel standing on the floor or on permanent platforms. Do not reduce or change maintenance and operating space and access provisions that are shown on the drawings.

B. Cutting Holes:

1. Cut holes through concrete and masonry by rotary core drill. Pneumatic hammer, impact electric, and hand or manual hammer type drill will not be allowed, except as permitted by Resident Engineer where working area space is limited.
2. Locate holes to avoid interference with structural members such as beams or grade beams. Holes shall be laid out in advance and drilling done only after approval by Resident Engineer. If the Contractor considers it necessary to drill through structural

members, this matter shall be referred to Resident Engineer for approval.

3. Do not penetrate membrane waterproofing.

C. Interconnection of Instrumentation or Control Devices: Generally, electrical interconnections are not shown but must be provided.

D. Minor Piping: Generally, small diameter pipe runs from drips and drains, water cooling, and other service are not shown but must be provided.

E. Electrical Interconnection of Controls and Instruments: This generally not shown but must be provided. This includes interconnections of sensors, transmitters, transducers, control devices, control and instrumentation panels, instruments and computer workstations. Comply with NFPA-70.

F. Protection and Cleaning:

1. Equipment and materials shall be carefully handled, properly stored, and adequately protected to prevent damage before and during installation, in accordance with the manufacturer's recommendations and as approved by the Resident Engineer. Damaged or defective items in the opinion of the Resident Engineer, shall be replaced.
2. Protect all finished parts of equipment, such as shafts and bearings where accessible, from rust prior to operation by means of protective grease coating and wrapping. Close pipe openings with caps or plugs during installation. Tightly cover and protect fixtures and equipment against dirt, water chemical, or mechanical injury. At completion of all work thoroughly clean fixtures, exposed materials and equipment.

G. Install gages, thermometers, valves and other devices with due regard for ease in reading or operating and maintaining said devices. Locate and position thermometers and gages to be easily read by operator or staff standing on floor. Servicing shall not require dismantling adjacent equipment or pipe work.

H. Work in Existing Building:

1. Perform as specified in Article, OPERATIONS AND STORAGE AREAS, Article, ALTERATIONS, and Article, RESTORATION of the Section 01 00 00, GENERAL REQUIREMENTS for relocation of existing equipment, alterations and restoration of existing building(s).

2. As specified in Section 01 00 00, GENERAL REQUIREMENTS, Article, OPERATIONS AND STORAGE AREAS, make alterations to existing service piping at times that will least interfere with normal operation of the facility.
3. Cut required openings through existing masonry and reinforced concrete using diamond core drills. Use of pneumatic hammer type drills, impact type electric drills, and hand or manual hammer type drills, will be permitted only with approval of the Resident Engineer. Locate openings that will least effect structural slabs, columns, ribs or beams. Refer to the Resident Engineer for determination of proper design for openings through structural sections and opening layouts approval, prior to cutting or drilling into structure. After Resident Engineer's approval, carefully cut opening through construction no larger than absolutely necessary for the required installation.

I. Switchgear/Electrical Equipment Drip Protection: Every effort shall be made to eliminate the installation of pipe above electrical and telephone switchgear. If this is not possible, encase pipe in a second pipe with a minimum of joints. Installation of piping, ductwork, leak protection apparatus or other installations foreign to the electrical installation shall be located in the space equal to the width and depth of the equipment and extending from to a height of 1.8 m (6 ft.) above the equipment of to ceiling structure, whichever is lower (NFPA 70).

J. Inaccessible Equipment:
1. Where the Government determines that the Contractor has installed equipment not conveniently accessible for operation and maintenance, equipment shall be removed and reinstalled or remedial action performed as directed at no additional cost to the Government.
2. The term "conveniently accessible" is defined as capable of being reached without the use of ladders, or without climbing or crawling under or over obstacles such as motors, fans, pumps, belt guards, transformers, high voltage lines, piping, and ductwork.

3.2 TEMPORARY PIPING AND EQUIPMENT

A. Continuity of operation of existing facilities will generally require temporary installation or relocation of equipment and piping.

B. The Contractor shall provide all required facilities in accordance with the requirements of phased construction and maintenance of service. All

piping and equipment shall be properly supported, sloped to drain, operate without excessive stress, and shall be insulated where injury can occur to personnel by contact with operating facilities. The requirements of Paragraph 3.1 apply.

3.3 MECHANICAL DEMOLITION

A. In an operating facility, maintain the operation, cleanliness and safety. Government personnel will be carrying on their normal duties of operating, cleaning and maintaining equipment and plant operation. Confine the work to the immediate area concerned; maintain cleanliness and wet down demolished materials to eliminate dust. Do not permit debris to accumulate in the area to the detriment of plant operation. Perform all flame cutting to maintain the fire safety integrity of this plant. Adequate fire extinguishing facilities shall be available at all times. Perform all work in accordance with recognized fire protection standards. Inspection will be made by personnel of the VA Medical Center, and Contractor shall follow all directives of the RE or COTR with regard to rigging, safety, fire safety, and maintenance of operations.

B. All valves including gate, globe, ball, butterfly and check, all pressure gages and thermometers with wells shall remain Government property and shall be removed and delivered to Resident Engineer and stored as directed. The Contractor shall remove all other material and equipment, devices and demolition debris under these plans and specifications. Such material shall be removed from Government property expeditiously and shall not be allowed to accumulate.

3.4 CLEANING AND PAINTING

A. Prior to final inspection and acceptance of the plant and facilities for beneficial use by the Government, the plant facilities, equipment and systems shall be thoroughly cleaned.

B. In addition, the following special conditions apply:

1. Cleaning shall be thorough. Use solvents, cleaning materials and methods recommended by the manufacturers for the specific tasks. Remove all rust prior to painting and from surfaces to remain unpainted. Repair scratches, scuffs, and abrasions prior to applying prime and finish coats.
2. Material And Equipment Not To Be Painted Includes:
   a. Motors, controllers, control switches, and safety switches.

b. Control and interlock devices.
c. Regulators.
d. Pressure reducing valves.
e. Control valves and thermostatic elements.
f. Lubrication devices and grease fittings.
g. Copper, brass, aluminum, stainless steel and bronze surfaces.
h. Valve stems and rotating shafts.
i. Pressure gauges and thermometers.
j. Glass.
k. Name plates.

3. Control and instrument panels shall be cleaned, damaged surfaces repaired, and shall be touched-up with matching paint obtained from panel manufacturer.

3.5 IDENTIFICATION SIGNS

A. Provide laminated plastic signs, with engraved lettering not less than 5 mm (3/16-inch) high, designating functions, for all equipment, switches, motor controllers, relays, meters, control devices, including automatic control valves. Nomenclature and identification symbols shall correspond to that used in maintenance manual, and in diagrams specified elsewhere. Attach by chain, adhesive, or screws.

B. Factory Built Equipment: Metal plate, securely attached, with name and address of manufacturer, serial number, model number, size, performance.

C. Pipe Identification: Refer to Section 09 91 00, PAINTING.

3.6 LUBRICATION

A. Equip all devices with required lubrication fittings or devices. Provide a minimum of one liter (one quart) of oil and 0.5 kg (one pound) of grease of manufacturer's recommended grade and type for each different application; also provide 12 grease sticks for lubricated plug valves. Deliver all materials to Resident Engineer in unopened containers that are properly identified as to application.

B. Provide a separate grease gun with attachments for applicable fittings for each type of grease applied.

3.7 COMMISSIONING

A. Provide commissioning documentation in accordance with the requirements of Section 23 08 00 - COMMISSIONING OF HVAC SYSTEMS for all inspection,

start up, and contractor testing required above and required by the System Readiness Checklist provided by the Commissioning Agent.

B. Components provided under this section of the specifications will be tested as part of a larger system. Refer to Section 23 08 00 - COMMISSIONING OF HVAC SYSTEMS and related sections for contractor responsibilities for system commissioning.

3.8 STARTUP AND TEMPORARY OPERATION

Start up equipment as described in equipment specifications. Verify that vibration is within specified tolerance prior to extended operation. Temporary use of equipment is specified in Section 01 00 00, GENERAL REQUIREMENTS, Article, TEMPORARY USE OF MECHANICAL AND ELECTRICAL EQUIPMENT.

3.9 OPERATING AND PERFORMANCE TESTS

A. Prior to the final inspection, perform required tests as specified in Section 01 00 00, GENERAL REQUIREMENTS and submit the test reports and records to the Resident Engineer.

B. Should evidence of malfunction in any tested system, or piece of equipment or component part thereof, occur during or as a result of tests, make proper corrections, repairs or replacements, and repeat tests at no additional cost to the Government.

C. When completion of certain work or system occurs at a time when final control settings and adjustments cannot be properly made to make performance tests, then make performance tests for heating systems and for cooling systems respectively during first actual seasonal use of respective systems following completion of work.

3.10 INSTRUCTIONS TO VA PERSONNEL

Provide in accordance with Article, INSTRUCTIONS, of Section 01 00 00, GENERAL REQUIREMENTS, and Section 23 08 11, DEMONSTRATIONS AND TESTS FOR BOILER PLANT.

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

PART 1 - GENERAL

1.1 DESCRIPTION

A. Testing, adjusting, and balancing (TAB) of heating, ventilating and air conditioning (HVAC) systems. TAB includes the following:
   1. Planning systematic TAB procedures.
   2. Design Review Report.
   3. Systems Inspection report.
   4. Systems Readiness Report.
   5. Balancing air and water distribution systems; adjustment of total system to provide design performance; and testing performance of equipment and automatic controls.
   6. Vibration and sound measurements. 7. Recording and reporting results.

B. Definitions:
   1. Basic TAB used in this Section: Chapter 38, "Testing, Adjusting and Balancing" of 2011 ASHRAE Handbook, "HVAC Applications".
   2. TAB: Testing, Adjusting and Balancing; the process of checking and adjusting HVAC systems to meet design objectives.
   3. AABC: Associated Air Balance Council.
   4. NEBB: National Environmental Balancing Bureau.
   5. Hydronic Systems: Includes chilled water, condenser water, heating hot water and glycol-water systems.
   6. Air Systems: Includes all outside air, supply air, return air, exhaust air and relief air systems.
   7. Flow rate tolerance: The allowable percentage variation, minus to plus, of actual flow rate from values (design) in the contract documents.

1.2 RELATED WORK

A. Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES.
B. Section 23 05 11, COMMON WORK RESULTS FOR HVAC.
C. Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS. Equipment Insulation.
D. Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

1.3 QUALITY ASSURANCE

A. Refer to Articles, Quality Assurance and Submittals, in Section 23 05 11, and Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS.

B. Qualifications:

1. TAB Agency: The TAB agency shall be a subcontractor of the General Contractor and shall report to and be paid by the General Contractor.
2. The TAB agency shall be either a certified member of AABC or certified by the NEBB to perform TAB service for HVAC, water balancing and vibrations and sound testing of equipment. The certification shall be maintained for the entire duration of duties specified herein. If, for any reason, the agency loses subject certification during this period, the General Contractor shall immediately notify the Resident Engineer and submit another TAB firm for approval. Any agency that has been the subject of disciplinary action by either the AABC or the NEBB within the five years preceding Contract Award shall not be eligible to perform any work related to the TAB. All work performed in this Section and in other related Sections by the TAB agency shall be considered invalid if the TAB agency loses its certification prior to Contract completion, and the successor agency’s review shows unsatisfactory work performed by the predecessor agency.
3. TAB Specialist: The TAB specialist shall be either a member of AABC or an experienced technician of the Agency certified by NEBB. The certification shall be maintained for the entire duration of duties specified herein. If, for any reason, the Specialist loses subject certification during this period, the General Contractor shall immediately notify the Resident Engineer and submit another TAB Specialist for approval. Any individual that has been the subject of disciplinary action by either the AABC or the NEBB within the five years preceding Contract Award shall not be eligible to perform any duties related to the HVAC systems, including TAB. All work specified in this Section and in other related Sections performed by the TAB specialist shall be considered invalid if the TAB Specialist loses its certification prior to Contract completion and must be performed by an approved successor.
4. TAB Specialist shall be identified by the General Contractor within 60 days after the notice to proceed. The TAB specialist will be coordinating, scheduling and reporting all TAB work and related

activities and will provide necessary information as required by the Resident Engineer. The responsibilities would specifically include:

a. Shall directly supervise all TAB work.
b. Shall sign the TAB reports that bear the seal of the TAB standard. The reports shall be accompanied by report forms and schematic drawings required by the TAB standard, AABC or NEBB.
c. Would follow all TAB work through its satisfactory completion.
d. Shall provide final markings of settings of all HVAC adjustment devices.
e. Permanently mark location of duct test ports.

5. All TAB technicians performing actual TAB work shall be experienced and must have done satisfactory work on a minimum of 3 projects comparable in size and complexity to this project. Qualifications must be certified by the TAB agency in writing. The lead technician shall be certified by AABC or NEBB

C. Test Equipment Criteria: The instrumentation shall meet the accuracy/calibration requirements established by AABC National Standards or by NEBB Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems and instrument manufacturer. Provide calibration history of the instruments to be used for test and balance purpose.

D. Tab Criteria:

1. One or more of the applicable AABC, NEBB or SMACNA publications, supplemented by ASHRAE Handbook "HVAC Applications" Chapter 38, and requirements stated herein shall be the basis for planning, procedures, and reports.
2. Flow rate tolerance: Following tolerances are allowed. For tolerances not mentioned herein follow 2011 ASHRAE Handbook "HVAC Applications", Chapter 38, as a guideline. Air Filter resistance during tests, artificially imposed if necessary, shall be at least 100 percent of manufacturer recommended change over pressure drop values for pre-filters and after-filters.
   a. Air handling unit and all other fans, cubic meters/min (cubic feet per minute): Minus 0 percent to plus 10 percent.
   b. Air terminal units (maximum values): Minus 2 percent to plus 10 percent.
   c. Minimum outside air: 0 percent to plus 10 percent.

d. Individual room air outlets and inlets, and air flow rates not mentioned above: Minus 5 percent to plus 10 percent except if the air to a space is 100 CFM or less the tolerance would be minus 5 to plus 5 percent.

e. Heating hot water coils: Minus 5 percent to plus 5 percent.

3. Systems shall be adjusted for energy efficient operation as described in PART 3.

4. Typical TAB procedures and results shall be demonstrated to the Resident Engineer for one air distribution system (including all fans, three terminal units, three rooms randomly selected by the Resident Engineer) and one hydronic system (three coils) as follows:

a. When field TAB work begins.

b. During each partial final inspection and the final inspection for the project if requested by VA.

1.4 SUBMITTALS

A. Submit in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES.

B. Submit names and qualifications of TAB agency and TAB specialists within 60 days after the notice to proceed. Submit information on three recently completed projects and a list of proposed test equipment.

C. For use by the Resident Engineer staff, submit one complete set of applicable AABC or NEBB publications that will be the basis of TAB work.

D. Submit Following for Review and Approval:

1. Design Review Report within 90 days for conventional design projects and within 60 days for design-build projects after the system layout on air and water side is completed by the Contractor.

2. Systems inspection report on equipment and installation for conformance with design.

3. Duct Air Leakage Test Report.

4. Systems Readiness Report.

5. Intermediate and Final TAB reports covering flow balance and adjustments, performance tests, vibration tests and sound tests.

6. Include in final reports uncorrected installation deficiencies noted during TAB and applicable explanatory comments on test results that differ from design requirements.

E. Prior to request for Final or Partial Final inspection, submit completed Test and Balance report for the area.

1.5 APPLICABLE PUBLICATIONS

A. The following publications form a part of this specification to the extent indicated by the reference thereto. In text the publications are referenced to by the acronym of the organization.

B. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE):

2011 .....HVAC Applications ASHRAE Handbook, Chapter 38, Testing, Adjusting, and Balancing and Chapter 48, Sound and Vibration Control

C. Associated Air Balance Council (AABC):

2002.....AABC National Standards for Total System Balance

D. National Environmental Balancing Bureau (NEBB):

7th Edition 2005 .....Procedural Standards for Testing, Adjusting, Balancing of Environmental Systems

2nd Edition 2006 .....Procedural Standards for the Measurement of Sound and Vibration

3rd Edition 2009 .....Procedural Standards for Whole Building Systems Commissioning of New Construction

E. Sheet Metal and Air Conditioning Contractors National Association (SMACNA):

3rd Edition 2002 .....HVAC SYSTEMS Testing, Adjusting and Balancing

PART 2 - PRODUCTS

2.1 PLUGS

Provide plastic plugs to seal existing holes in ductwork for test purposes.

PART 3 - EXECUTION

3.1 GENERAL

A. Refer to TAB Criteria in Article, Quality Assurance.

B. Obtain applicable contract documents and copies of approved submittals for HVAC equipment and automatic control systems.

3.2 DESIGN REVIEW REPORT

The TAB Specialist shall review the Contract Plans and specifications and advise the Resident Engineer of any design deficiencies that would prevent the HVAC systems from effectively operating in accordance with

the sequence of operation specified or prevent the effective and accurate TAB of the system. The TAB Specialist shall provide a report individually listing each deficiency and the corresponding proposed corrective action necessary for proper system operation.

3.3 SYSTEMS INSPECTION REPORT

A. Inspect equipment and installation for conformance with design.

B. The inspection and report is to be done after air distribution equipment is on site and duct installation has begun, but well in advance of performance testing and balancing work. The purpose of the inspection is to identify and report deviations from design and ensure that systems will be ready for TAB at the appropriate time.

C. Reports: Follow check list format developed by AABC, NEBB or SMACNA, supplemented by narrative comments, with emphasis on air handling units and fans. Check for conformance with existing data and existing condition baseline tests.

3.5 SYSTEM READINESS REPORT

A. The TAB Contractor shall measure existing air and water flow rates associated with existing systems utilized to serve renovated areas as indicated on drawings. Submit report of findings to resident engineer.

B. Inspect each System to ensure that it is complete including installation and operation of controls. Submit report to RE in standard format and forms prepared and or approved by the Commissioning Agent.

C. Verify that all items that is required for TAB are installed. Provide a report to the Resident Engineer.

3.6 TAB REPORTS

A. Submit an intermediate report for 25 percent of systems and equipment tested and balanced to establish satisfactory test results.

B. The TAB contractor shall provide raw data immediately in writing to the Resident Engineer if there is a problem in achieving intended results before submitting a formal report.

D. Do not proceed with the remaining systems until intermediate report is approved by the Resident Engineer.

3.7 TAB PROCEDURES

A. Tab shall be performed in accordance with the requirement of the Standard under which TAB agency is certified by either AABC or NEBB.

B. General: During TAB all related system components shall be in full operation. Fan and pump rotation, motor loads and equipment vibration shall be checked and corrected as necessary before proceeding with TAB. Set controls to simulate design operation of variable volume air or water systems for test and balance work.

C. Coordinate TAB procedures with existing systems and any phased construction completion requirements for the project. Provide TAB reports for pre construction air and water flow rate and for each phase of the project prior to partial final inspections of each phase of the project. Return existing areas to pre constructed conditions.

D. Allow time in construction schedule for TAB and submission of all reports for an organized and timely correction of deficiencies.

E. Air Balance and Equipment Test: Include air handling units, fans, and terminal units, associated with the project.

1.

2. Adjust fan speeds to provide design air flow.

3. Test and balance systems in all specified modes of operation, including variable volume, economizer, and fire emergency modes. Verify that dampers and other controls function properly.

4. Variable air volume (VAV) systems:

   a. Coordinate TAB, including system volumetric controls, with Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC.

   b. Check and readjust ATU flow rates if necessary. Balance air distribution from ATU on full cooling maximum scheduled cubic meters per minute (cubic feet per minute). Reset room thermostats and check ATU operation from maximum to minimum cooling, to the heating mode, and back to cooling. Record and report the heating coil leaving air temperature when the ATU is in the maximum heating mode. Record and report outdoor air flow rates under all operating conditions (The test shall demonstrate that the minimum outdoor air ventilation rate shall remain constant under al operating conditions).

   c. Adjust operating pressure control setpoint to maintain the design flow to each space with the lowest setpoint.

5. Record final measurements for air handling equipment performance data sheets.

F. Water Balance and Equipment Test: Include reheat coils.
   1. Coordinate water chiller flow balancing with Section 23 64 00, PACKAGED WATER CHILLERS.
   2. Adjust flow rates for equipment. Set coils and evaporator to values on equipment submittals, if different from values on contract drawings.
   3. Primary-secondary (variable volume) systems: Coordinate TAB with Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC. Balance systems at design water flow and then verify that variable flow controls function as designed.
   4. Record final measurements for hydronic equipment on performance data sheets. Include entering and leaving water temperatures for heating and cooling coils, and for convertors. Include entering and leaving air temperatures (DB/WB for cooling coils) for air handling units and reheat coils. Make air and water temperature measurements at the same time.

3.8 MARKING OF SETTINGS

Following approval of Tab final Report, the setting of all HVAC adjustment devices including valves, splitters and dampers shall be permanently marked by the TAB Specialist so that adjustment can be restored if disturbed at any time. Style and colors used for markings shall be coordinated with the Resident Engineer.

3.9 IDENTIFICATION OF TEST PORTS

The TAB Specialist shall permanently and legibly identify the location points of duct test ports. If the ductwork has exterior insulation, the identification shall be made on the exterior side of the insulation. All penetrations through ductwork and ductwork insulation shall be sealed to prevent air leaks and maintain integrity of vapor barrier.

3.10 PHASING

A. Phased Projects: Testing and Balancing Work to follow project with areas shall be completed per the project phasing. Upon completion of the project all areas shall have been tested and balanced per the contract documents.

B. Existing Areas: Systems that serve areas outside of the project scope shall not be adversely affected. Measure existing parameters where shown to document system capacity.

3.11 COMMISSIONING

A. Provide commissioning documentation in accordance with the requirements of Section 23 08 00 – COMMISSIONING OF HVAC SYSTEMS for all inspection, start up, and contractor testing required above and required by the System Readiness Checklist provided by the Commissioning Agent.

B. Components provided under this section of the specification will be tested as part of a larger system. Refer to Section 23 08 00 – COMMISSIONING OF HVAC SYSTEMS and related sections for contractor responsibilities for system commissioning.

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SECTION 23 08 00
COMMISSIONING OF HVAC SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

A. The requirements of this Section apply to all sections of Division 23.

B. This project will have selected building systems commissioned. The complete list of equipment and systems to be commissioned is specified in Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS. The commissioning process, which the Contractor is responsible to execute, is defined in Section 01 91 00 GENERAL COMMISSIONING REQUIRMENTS. A Commissioning Agent (CxA) appointed by the VA will manage the commissioning process.

1.2 RELATED WORK

A. Section 01 00 00 GENERAL REQUIREMENTS.

B. Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS.

C. Section 01 33 23 SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.

1.3 SUMMARY

A. This Section includes requirements for commissioning the upgraded HVAC Temperature Controls. This Section supplements the general requirements specified in Section 01 91 00 General Commissioning Requirements.

B. Refer to Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS for more details regarding processes and procedures as well as roles and responsibilities for all Commissioning Team members.

1.4 DEFINITIONS

A. Refer to Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS for definitions.

1.5 COMMISSIONED SYSTEMS

A. Commissioning of a system or systems specified in Division 23 is part of the construction process. Documentation and testing of these systems, as well as training of the VA’s Operation and Maintenance personnel in accordance with the requirements of Section 01 91 00 and of Division 23, is required in cooperation with the VA and the Commissioning Agent.

1.6 SUBMITTALS

A. The commissioning process requires review of selected Submittals that pertain to the systems to be commissioned. The Commissioning Agent will provide a list of submittals that will be reviewed by the

Commissioning Agent. This list will be reviewed and approved by the VA prior to forwarding to the Contractor. Refer to Section 01 33 23 SHOP DRAWINGS, PRODUCT DATA, and SAMPLES for further details.

B. The commissioning process requires Submittal review simultaneously with engineering review. Specific submittal requirements related to the commissioning process are specified in Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.1 CONSTRUCTION INSPECTIONS

A. Commissioning of HVAC systems will require inspection of individual elements of the HVAC systems construction throughout the construction period. The Contractor shall coordinate with the Commissioning Agent in accordance with Section 01 19 00 and the Commissioning plan to schedule HVAC systems inspections as required to support the Commissioning Process.

3.2 PRE-FUNCTIONAL CHECKLISTS

A. The Contractor shall complete Pre-Functional Checklists to verify systems, subsystems, and equipment installation is complete and systems are ready for Systems Functional Performance Testing. The Commissioning Agent will prepare Pre-Functional Checklists to be used to document equipment installation. The Contractor shall complete the checklists. Completed checklists shall be submitted to the VA and to the Commissioning Agent for review. The Commissioning Agent may spot check a sample of completed checklists. If the Commissioning Agent determines that the information provided on the checklist is not accurate, the Commissioning Agent will return the marked-up checklist to the Contractor for correction and resubmission. If the Commissioning Agent determines that a significant number of completed checklists for similar equipment are not accurate, the Commissioning Agent will select a broader sample of checklists for review. If the Commissioning Agent determines that a significant number of the broader sample of checklists is also inaccurate, all the checklists for the type of equipment will be returned to the Contractor for correction and resubmission. Refer to SECTION 01 91 00 GENERAL COMMISSIONING REQUIREMENTS for submittal requirements for Pre-Functional Checklists, Equipment Startup Reports, and other commissioning documents.

3.3 CONTRACTORS TESTS

A. Contractor tests as required by other sections of Division 23 shall be scheduled and documented in accordance with Section 01 00 00 GENERAL REQUIREMENTS. All testing shall be incorporated into the project schedule. Contractor shall provide no less than 7 calendar days' notice of testing. The Commissioning Agent will witness selected Contractor tests at the sole discretion of the Commissioning Agent. Contractor tests shall be completed prior to scheduling Systems Functional Performance Testing.

3.4 SYSTEMS FUNCTIONAL PERFORMANCE TESTING:

A. The Commissioning Process includes Systems Functional Performance Testing that is intended to test systems functional performance under steady state conditions, to test system reaction to changes in operating conditions, and system performance under emergency conditions. The Commissioning Agent will prepare detailed Systems Functional Performance Test procedures for review and approval by the Resident Engineer. The Contractor shall review and comment on the tests prior to approval. The Contractor shall provide the required labor, materials, and test equipment identified in the test procedure to perform the tests. The Commissioning Agent will witness and document the testing. The Contractor shall sign the test reports to verify tests were performed. See Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS, for additional details.

3.5 TRAINING OF VA PERSONNEL

A. Training of the VA operation and maintenance personnel is required in cooperation with the Resident Engineer and Commissioning Agent. Provide competent, factory authorized personnel to provide instruction to operation and maintenance personnel concerning the location, operation, and troubleshooting of the installed systems. Contractor shall submit training agendas and trainer resumes in accordance with the requirements of Section 01 19 00. The instruction shall be scheduled in coordination with the VA Resident Engineer after submission and approval of formal training plans. Refer to Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS and Division 23 Sections for additional Contractor training requirements.

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SECTION 23 09 23
DIRECT-DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

PART 1 – GENERAL

1.1 DESCRIPTION

A. Provide direct-digital control system(s) as indicated on the project documents, point list, interoperability tables, and drawings as described in these specifications. This scope of work shall include a complete and working direct-digital control system. Include all engineering, programming, controls and installation materials, installation labor, testing and start-up, training, final project documentation and warranty. The direct-digital control (DDC) system(s) shall consist of high-speed, peer-to-peer network of DDC controllers, a control system server, and an Engineering Control Center. Provide a remote user using a standard web browser to access the control system graphics and change adjustable setpoints with the proper password.

1. The direct-digital control system(s) shall be native BACnet. All new workstations software, controllers, devices and components shall be listed by BACnet Testing Laboratories. All new workstations, controller, devices and components shall be accessible using a Web browser interface and shall communicate exclusively using the ASHRAE Standard 135 BACnet communications protocol without the use of gateways, unless otherwise allowed by this Section of the technical specifications, specifically shown on the design drawings and specifically requested otherwise by the VA.
   a. If used, gateways shall support the ASHRAE Standard 135 BACnet communications protocol.
2. Warranty on all DDC Control System, to include hardware and software, shall be extended to 3 years. Also include all software upgrades during the warranty period.

B. Engineering Control Center (ECC) shall include:

1. All new DDC work will be through the existing Alerton Network PC or existing Honeywell frontend located in room D-72 in the basement of the Hospital all DDC points listed in this spec section, 230993, or the points list in the mechanical pages specifically stated or as needed to make the sequence work will be displayed on either the Honeywell or Alerton Graphical User Interface systems.

2. New DDC Controls to interface with the existing Alerton or Honeywell System via the Alerton BACNET Router or Honeywell BACNET Router located in Room F-8 in the basement of the VA ACRE Building, Fan room #4 (only has Alerton Router) in the basement of the hospital or in Room D-72 in the basement of the hospital.
3. Ethernet, IP Supervisory Network shall connect the BACNET Router to a BACNET HUB located at the Existing Alerton or Honeywell Workstations located in the Basement of the VA Hospital.
4. Provide Custom Images of new Control Systems, fans, pumps, fire pump, booster pumps, heat recovery systems, VAV boxes, venturi air valves and points for the Graphic interface of each system.
5. Software Configuration Tools, including the software to modify graphics, upload and down load controllers, and re-configure the sequence of operation as programmed in the stand-alone controllers.
6. Scheduling and Alarm Management software.
7. Network Area Controllers.
8. Unitary Control Units (UCU).
9. Connected I/O devices.
10. Third party system Data Integration.

C. Existing Engineering Control Center: The existing Honeywell Graphical User Interface, Existing Alerton Graphical User Interface, and the Existing Tridium N4 Graphical User Interface are interconnected on the Existing HVAC BAS Intranet/Ethernet LAN. All existing Graphical User Interfaces have the ability to create and program new Custom Images of the new Control Systems, fans, pumps, fire pump, booster pumps, heat recovery systems, VAV boxes, venturi air valves, VAV offset flow controls and real-time point display for the Graphic interface of each new system.

D. The work administered by this Section of the technical specifications shall include all labor, materials, special tools, equipment, enclosures, power supplies, power wiring and conduit from emergency power panels to the devices or control transformers, software, software licenses, Project specific software configurations and database entries, interfaces, wiring, tubing, installation, labeling, engineering, calibration, documentation, submittals, testing, verification, training services, permits and licenses, transportation, shipping, handling, administration, supervision, management, insurance,

Warranty, specified services and items required for complete and fully functional Controls Systems.

E. Controls contractor shall run conduit, run wire and connect ALL controls operating below 125-volts in accordance with approved wiring diagrams.

F. Controls contractor shall furnish and install ALL wiring and conduit for hardwired connections between fans, pumps, plenum lights and other devices shown on the Control Drawings or listed in the Sequence of Control.

G. Controls contractor to include ALL wiring, conduit between control panels, pressure sensors, differential room pressure monitors, control motor-actuators, electronic valves, electronic dampers, terminal VAV/constant volume controllers, Fixed Offset Pressure Controllers, Room Pressure Controllers and Venturi Valves, electric fire/smoke dampers and control transformers. Controls contractor shall coordinate with Division 26 for spare breakers in emergency electrical panels to power required circuits.

H. The control systems shall be designed such that each mechanical system shall "**Operate as a Stand-Alone Mode**". The contractor administered by this Section of the technical specifications shall provide controllers for each mechanical system. In the event of a network communication failure, or the loss of any other controller, the control system shall continue to operate independently. Failure of the ECC shall have no effect on the field controllers, including those involved with global strategies.

I. The control system shall accommodate 4 Engineering Control Center workstations and the control system shall accommodate up to 10 web-based Users simultaneously, and the access to the system should be limited only by operator password.

J. Some products are furnished but not installed by the contractor administered by this Section of the technical specifications. The contractor administered by this Section of the technical specifications shall formally coordinate in writing and receive from other contractors formal acknowledgements in writing prior to submission the installation of the products. These products include the following:

1. Control valves.
2. Flow switches.
3. Flow meters.

4. Sensor wells and sockets in piping.
5. Terminal unit controllers.

K. Some products are not provided by, but are nevertheless integrated with the work executed by, the contractor administered by this Section of the technical specifications. The contractor administered by this Section of the technical specifications shall formally coordinate in writing and receive from other contractors formal acknowledgements in writing prior to submission the particulars of the products. These products include the following:

1. Fire alarm systems. If zoned fire alarm is required by the project-specific requirements, this interface shall require multiple relays, which are provided and installed by the fire alarm system contractor, to be monitored.
2. Terminal units' velocity sensors
3. Variable frequency drives. These controls, if not native BACnet, will require a BACnet Gateway.

L. Responsibility Table:

Work/Item/System	**Furnish**	**Install**	**Low Voltage Wiring**	**Line Power**
Control system low voltage and communication wiring	23 09 23	23 09 23	23 09 23	N/A
Terminal units	23	23	N/A	23
Controllers for terminal units	23 09 23	23 09 23	23 09 23	N/A
LAN conduits and raceway	23 09 23	23 09 23	23 09 23	N/A
Automatic dampers (not furnished with equipment)	23 09 23	23	N/A	N/A
Automatic damper actuators	23 09 23	23 09 23	23 09 23	23 09 23
Manual valves	23	23	N/A	N/A
Automatic valves	23 09 23	23	23 09 23	23 09 23
Pipe insertion devices and taps, flow and pressure stations.	23	23	N/A	N/A
Thermowells	23 09 23	23	N/A	N/A
Current Switches	23 09 23	23 09 23	23 09 23	N/A
Control Relays	23 09 23	23 09 23	23 09 23	N/A
Laboratory Offset Flow Tracking controls interface with control	23	23	23 09 23	23

Work/Item/System	**Furnish**	**Install**	**Low Voltage Wiring**	**Line Power**
system				
All control system nodes, equipment, housings, enclosures and panels.	23 09 23	23 09 23	23 09 23	23
Smoke detectors	28 31 00	28 31 00	28 31 00	28 31 00
Fire/Smoke Dampers	23	23	28 31 00	28 31 00
Fire Dampers	23	23	N/A	N/A
VFDs	23 09 23	26	23 09 23	26
Laboratory Environmental Controls	23 09 23	23 09 23	23 09 23	23
Fume hood controls	23 09 23	23 09 23	23 09 23	23
Laboratory Air Valves	23	23	23 09 23	N/A
Fire Alarm shutdown relay interlock wiring	28	28	28	26
Starters, HOA switches	23	23	N/A	26

M. This facility's existing direct-digital control systems are manufactured by Honeywell, Alerton, and Tridium with their ECC located in the Room D-72 and the boiler plant of the Hospital. The existing Tridium Niagara 4 Server must be compatible with all newly added control points and systems. The contractor administered by this Section of the technical specifications shall observe the capabilities, communication network, services, spare capacity of the existing control system and its ECC prior to beginning work. The ECC shall communicate directly with the new native-BACnet devices over the existing control system's communications network without the use of a gateway. Provide programming converting the existing non-BACnet devices, objects and services to ASHRAE Standard 135 BACnet-complaint BIBBs. The contractor administered by this Section of the technical specifications shall provide all necessary investigation and site-specific programming to execute the interoperability schedules.

1. The performance requirement for the combined system: the combined system shall operate and function as one complete system including one database of control point objects and global control logic capabilities. Facility operators shall have complete operations and control capability over all systems, new and existing including;

monitoring, trending, graphing, scheduling, alarm management, global point sharing, global strategy deployment, graphical operations interface and custom reporting as specified.

N. Responsibility Table:

Item/Task	**Section 230923, 230993 contactor**	**Control system integrator**	**VA**
ECC expansion	X		
ECC programming	X		
Devices, controllers, control panels and equipment	X		
Point addressing: all hardware and software points including setpoint, calculated point, data point(analog/ binary), and reset schedule point	X		
Point mapping	X		
Network Programming	X		
ECC Graphics	X		
Controller programming and sequences	X		
Integrity of LAN communications	X		
Electrical wiring	X		
Operator system training	X		
LAN connections to devices	X		
LAN connections to ECC	X		
IP / BACnet IP/MSTP Network addresses			X
Overall system verification	X		X
Controller and LAN system verification	X		

O. Following control devices and systems shall be used to provide the functional requirements of HVAC equipment and systems.

1. Direct Digital Control (DDC) of HVAC equipment and systems with electric or electronic positioning of valves and dampers.
2. Terminal units including VAV Boxes, air valves and similar units for control of room environment conditions may be equipped with integral controls furnished and installed by the equipment manufacturer or field mounted. Refer to equipment specifications and as indicated in project documents.

P. The direct-digital control system shall start and stop equipment, move (position) damper actuators and valve actuators, and vary speed of equipment to execute the mission of the control system. Use electricity as the motive force for all damper and valve actuators, unless use of pneumatics as motive force is specifically granted by the VA.

Q. General and Misc DDC Work: The following items shall be completed with the project:

1. BACNet Zone polling (for resets based on VAV's/Terminal Units) should be done at sub-panels, not at frontend/ECC.
2. Schedule changes shall be from the frontend/ECC/Web Interface.
3. All digital and analog outputs overrides, temperature setpoints, PID Loop configuration/tuning parameters, timed overrides and key parameters shall be adjustable from the ECC and Web Interface. The operator shall be able to periodically adjust parameter within the application, such as reset schedule values, timing parameters, calibration offsets, tuning parameters, set point values, globe/zone/VAV/TU schedules, and be able to manually override of output points and manual overrides of physical sensor values or states. All overrides shall change color state while the point is in override. This shall be displayed on the web graphic depicting the point, and in a summary page of all active overrides.
4. Use Primary Controllers for all DDC controllers. Every piece of mechanical equipment shall be provided with a controller capable of standalone operation. For example 1 controller shall not serve 2 AHUs.
5. Initial setup of all VAV/TU's shall be set for +/- 2 degrees (adjustable) space temp adjustment.
6. All BACNet DDC systems and devices shall use BACNet Objects and BACNet Properties. And shall use BACNet Interoperability Building Blocks (BIBB's).
7. All installed devices shall be native BACNET and shall be BACNET Testing Lab (BTL) listed as a BACnet type device.
8. All points shall be exposed as BACnet objects or properties when the device is programmed.
9. All Objects and Properties shall be writable. To include override of setpoints, reset to previous and writeable setpoints.
10. Use Advanced Applications Controllers (B-BC or B-AAC) for all field controllers. DDC contractor shall use a Graphical Programming language and graphic logic diagrams.

11. Controls contractors shall provide the VA with the software keys, access codes and passwords (to access the entire installed software system) and provide software to allow the VA to perform the following functions:
    a) Monitor and supervise control of all points/objects,
    b) Add new points and edit the system database,
    c) Change control setpoints, timing parameters and loop-tuning constants in all control units,
    d) Enter programming start/stop time schedules,
    e) Modify existing control programs in all control units,
    f) Upload and Download programs, databases,
    g) All control parameters,
12. Frontend system shall allow trending of any point/object, hardware or software (virtual). Include tabular and graphical formats, simulation display of multiple values, user adjustable ranges and scaling, high resolution capable sampling on PID control loops, archiving and storage.
13. System shall include a Trend Wizard for setup of logs. Wizard shall walk user through all necessary steps. Wizard shall have its own pull-down selection for startup, or may be started by right-clicking on value displayed on graphic, and then selecting Trend logs from the displayed menu.

R. New system including interface to existing systems and equipment shall operate and function as one complete system including one database of control point objects and global control logic capabilities. Facility operators shall have complete operations and control capability over all systems, new and existing including; monitoring, trending, graphing, scheduling, alarm management, global point sharing, global strategy deployment, graphical operations interface and custom reporting as specified. Modify the existing ECC, if necessary, to accommodate the additional control points.

S. The control subcontractor shall supply all necessary hardware equipment, cables, BACnet MSTP router, BACnet IP router, and software packages to interface between any existing and new system Network Area Controllers (NAC) as part of this contract. Number of area controllers required is dependent on the type and quantity of devices, hardware and software points provided. Network area controllers are same as remote controller units (RCU).

T. The control systems shall be designed such that each mechanical system shall operate under stand-alone mode. Temperature Controls contractor shall provide controllers for each mechanical system. In the event of a network communication failure, or the loss of any other controller, the control system shall continue to operate independently. Failure of the ECC shall have no effect on the field controllers, including those involved with global strategies.

U. The Top End of the NAC shall communicate using American Society of Heating and Refrigerating Engineers/American National Standards Institute (ASHRAE/ANSI) Standard 135(BACnet) protocol. The NAC shall reside on the BACnet/IP Ethernet (ISO 8802-3) local area network, and provide information via standard BACnet object types and application services. The Bottom End of the NAC, the unit level controllers and all other field devices shall reside on the BACNET Link A or Link B Network. The intent of this specification is to provide a peer-to peer networked, stand-alone, distributed control system. Power wiring shall not be run in conduit with communications trunk wiring or signal or control wiring operating at 100 volts or less.

1.2 RELATED WORK

A. Section 23 05 11, COMMON WORK RESULTS FOR HVAC.

B. Section 23 05 93, TESTING, ADJUSTING, AND BALANCING FOR HVAC.

C. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

D. Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS.

E. Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW).

F. Section 26 27 26, WIRING DEVICES.

1.3 DEFINITION

A. Algorithm: A logical procedure for solving a recurrent mathematical problem; a prescribed set of well-defined rules or processes for the solution of a problem in a finite number of steps.

B. ACU: Auxiliary Control Unit (ACU) used for controls of air handling units, reports to RCU.

C. Analog: A continuously varying signal value (e.g., temperature, current, velocity etc.

D. BACnet: A Data Communication Protocol for Building Automation and Control Networks, ANSI/ASHRAE Standard 135. This communications protocol allows diverse building automation devices to communicate data

over and services over a network.Control Network Protocol, ASHRAE Standard 135.

E. BACnet/IP: Annex J of Standard 135. It defines and allows for using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP sub-networks that share the same BACnet network number.

F. BACnet Internetwork: Two or more BACnet networks connected with routers. The two networks may sue different LAN technologies.

G. BACnet Network: One or more BACnet segments that have the same network address and are interconnected by bridges at the physical and data link layers.

H. BACnet Segment: One or more physical segments of BACnet devices on a BACnet network, connected at the physical layer by repeaters.

I. BACnet Broadcast Management Device (BBMD): A communications device which broadcasts BACnet messages to all BACnet/IP devices and other BBMDs connected to the same BACnet/IP network.

J. BACnet Interoperability Building Blocks (BIBBs): BACnet Interoperability Building Blocks (BIBBs) are collections of one or more BACnet services. These are prescribed in terms of an "A" and a "B" device. Both of these devices are nodes on a BACnet internetwork.

K. BACnet Testing Laboratories (BTL). The organization responsible for testing products for compliance with the BACnet standard, operated under the direction of BACnet International.

L. Baud: It is a signal change in a communication link. One signal change can represent one or more bits of information depending on type of transmission scheme. Simple peripheral communication is normally one bit per Baud. (e.g., Baud rate = 78,000 Baud/sec is 78,000 bits/sec, if one signal change = 1 bit).

M. Binary: A two-state system where a high signal level represents an "ON" condition and an "OFF" condition is represented by a low signal level.

N. BMP or bmp: Suffix, computerized image file, used after the period in a DOS-based computer file to show that the file is an image stored as a series of pixels.

O. Bus Topology: A network topology that physically interconnects workstations and network devices in parallel on a network segment.

P. Control Unit (CU): Generic term for any controlling unit, stand-alone, microprocessor based, digital controller residing on secondary LAN or Primary LAN, used for local controls or global controls. In this

specification, there are three types of control units are used; Unitary Control Unit (UCU), Auxiliary Control Unit (ACU), and Remote Control Unit (RCU).

Q. Deadband: A temperature range over which no heating or cooling is supplied, i.e., 22-25 degrees C (72-78 degrees F), as opposed to a single point change over or overlap).

R. Device: a control system component that contains a BACnet Device Object and uses BACnet to communicate with other devices.

S. Device Object: Every BACnet device requires one Device Object, whose properties represent the network visible properties of that device. Every Device Object requires a unique Object Identifier number on the BACnet internetwork. This number is often referred to as the device instance.

T. Device Profile: A specific group of services describing BACnet capabilities of a device, as defined in ASHRAE Standard 135-2008, Annex L. Standard device profiles include BACnet Operator Workstations (B-OWS), BACnet Building Controllers (B-BC), BACnet Advanced Application Controllers (B-AAC), BACnet Application Specific Controllers (B-ASC), BACnet Smart Actuator (B-SA), and BACnet Smart Sensor (B-SS). Each device used in new construction is required to have a PICS statement listing which service and BIBBs are supported by the device.

U. Diagnostic Program: A software test program, which is used to detect and report system or peripheral malfunctions and failures. Generally, this system is performed at the initial startup of the system.

V. Direct Digital Control (DDC): Microprocessor based control including Analog/Digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices in order to achieve a set of predefined conditions.

W. Distributed Control System: A system in which the processing of system data is decentralized and control decisions can and are made at the subsystem level. System operational programs and information are provided to the remote subsystems and status is reported back to the Engineering Control Center. Upon the loss of communication with the Engineering Control center, the subsystems shall be capable of operating in a stand-alone mode using the last best available data.

X. Download: The electronic transfer of programs and data files from a central computer or operation workstation with secondary memory devices to remote computers in a network (distributed) system.

Y. DXF: An AutoCAD 2-D graphics file format. Many CAD systems import and export the DXF format for graphics interchange.

Z. Electrical Control: A control circuit that operates on line or low voltage and uses a mechanical means, such as a temperature sensitive bimetal or bellows, to perform control functions, such as actuating a switch or positioning a potentiometer.

AA. Electronic Control: A control circuit that operates on low voltage and uses a solid-state components to amplify input signals and perform control functions, such as operating a relay or providing an output signal to position an actuator.

BB. Engineering Control Center (ECC): The centralized control point for the intelligent control network. The ECC comprises of personal computer and connected devices to form a single workstation.

CC. Ethernet: A trademark for a system for exchanging messages between computers on a local area network using coaxial, fiber optic, or twisted-pair cables.

DD. Firmware: Firmware is software programmed into read only memory (ROM) chips. Software may not be changed without physically altering the chip.

EE. Gateway: Communication hardware connecting two or more different protocols. It translates one protocol into equivalent concepts for the other protocol. In BACnet applications, a gateway has BACnet on one side and non-BACnet (usually proprietary) protocols on the other side.

FF. GIF: Abbreviation of Graphic interchange format.

GG. Graphic Program (GP): Program used to produce images of air handler systems, fans, chillers, pumps, and building spaces. These images can be animated and/or color-coded to indicate operation of the equipment.

HH. Graphic Sequence of Operation: It is a graphical representation of the sequence of operation, showing all inputs and output logical blocks.

II. I/O Unit: The section of a digital control system through which information is received and transmitted. I/O refers to analog input (AI, digital input (DI), analog output (AO) and digital output (DO). Analog signals are continuous and represent temperature, pressure, flow rate etc, whereas digital signals convert electronic signals to digital

pulses (values), represent motor status, filter status, on-off equipment etc.

JJ. I/P: a method for conveying and routing packets of information over LAN paths. User Datagram Protocol (UDP) conveys information to "sockets" without confirmation of receipt. Transmission Control Protocol (TCP) establishes "sessions", which have end-to-end confirmation and guaranteed sequence of delivery.Z. I/P: Internet Protocol-global network, connecting workstations and other host computers, servers etc. to share the information.

KK. JPEG: A standardized image compression mechanism stands for Joint Photographic Experts Group, the original name of the committee that wrote the standard.

LL. Local Area Network (LAN): A communication bus that interconnects operator workstation and digital controllers for peer-to-peer communications, sharing resources and exchanging information.

MM. Network: A set of computers or other digital devices communicating with each other over a medium such as wire, coax, fiber optics cable etc.

NN. Network Area Controller: Digital controller, supports a family of auxiliary control units and unitary control units, and communicates with peer-to-peer network for transmission of global data.

OO. Network Repeater: A device that receives data packet from one network and rebroadcasts to another network. No routing information is added to the protocol.

PP. Native BACnet Device: A device that uses BACnet as its primary method of communication with other BACnet devices without intermediary gateways. A system that uses native BACnet devices at all levels is a native BACnet system.

QQ. Network Number: A site-specific number assigned to each network segment to identify for routing. This network number must be unique throughout the BACnet internetwork.

RR. Object: The concept of organizing BACnet information into standard components with various associated properties. Examples include analog input objects and binary output objects.

SS. Object Identifier: An object property used to identify the object, including object type and instance. Object Identifiers must be unique within a device.

TT. Object Properties: Attributes of an object. Examples include present value and high limit properties of an analog input object. Properties

are defined in ASHRAE 135; some are optional and some are required. Objects are controlled by reading from and writing to object properties.

UU. Operating system (OS): Software, which controls the execution of computer application programs.

VV. PCX: File type for an image file. When photographs are scanned onto a personal computer they can be saved as PCX files and viewed or changed by a special application program as Photo Shop.

WW. Peripheral: Different components that make the control system function as one unit. Peripherals include monitor, printer, and I/O unit.

XX. Peer-to-Peer: A networking architecture that treats all network stations as equal partners. Any device can initiate and respond to communication with other devices.

YY. PICS: Protocol Implementation Conformance Statement describing the BACnet capabilities of a device. All BACnet devices have published PICS.

ZZ. PID: Proportional, integral, and derivative control, used to control modulating equipment to maintain a setpoint.

AAA. Repeater: A network component that connects two or more physical segments at the physical layer.

BBB. Router: a component that joins together two or more networks using different LAN technologies. Examples include joining a BACnet Ethernet LAN to a BACnet MS/TP LAN.

CCC. Sensors: devices measuring state points or flows, which are then transmitted back to the DDC system.

DDD. Thermostats: devices measuring temperatures, which are used in control of standalone or unitary systems and equipment not attached to the DDC system.

EEE. UCU: Unitary Control Unit, digital controller, dedicated to a specific piece of equipment, such as VAV boxes, heat exchangers etc.

1.4 QUALITY ASSURANCE

A. Criteria:

1. The Controls and Instrumentation System Contractor shall be a primary equipment manufacturer-owned branch office or a fully trained manufacturer representative that is regularly engaged in the engineering, programming, installation and service of total integrated Facility Management Systems of similar size, scope and complexity to the EEC specified in this Contract for no less than 10 years. A resume of past projects, including contracted dollar

amounts and owner/end-user contact information shall be submitted upon request.

2. Single Source Responsibility of subcontractor: The Contractor shall obtain hardware and software supplied under this Section and delegates the responsibility to a single source controls installation subcontractor. The controls subcontractor shall be responsible for the complete design, installation, and testing of the system. The controls subcontractor shall be in the business of design, installation and service of such building automation control systems similar in size and complexity.
3. Equipment and Materials: Equipment and materials shall be cataloged products of manufacturers regularly engaged in production and installation of HVAC control systems. Products shall be manufacturer’s latest standard design and have been tested and proven in actual use.
4. The controls subcontractor shall provide a list of no less than five similar projects which have building control systems as specified in this Section. These projects must be on-line and functional such that the Department of Veterans Affairs, COR would observe the control systems in full operation.
5. The controls subcontractor shall have in-place facility within 50 miles with technical staff, spare parts inventory for the next five (5) years, trained and experience with BACNET DDC systems and necessary test and diagnostic equipment to support the control systems.
6. The controls subcontractor shall have (minimum of three years) experience in design and installation of building automation systems similar in performance to those specified in this Section. Provide evidence of experience by submitting resumes of the project manager, the local branch manager, COR, the application engineering staff, and the electronic technicians who would be involved with the supervision, the engineering, and the installation of the control systems. Training and experience of these personnel shall not be less than three years. Failure to disclose this information will be a ground for disqualification of the supplier.
7. Provide a competent and experienced Project Manager employed by the Controls Contractor. The Project Manager shall be supported as necessary by other Contractor employees in order to provide

professional engineering, technical and management service for the work. The Project Manager shall attend scheduled Project Meetings as required and shall be empowered to make technical, scheduling and related decisions on behalf of the Controls Contractor.

B. Codes and Standards:
   1. All work shall conform to the applicable Codes and Standards.
   2. Electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference, and be so labeled.
   3. Peer-to-peer controllers, unitary controllers shall conform to the requirements of UL 916, Category PAZX.

1.5 PERFORMANCE

A. The system shall conform to the following:
   1. Graphic Display: The system shall display up to four (4) graphics on a single screen with a minimum of twenty (20) dynamic points per graphic. All current data shall be displayed within ten (10) seconds of the request.
   2. Graphic Refresh: The system shall update all dynamic points with current data within eight (8) seconds. Data refresh shall be automatic, without operator intervention.
   3. Object Command: The maximum time between the command of a binary object by the operator and the reaction by the device shall be two (2) seconds. Analog objects shall start to adjust within 3 seconds.
   4. Object Scan: All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or work-station will be current, within the prior six (6) seconds.
   5. Alarm Response Time: The maximum time from when an object goes into alarm to when it is annunciated at the workstation shall not exceed (10) seconds.
   6. Program Execution Frequency: Custom and standard applications shall be capable of running as often as once every (5) seconds. The Contractor shall be responsible for selecting execution times consistent with the mechanical process under control.
   7. Multiple Alarm Annunciations: All workstations on the network shall receive alarms within five (5) seconds of each other.
   8. Performance: Programmable Controllers shall be able to execute DDC PID control loops at a selectable frequency from at least once every

one (1) second. The controller shall scan and update the process value and output generated by this calculation at this same frequency.

9. Multiple Alarm Annunciations: All workstations on the network shall receive alarms within (5) seconds of each other.
10. Reporting Accuracy: Listed below are minimum acceptable reporting end-to-end accuracies for all values reported by the specified system:

Measured Variable	**Reported Accuracy**
Space temperature	±0.5°C (±1°F)
Space temperature	±0.5 degrees C (±1 degrees F)
Ducted air temperature	±0.5°C [±1°F]
Ducted air temperature	±1.0 degrees C [±2 degrees F]
Outdoor air temperature	±1.0°C [±2°F]
Dew Point	±1.5°C [±3°F]
Outdoor air temperature	±1.0 degrees C [±2 degrees F]
Water temperature	±0.5 degrees C [±1 degrees F]
Water flow	±1% of reading
Relative humidity	±2 percent RH
Air flow (terminal)	±10 percent of reading
Air flow (measuring stations)	±5% of reading
Air pressure (ducts)	±25 Pa [±0.1"w.c.]
Water pressure	±2% of full scale *Note 1
Electrical Power	5 percent of reading

Note 1: for both absolute and differential pressure

11. Control stability and accuracy: Control sequences shall maintain measured variable at setpoint within the following tolerances:

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in. w.g.)	0-1.5 kPa (0-6 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±1.0°C (±2.0°F)	
Duct Temperature	±1.5°C (±3°F)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi)	0-1 MPa (1-150 psi)

12. Extent of direct digital control: control design shall allow for at least the points indicated on the points lists on the drawings.

1.6 WARRANTY

A. Labor, software programming and material for control systems shall be warranted as specified under Warranty in FAR clause 52.246-21. However, the warranty period shall be for three years.

B. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no cost or reduction in service to the owner. The system includes all computer equipment, transmission equipment, and all sensors, programming and control devices.

C. The on-line support service shall allow the Controls supplier to connect to the VA BAS Intranet to monitor and control the facility's building automation system. This remote connection to the facility shall be within two (2) hours of the time that the problem is reported. This coverage shall be extended to include normal business hours, after business hours, weekend and holidays. If the problem cannot be resolved with on-line support services, the Controls supplier shall dispatch the qualified personnel to the job site to resolve the problem within 24 hours after the problem is reported.

D. Controls and Instrumentation subcontractor shall be responsible for temporary operations and maintenance of the control systems during the construction period until final testing, training of facility operators and acceptance of the project by VA.

1.7 SUBMITTALS

A. Submit shop drawings in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.

B. Manufacturer's literature and data for all components including the following:

1. A wiring diagram for each type of input device and output device including DDC controllers, modems, repeaters. Diagram shall show how the device is wired and powered, showing typical connections at the digital controllers and each power supply, as well as the device itself. Show for all field connected devices, including control relays, motor starters, electric or electronic actuators, and temperature pressure, flow and humidity sensors and transmitters.
2. Provide a single-line diagram of all DDC related equipment including communications protocol, type of wire, type of devices and location.
3. A diagram of each terminal strip, including digital controller terminal strips, terminal strip location, termination numbers and the associated point names.
4. Control dampers and control valves schedule, including the size and pressure drop.
5. Installation instructions for smoke dampers and combination smoke/fire dampers, if furnished.
6. Catalog cut sheets of all equipment used. This includes software (by manufacturer and by third parties), DDC controllers, panels, peripherals, airflow measuring stations and associated components, and auxiliary control devices such as sensors, actuators, and control dampers. When manufacturer's cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted. Each submitted piece of literature and drawings should clearly reference the specification and/or drawings that it supposed to represent.
7. Sequence of operations for each HVAC system and the associated control diagrams. Equipment and control labels shall correspond to those shown on the drawings.
8. Color prints of proposed graphics with a list of points for display.
9. Furnish a BACnet Protocol Implementation Conformance Statement (PICS) for each BACnet-compliant device.
10. Schematic wiring diagrams for all control, communication and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with computer manufacturers' model numbers and functions. Show all interface wiring to the control system.

11. An instrumentation list for each controlled system. Each element of the controlled system shall be listed in table format. The table shall show element name, type of device, manufacturer, model number, and product data sheet number.
12. Riser diagrams of wiring between central control unit and all control panels.
13. Scaled plan drawings showing routing of LAN and locations of control panels, controllers, routers, gateways, ECC, and larger controlled devices.
14. Construction details for all installed conduit, cabling, raceway, cabinets, and similar. Construction details of all penetrations and their protection.
15. Quantities of submitted items may be reviewed but are the responsibility of the contractor administered by this Section of the technical specifications.
16. Furnish PICS for each BACNET compliant device.

C. Product Certificates: Compliance with Article, QUALITY ASSURANCE.

D. Licenses: Provide licenses for all software residing on and used by the Controls Systems and transfer these licenses to the Owner prior to completion.

E. As Built Control Drawings:
   1. Furnish three (3) copies of as-built drawings for each control system. The documents shall be submitted for approval prior to final completion.
   2. Furnish one (1) stick set of applicable control system prints for each mechanical system for wall mounting. The documents shall be submitted for approval prior to final completion.
   3. Furnish one (1) CD-ROM in CAD DWG and/or .DXF format for the drawings noted in subparagraphs above.

F. Operation and Maintenance (O/M) Manuals):
   1. Submit in accordance with Article, INSTRUCTIONS, in Specification Section 01 00 00, GENERAL REQUIREMENTS.
   2. Include the following documentation:
      a. General description and specifications for all components, including logging on/off, alarm handling, producing trend reports, overriding computer control, and changing set points and other variables.

b. Detailed illustrations of all the control systems specified for ease of maintenance and repair/replacement procedures, and complete calibration procedures.
c. One copy of the final version of all software provided including operating systems, programming language, operator workstation software, and graphics software.
d. Complete troubleshooting procedures and guidelines for all systems.
e. Complete operating instructions for all systems.
f. Recommended preventive maintenance procedures for all system components including a schedule of tasks for inspection, cleaning and calibration. Provide a list of recommended spare parts needed to minimize downtime.
g. Licenses, guaranty, and other pertaining documents for all equipment and systems.
h. Training Manuals: Submit the course outline and training material to the Owner for approval three (3) weeks prior to the training to VA facility personnel. These persons will be responsible for maintaining and the operation of the control systems, including programming. The Owner reserves the right to modify any or all of the course outline and training material.

G. Licenses, guaranty, and other pertaining documents for all equipment and systems. Submit Performance Report to COR prior to final inspection.
H. Submit a complete Points Listing of all new devices, sensors, controllers, etc with the Project Close Out Documents.

1.8 INSTRUCTIONS

A. Instructions to VA operations personnel: Perform in accordance with Article, INSTRUCTIONS, in Specification Section 01 00 00, GENERAL REQUIREMENTS, and as noted below. Contractor shall also video tape instruction sessions noted below.

1. First Phase: Formal instructions to the VA facilities personnel for a total of **40 hours** of hands-on DDC Training, conducted sometime between the completed installation and prior to the performance test period of the control system, at a time mutually agreeable to the Contractor and the VA. Training shall include:
   A. Explanation of drawings, operations and maintenance manuals.
   B. Walk-through of the job to locate control components.

C. Operator workstation and peripherals.

D. DDC controller and ASC operation/function.

E. Operator control functions including graphic generation and field panel programming.

F. Hands on removal, troubleshooting and replacement of select controls related equipment. For example, Hot Water valve actuators, air damper controls, thermostat replacement.

G. Operation of portable operator's terminal.

H. Explanation of adjustment, calibration and replacement procedures.

I. Student binder with training modules.

2. Second Phase: This phase of training shall comprise of on the job training during start-up, checkout period, and performance test period. VA facilities personnel will work with the Contractor's installation and test personnel on a daily basis during start-up and checkout period. During the performance test period, controls subcontractor will provide **40 hours** of instructions, given in multiple training sessions (each no longer than four hours in length), to the VA facilities personnel.

3. The O/M Manuals shall contain approved submittals as outlined in Article 1.7, SUBMITTALS. The Controls subcontractor will review the manual contents with VA facilities personnel during second phase of training.

4. Factory Training consisting of **40 hours** of Manufacturer Training at their site for two Veterans Administration HVAC Technicians.

1.9 PROJECT CONDITIONS (ENVIRONMENTAL CONDITIONS OF OPERATION)

A. The ECC and peripheral devices and system support equipment shall be designed to operate in ambient condition of 20 to 35 degrees C (65 to 90 degrees F) at a relative humidity of 20 to 80 percent non-condensing.

B. The CUs and associated equipment used in controlled environment shall be mounted in NEMA 1 enclosures for operation at 0 to 50 degrees C (32 to 122 degrees F) at a relative humidity of 10 to 90 percent non-condensing.

C. The CUs used outdoors shall be mounted in NEMA 4 waterproof enclosures, and shall be rated for operation at –40 to 65 degrees C (-40 to 150 degrees F).

D. All electronic equipment shall operate properly with power fluctuations of plus 10 percent to minus 15 percent of nominal supply voltage.

E. Sensors and controlling devices shall be designed to operate in the environment, which they are sensing or controlling.

1.10 APPLICABLE PUBLICATIONS

A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.

B. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):
Standard 135-10.....BACNET Building Automation and Control Networks

C. American Society of Mechanical Engineers (ASME):
B16.18-01.....Cast Copper Alloy Solder Joint Pressure Fittings.
B16.22-01.....Wrought Copper and Copper Alloy Solder Joint Pressure Fittings.
BPVC-CC-N-04.....Boiler and Pressure Vessel Code

D. American Society of Testing Materials (ASTM):
B32-08.....Standard Specification for Solder Metal
B88-09.....Standard Specifications for Seamless Copper Water Tube
B88M-09.....Standard Specification for Seamless Copper Water Tube (Metric)
B280-08.....Standard Specification for Seamless Copper Tube for Air-Conditioning and Refrigeration Field Service
D2737-03.....Standard Specification for Polyethylene (PE) Plastic Tubing

E. Federal Communication Commission (FCC):
Rules and Regulations Title 47 Chapter 1-2001 Part 15.Radio Frequency Devices.

F. Institute of Electrical and Electronic Engineers (IEEE):
802.3-11.....Information Technology-Telecommunications and Information Exchange between Systems-Local and Metropolitan Area Networks- Specific Requirements-Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access method and Physical Layer Specifications

G. Instrument Society of America (ISA):
7.0.01-1996.....Quality Standard for Instrument Air

H. National Fire Protection Association (NFPA):

70-11.....National Electric Code

90A-09.....Standard for Installation of Air-Conditioning and Ventilation Systems

I. Underwriter Laboratories Inc (UL):

94-10.....Tests for Flammability of Plastic Materials for Parts and Devices and Appliances

294-10.....Access Control System Units

486A/486B-10.....Wire Connectors

555S-11.....Standard for Smoke Dampers

916-10.....Energy Management Equipment

PART 2 – PRODUCTS

2.1 MATERIALS

A. Use new products that the manufacturer is currently manufacturing and that have been installed in a minimum of 25 installations. Spare parts shall be available for at least five years after completion of this contract.

2.2 CONTROLS SYSTEM ARCHITECTURE

A. General

1. The Controls Systems shall consist of multiple Nodes and associated equipment connected by industry standard digital and communication network arrangements.
2. The Servers and principal communications network computer equipment shall be standard products of recognized major manufacturers available through normal PC and computer vendor channels – not "Clones" assembled by a third-party subcontractor.
3. Provide licenses for all software residing on and used by the Controls Systems and transfer these licenses to the Owner prior to completion.
4. The networks shall, at minimum, comprise, as necessary, the following:
   a. A fixed ECC and a portable DDC Interface device. Device shall be a specialized PC setup for direct interface to the DDC system of DDC panels throughout the Medical Center.
   b. Network computer processing, data storage and BACnet-compliant communication equipment including Servers and digital data processors.

c. BACnet-compliant routers, bridges, switches, hubs, modems, gateways, interfaces and similar like communication equipment.
d. Active processing BACnet-compliant building controllers connected to other BACNet-compliant programmable field panels and controllers together with their power supplies and associated equipment.
d. Addressable elements, sensors, transducers and end devices.
e. Third-party equipment interfaces and gateways as described and required by the Contract Documents.
f. Other components required for a complete and working Control Systems as specified.

B. The Specifications for the individual elements and component subsystems shall be minimum requirements and shall be augmented as necessary by the Contractor to achieve both compliance with all applicable codes, standards and to meet all requirements of the Contract Documents.

C. Network Architecture
1. The Controls communication Systems Application network shall utilize BACnet an open architecture capable of each and all of the following:
a. Communications protocol operating over astandard Ethernet LAN and operate at a minimum speed of 100 Mb/sec.

D. The networks shall utilize only copper and optical fiber communication media as appropriate and shall comply with applicable codes, ordinances and regulations. They may also utilize digital wireless technologies as appropriate to the application and if approved by the VA.

E. All necessary telephone lines, ISDN lines and internet Service Provider services and connections will be provided by the VA.

F. Third Party Interfaces:
1. The contractor administered by this Section of the technical specifications shall include necessary hardware, equipment, software and programming to allow data communications between the controls systems and building systems supplied by other trades.
2. Other manufacturers and contractors supplying other associated systems and equipment shall provide their necessary hardware, software and start-up at their cost and shall cooperate fully with the contractor administered by this Section of the technical specifications in a timely manner and at their cost to ensure complete functional integration.

E. Servers:
   1. Provide data storage server(s) to archive historical data including trends, alarm and event histories and transaction logs.
   2. Equip these server(s) with the same software tool set that is located in the BACnet building controllers for system configuration and custom logic definition and color graphic configuration.
   3. Access to all information on the data storage server(s) shall be through the same browser functionality used to access individual nodes. When logged onto a server the operator will be able to also interact with any other controller on the control system as required for the functional operation of the controls systems. The contractor administered by this Section of the technical specifications shall provide all necessary digital processor programmable data storage server(s).
   4. These server(s) shall be utilized for controls systems application configuration, for archiving, reporting and trending of data, for operator transaction archiving and reporting, for network information management, for alarm annunciation, for operator interface tasks, for controls application management and similar. These server(s) shall utilize IT industry standard data base platforms which utilize a database declarative language designed for managing data in relational database management systems (RDBMS) such as SQL.

2.3 COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135-2008, BACnet.
B. The Data link / physical layer protocol (for communication) acceptable to the VA throughout its facilities is Ethernet (ISO 8802-3) and MS/TP.
C. Each controller shall have a communication port for connection to an operator interface.
D. Internetwork operator interface and value passing shall be transparent to internetwork architecture.
   1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status,

reports, system software, and custom programs shall be viewable and editable from each internetwork controller.

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

E. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring. Expansion shall not require operator interface hardware additions or software revisions.

F. ECCs and Controllers with real-time clocks shall use the BACnet Time Synchronization service. The system shall automatically synchronize system clocks daily from an operator-designated device via the internetwork. The system shall automatically adjust for daylight savings and standard time as applicable.

2.4 ENGINEERING CONTROL CENTER (ECC) <u>CONTROL CENTER INTERFACE:</u>

1. Provide integration with the existing ECC located in the basement of the Hospital. Workstation shall connect to the Network via BACNET. If required in this project.
2. New DDC Controls to interface with the existing Honeywell or Alerton Networks and be viewable and modifiable via the existing ECC Graphical User Interfaces and Web Graphics.
4. Ethernet, IP Supervisory Network shall connect the BACNET Router to a BACNET HUB located at the Existing Alerton and Honeywell Workstations located in the Basement of the VA Hospital.
5. Provide Custom Images of new Control Systems, fans, pumps, fire pump, booster pumps, heat recovery systems, VAV boxes, venturi air valves and points for the Graphic interface of each system.
6. Software Configuration Tools.
7. Scheduling and Alarm Management software.
8. Network Area Controllers.
9. Unitary Control Units (UCU).
10. Connected I/O devices.
11. Third party system Data Integration.

A. The ECC shall reside on a high-speed network with controllers as shown on system drawings. The ECC and each standard browser connected to server shall be able to access all system information.

B. ECC and controllers shall communicate using BACnet protocol. ECC and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and MS/TP addressing.

C. Hardware: ECC shall conform to the BACnet Advanced Workstation (B-AWS) Profile and shall be BTL-Listed as a B-AWS device.

1. If this project requires a new ECC it shall be a commercial standard with supporting 64-bit hardware (as required by the direct-digital control system software) and software enterprise server. Internet Explorer v.11 or higher, Windows Script Hosting version 5.6 or higher, Windows Message Queuing, Windows Internet Information Services (IIS) v5.0 or higher, minimum 2.8 GHz processor, minimum 8 GB DDR3 SDRAM (minimum 1333 Mhz) memory, 512 MB video card, and 16 speed high density DVD-RW+/- optical drive.
   a. The hard drives shall be at the minimum 1 TB 7200 rpm SATA hard drives setup in a Raid or mirroring configuration with 16 MB cache, and shall have sufficient memory to store:
      1) All required operator workstation software
      2) A DDC database at least twice the size of the delivered system database
      3) One year of trend data based on the points specified to be trended at their specified trend intervals.
   b. Real-time clock:
      1) Accuracy: Plus or minus 1 minute per month.
      2) Time Keeping Format: 24-hour time format including seconds, minutes, hours, date, day, and month; automatic reset by software.
      3) Clock shall function for one year without power.
      4) Provide automatic time correction once every 24 hours by synchronizing clock with the Time Service Department of the U.S. Naval Observatory.
   c. Serial ports: Four USB ports and two RS-232-F serial ports for general use, with additional ports as required. Data transmission rates shall be selectable under program control.
   d. Parallel port: Enhanced.

e. Sound card: For playback and recording of digital WAV sound files associated with audible warning and alarm functions.

f. Color monitor: PC compatible, not less than 24 inches, LED type, with a minimum resolution of 1280 by 1024 pixels, non-interlaced, and a maximum dot pitch of 0.28 mm.

g. Keyboard: Minimum of 64 characters, standard ASCII character set based on ANSI INCITS 154.

h. Mouse: Standard, compatible with installed software.

i. Removable disk storage: Include the following, each with appropriate controller:

1) Minimum 1 TB removable hard disk, maximum average access time of 10 ms.

j. Network interface card (NIC): integrated 10-100-1000 Base-TX Ethernet NIC with an RJ45 connector or a 100Base-FX Ethernet NIC with an SC/ST connector.

2. RS-232 ASCII Interface

a. ASCII interface shall allow RS-232 connections to be made between a meter or circuit monitor operating as the host PC and any equipment that will accept RS-232 ASCII command strings, such as local display panels, dial-up modems, and alarm transmitters.

b. Pager System Interface: Alarms shall be able to activate a pager system with customized message for each input alarm.

c. Alarm System Interface: RS-232 output shall be capable of transmitting alarms from other monitoring and alarm systems to workstation software.

d. RS-232 output shall be capable of connection to a pager interface that can be used to call a paging system or service and send a signal to a portable pager. System shall allow an individual alphanumeric message per alarm input to be sent to paging system. This interface shall support both numeric and alphanumeric pagers.

e. Cables: provide Plenum-Type, RS-232 Cable: Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors, plastic insulation, and individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage; plastic jacket. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned copper drain wire.

1) NFPA 70, Type CMP.

2) Flame Resistance: NFPA 262, Flame Test.

3. Self-contained uninterruptible power supply (UPS):
   a. Size: Provide a minimum of six hours of operation of ECC equipment.
   b. Batteries: Sealed, valve regulated, recombinant, lead calcium.
   c. Accessories:
      1) Transient voltage suppression.
      2) Input-harmonics reduction.
      3) Rectifier/charger.
      4) Battery disconnect device.
      5) Static bypass transfer switch.
      6) Internal maintenance bypass/isolation switch.
      7) External maintenance bypass/isolation switch.
      8) Output isolation transformer.
      9) Remote UPS monitoring.
      10) Battery monitoring.
      11) Remote battery monitoring.

4. ECC Software:

   1. Provide for automatic system database save and restore on the ECC's hard disk a copy of the current database of each Controller. This database shall be updated whenever a change is made in any system panel. In the event of a database loss in a building management panel, the ECC shall automatically restore the database for that panel. This capability may be disabled by the operator.

   2. Provide for manual database save and restore. An operator with proper clearance shall be able to save the database from any system panel. The operator also shall be able to clear a panel database and manually initiate a download of a specified database to any panel in the system.

   3. Provide a method of configuring the system. This shall allow for future system changes or additions by users with proper clearance.

   4. Operating System. Furnish a concurrent multi-tasking operating system. The operating system also shall support the use of other common software applications. Acceptable operating systems are Windows 7/10, Windows Server 2012 or greater.

5. System Graphics. The operator workstation software shall be graphically oriented. The system shall allow display of up to 10 graphic screens at once for comparison and monitoring of system status. Provide a method for the operator to easily move between graphic displays and change the size and location of graphic displays on the screen. The system graphics shall be able to be modified while on-line. An operator with the proper password level shall be able to add, delete, or change dynamic objects on a graphic. Dynamic objects shall include analog and binary values, dynamic text, static text, and animation files. Graphics shall have the ability to show animation by shifting image files based on the status of the object.

6. Custom Graphics. Custom graphic files shall be created with the use of a graphics generation package furnished with the system. The graphics generation package shall be a graphically based system that uses the mouse to create and modify graphics that are saved in industry standard formats such as PCX, TIFF, and GEM. The graphics generation package also shall provide the capability of capturing or converting graphics from other programs such as Designer or AutoCAD.

7. Graphics Library. Furnish a complete library of standard HVAC equipment graphics such as chillers, boilers, air handlers, terminals, fans, and unit ventilators. This library also shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. The library shall be furnished in a file format compatible with the graphics generation package program.

8. The Controls Systems Operator Interfaces shall be user friendly, readily understood and shall make maximum use of colors, graphics, icons, embedded images, animation, text based information and data visualization techniques to enhance and simplify the use and understanding of the displays by authorized users at the ECC. The operating system shall be Windows 7 or better, and shall support the third party software.

9. Provide graphical user software, which shall minimize the use of keyboard through the use of the mouse and "point and click" approach to menu selection.

10. The software shall provide a multi-tasking type environment that will allow the user to run several applications simultaneously. The mouse or Alt-Tab keys shall be used to quickly select and switch between multiple applications. The operator shall be able automatically export data to and work in Microsoft Word, Excel, and other Windows based software programs, while concurrently on-line system alarms and monitoring information.

11. On-Line Help. Provide a context-sensitive, on-line help system to assist the operator in operating and editing the system. On-line help shall be available for all applications and shall provide the relevant data for that particular screen. Additional help information shall be available through the use of hypertext.

12. User access shall be protected by a flexible and Owner re-definable software-based password access protection. Password protection shall be multi-level and partition able to accommodate the varied access requirements of the different user groups to which individual users may be assigned. Provide the means to define unique access privileges for each individual authorized user. Provide the means to on-line manage password access control under the control of a project specific Master Password. Provide an audit trail of all user activity on the Controls Systems including all actions and changes.

13. The system shall be completely field-programmable from the common operator’s keyboard thus allowing hard disk storage of all data automatically. All programs for the CUs shall be able to be downloaded from the hard disk. The software shall provide the following functionality as a minimum:

a. Point database editing, storage and downloading of controller databases.

b. Scheduling and override of building environmental control systems.

c. Collection and analysis of historical data.

d. Alarm reporting, routing, messaging, and acknowledgement.

e. Definition and construction of dynamic color graphic displays.

f. Real-time graphical viewing and control of environment.

g. Scheduling trend reports.

h. Program editing.

i. Operating activity log and system security.

j. Transfer data to third party software.

14. Provide functionality such that using the least amount of steps to initiate the desired event may perform any of the following simultaneously:

a. Dynamic color graphics and graphic control.

b. Alarm management.

c. Event scheduling.

d. Dynamic trend definition and presentation.

e. Program and database editing.

f. Each operator shall be required to log on to the system with a user name and password to view, edit or delete the data. System security shall be selectable for each operator, and the password shall be able to restrict the operator's access for viewing and changing the system programs. Each operator shall automatically be logged off the system if no keyboard or mouse activity is detected for a selected time.

15. Graphic Displays:

a. The workstation shall allow the operator to access various system schematics and floor plans via a graphical penetration scheme, menu selection, or text based commands. Graphic software shall permit the importing of AutoCAD or scanned pictures in the industry standard format (such as PCX, BMP, GIF, and JPEG) for use in the system.

b. System Graphics shall be project specific and schematically correct for each system. (ie: coils, fans, dampers located per equipment supplied with project.) Standard system graphics that do not match equipment or system configurations are not acceptable. Operator shall have capability to manually operate the entire system from each graphic screen at the ECC. Each system graphic shall include a button/tab to a display of the applicable sequence of operation.

c. Dynamic temperature values, humidity values, flow rates, and status indication shall be shown in their locations and shall automatically update to represent current conditions without operator intervention and without pre-defined screen refresh values.

d. Color shall be used to indicate status and change in status of the equipment. The state colors shall be user definable.

e. A clipart library of HVAC equipment, such as chillers, boilers, air handling units, fans, terminal units, pumps, coils, standard ductwork, piping, valves and laboratory symbols shall be provided in the system. The operator shall have the ability to add custom symbols to the clipart library.

f. A dynamic display of the site-specific architecture showing status of the controllers, the ECC and network shall be provided.

g. The windowing environment of the workstation shall allow the user to simultaneously view several applications at a time to analyze total building operation or to allow the display of graphic associated with an alarm to be viewed without interrupting work in progress. The graphic system software shall also have the capability to split screen, half portion of the screen with graphical representation and the other half with sequence of operation of the same HVAC system.

16. Graphical Engineering Tools

A. Operator’s workstation software shall include graphical engineering tools for programming all controllers supplied. All controllers shall be programmed using graphical tools that allow the user to connect function blocks on screen that provide sequencing of all control logic. Function blocks shall be represented by graphical displays that are easily identified and distinct from other types of blocks. Graphical programming that uses simple rectangles and squares is not acceptable.

B. User shall be able to select a graphical function block from menu and place on screen. Provide zoom in and

zoom out capabilities. Function blocks shall be downloaded to controller without any reentry of data.

C. Programming tools shall include a real-time operation mode. Function blocks shall display real-time data and be animated to show status of data inputs and outputs when in real-time operation. Animation shall show change of status on logic devices and countdown of timer devices in graphical format.

D. Graphical engineering tools shall also include a database manager of applications that include logic files for controllers and associated graphics. Operator shall be able to select unit type, input/output configuration and other items that define unit to be controlled. Supply minimum of 200 applications as part of workstation software. Applications to include:

- AHU's with 100% OA or Return Air with following options:
  - 1/3 & 2/3 or single Steam Pre-heat valve,
  - Unoccupied modes for reduced static pressure (or flow) and DAT setback or off,
  - Reset of DAT,
  - Reset of Static Pressure,
  - Reset based on Terminal Units,
  - Humidification and Dehumidification,
  - Economizer based on enthalpy
- Air-to-Air Heat Exchangers,
- VAV with zero flow during unoccupied mode or with 50% (adj.) flow during unoccupied mode,
- VAV with option for Standby mode, with Occupancy sensor override and Boost mode for Conference/Class rooms,
- Fan Coil Units, with unoccupied modes and sensing hot or cold water modes

E. Graphical engineering tool shall include Device Manager for detection of devices connected anywhere on the BACnet network by scanning of the entire network. This function shall display device instance, network identification, model number, and description of connected

devices. It shall record and display software file loaded into each controller. A copy of each file shall be stored on the computer's hard drive. If needed, this file shall be downloaded to the appropriate controller using the mouse.

F. System shall automatically notify the user when a device that is not in the database is added to the network.

G. System shall include backup/restore function that will back up entire system to selected medium and then restore system from that media. The system shall be capable of creating a backup for the purpose of instantiating a new client PC.

H. The system shall provide a means to scan, detect, interrogate, and edit third-party BACnet devices and BACnet objects within those devices."

16. Trend reports shall be generated on demand or pre-defined schedule and directed to monitor display, printers or disk. As a minimum, the system shall allow the operator to easily obtain the following types of reports:

a. A general list of all selected points in the network.
b. List of all points in the alarm.
c. List of all points in the override status.
d. List of all disabled points.
e. List of all points currently locked out.
f. List of user accounts and password access levels.
g. List of weekly schedules.
h. List of holiday programming.
i. List of limits and dead bands.
j. Custom reports.
k. System diagnostic reports, including, list of digital controllers on the network.

17. List of programs

Scheduling and Override:

a. Provide override access through menu selection from the graphical interface and through a function key.
b. Connecting via BACNET with ANSI/ASHRAE Standard 135.

18. The networks shall utilize only copper and optical fiber communication media as appropriate and shall comply with applicable codes, ordinances and regulations.
19. All necessary Internet Service Provider services and connections will be provided by the owner.
20. The Controls Contractor shall provide the IT interfacing equipment and shall coordinate on configuration and interfacing arrangements with the Data Cabling System contractor. The Controls Contractor shall coordinate IT equipment interfacing with the Data Cabling Systems contractor. This IT equipment shall be provided by the Data Cabling systems contractor directly at that contractor's cost. The Controls Contractor shall provide all IT interfacing equipment and cabling to a detail coordinated with the Owner.
21. Collection and Analysis of Historical Data:
    1. Provide trending capabilities that will allow the operator to monitor and store records of system activity over an extended period of time. Points may be trended automatically on time based intervals or change of value, both of which shall be user definable. The trend interval could be one (1) minute to 120 hours. Trend data may be stored on hard disk for future diagnostic and reporting. Additionally trend data may be archived to network drives or removable disk media for off-site retrieval.
    2. Reports may be customized to include individual points or predefined groups of at least six points. Provide additional functionality to allow pre-defined groups of up to 250 trended points to be easily accessible by other industry standard word processing and spreadsheet packages. The reports shall be time and date stamped and shall contain a report title and the name of the facility.
    3. System server shall be capable of periodically producing reports of trendlogs, alarm history, tenant activities, device summary, energy logs, and override points. The frequency, content, and delivery are to be user adjustable.
    4. All reports shall be capable of being delivered in multiple formats including text- and comma-separated value

(CSV) files. The files can be printed, emailed, or saved to a folder, either on the server hard drive or on any network drive location

5. System shall have the set up to generate spreadsheet reports to track energy usage and cost based on weekly or monthly interval, equipment run times, equipment efficiency, and/or building environmental conditions.

6. Provide additional functionality that will allow the operator to view real time trend data on trend graph displays. A minimum of 20 points may be graphed regardless of whether they have been predefined for trending. In addition, the user may pause the graph and take snapshots of the screens to be stored on the workstation disk for future reference and trend analysis. Exact point values may be viewed and the graph may be printed. Operator shall be able to command points directly on the trend plot by double clicking on the point.

22. Alarm Management:

1. Alarm routing shall allow the operator to send alarm notification to selected printers or operator workstation based on time of day, alarm severity, or point type.

2. Alarm notification shall be provided via two alarm icons, to distinguish between routine, maintenance type alarms and critical alarms. The critical alarms shall display on the screen at the time of its occurrence, while others shall display by clicking on their icon.

3. Alarm display shall list the alarms with highest priority at the top of the display. The alarm display shall provide selector buttons for display of the associated point graphic and message in English language. The operator shall be able to sort out the alarms.

4. Alarm messages shall be customized for each point to display detailed instructions to the operator regarding actions to take in the event of an alarm.

5. An operator with proper security level access may acknowledge and clear the alarm. All that have not been cleared shall be archived at workstation disk.

23. Clock Synchronization:
    The system shall be able to automatically synchronize all system clocks from any operator-designated device in the system, and shall adjust for daylight savings and standard time, if applicable. In the event of a power failure, all clocks shall be adjusted on the command of an operator if the power outage is extended beyond 72 hours.
24. Remote Communications:
    The system shall have the ability to dial out in the event of an alarm. Receivers shall include operator workstations, e-mail addresses, and alpha-numeric pagers. The alarm message shall include the name of the calling location, the device that generated the alarm, and the alarm message itself.
25. System Configuration:
    1. Network control strategies shall not be restricted to a single digital controller, but shall be able to include data from all other network devices to allow the development of global control strategies.
    2. Provide automatic backup and restore of all digital controller databases on the workstation hard disk. In addition to all backup data, all databases shall be performed while the workstation is on-line without disturbing other system operations.

D. Third Party Interfaces:
   1. The Controls Systems shall include necessary hardware, equipment and software to allow data communications between the Controls Systems and building systems supplied by other trades.
   2. The other manufacturers and contractors supplying other associated systems and equipment will provide their necessary hardware, software and start-up at their cost and will cooperate fully with the Controls Contractor in a timely manner and at their cost to ensure complete functional integration.

2.5 DIRECT DIGITAL CONTROLLERS

A. (NAC) Network Area Controllers shall be stand-alone, multi-tasking, multi-user, real-time digital processor complete with all hardware, software, and communications interfaces, power supplies. The Controls System shall be designed and implemented entirely for use and operation

on the Internet. NACs shall have access to data within the industry standard IT network to the Data Server and other NACs as needed to accomplish required global control strategies.

1. NACs shall provide both standalone and networked direct digital control of mechanical and electrical building system controllers as required by the Specifications. The primary NAC shall support a minimum of [5,000] field points together with all associated features, sequences, schedules, applications required for a fully functional distributed processing operation.
2. NACs shall monitor and report communication status to the Controls Systems Application. The Controls Systems shall provide a system advisory upon communication failure and restoration.
3. All NACs on the network shall be equipped with all software functionality necessary to operate the complete user interface, including graphics, via a Browser connected to the Node on the network or directly via a local port on the NAC.
4. All NAC shall be provided with face mounted LED type annunciation to continually display its operational mode, power and communications.
5. The controllers shall reside on the BACnet Ethernet (ISO 8802-3) local area network and provide Read (Initiate) and Write (Execute) services as defined in Clauses 15.5 and 15.8, respectively of ASHRAE Standard 135, to communicate BACnet objects. Objects supported shall include: Analog input, analog output, analog value, binary input, binary output, binary value, and device.
6. Each NAC shall be provided with the necessary un-interruptible power facilities to ensure its continued normal operation during periods of line power outages of, at minimum, 1-minute duration. Normal functionality shall include all normal software processing, communication with powered field devices and network communications with other powered Controls Systems NAC, Data Servers and OWS. Each NAC shall report its communication status to the Application. The Application shall provide a system advisory upon communication failure and restoration. Each NAC shall retain program, control algorithms, and setpoint information in non-volatile memory in the event of a power failure, and shall return to normal operation upon restoration of power.
7. Each NAC shall have sufficient memory to support its operating system, database, and program requirements, including the following:

a. Device and network management.
b. Data sharing.
c. Alarm and event management including custom alarm messages for each level alarm for the points noted in the I/O Schedule.
d. Energy management.
e. Historical trend data for points specified.
f. Maintenance report.
g. Scheduling.
h. Dial up and network communications.
i. Manual override monitoring.

8. Each NAC shall support firmware upgrades without the need to replace hardware and shall have a minimum of 15 percent spare capacity of secondary system controllers, point capacity and programming functions.
9. Each NAC shall continuously perform self-diagnostics, communication diagnosis, and provide both local and remote annunciation of any detected component failures, low battery condition; and upon failure shall assume the predetermined failure mode.
10. Each NAC shall monitor the status of all overrides and inform the operator that automatic control has inhibited, and allow the operator to manually override automatic or centrally executed command.
11. Provide the capability to generate and modify the Controls Systems Application software-based sequences, database elements, associated operational definition information and user-required revisions to same at any designated Workstation together with the means to download same to the associated System Controllers.
12. In the event of loss of normal power, there shall be orderly shut down of the controllers to prevent the loss of database or software programming. When power is restored flash memory, battery backup or super capacitor will be automatically loaded into non-volatile flash memory and shall be incorporated for all programming data.
13. Building controllers shall include complete energy management software, including scheduling building control strategies with optimum start and logging routines. All energy management software and firmware shall be resident in field hardware and shall not be dependent on the operator’s terminal. Operator’s terminal software is to be used for access to field-based energy management functions

only. Provide zone-by-zone direct digital logic control of space temperature, scheduling, runtime accumulation, equipment alarm reporting, and override timers for after-hours usage.

B. All application controllers for every terminal unit (VAV, HP, UV, etc.) air handler, all central plant equipment, and any other piece of controlled equipment shall be fully programmable. Application controllers shall be mounted next to controlled equipment and communicate with building controller through BACnet LAN.

C. Auxiliary Control Units (ACUs) shall be stand-alone, multi-tasking, multi-user, real time digital processor complete with all hardware, software and communication interfaces, power supplies, and input/output modular devices.

1. All ACUs shall be provided with LED type annunciation to continually display its operational mode, power and communications.
2. Each ACU shall have sufficient memory to support its operating system, database including the following:
   a. Data sharing.
   b. Device and network management.
   c. Alarm and event management.
   d. Scheduling.
   e. Energy Management.
3. Each ACU shall support firmware upgrades without the need to replace hardware and shall have a minimum of 15 percent spare capacity of I/O functions. The type of spares shall be in the same proportion as the implemented functions on the controller, but in no case there shall be less than one point of each implemented I/O type.
4. Each ACU shall continuously perform self-diagnostics, communication diagnosis, and provide both local and remote annunciation of any detected component failures, low battery condition; and upon failure shall assume the predetermined failure mode.
5. In the event of loss of normal power, there shall be orderly shut down of the controllers to prevent the loss of database or software programming. When power is restored flash memory, battery backup or super capacitor will be automatically loaded into non-volatile flash memory and shall be incorporated for all programming data.

D. Unitary Control Units (UCUs) shall be microprocessor-based. They shall be capable of stand-alone operation, continuing to provide stable control functions if communication is lost with the rest of the system.

1. Each UCU shall have sufficient memory to support its own operating system, including data sharing.
2. All UCUs shall be provided with LED type annunciation to continually display its operational mode, power and communications.
3. In the event of loss of normal power, there shall be orderly shut down of the controllers to prevent the loss of database or software programming. When power is restored flash memory, battery backup or super capacitor will be automatically loaded into non-volatile flash memory and shall be incorporated for all programming data.

E. Provide I/O module that connects sensors and actuators onto the field bus network for use by the direct digital controllers. I/O devices shall support the communication technology specified for each controller.

1. Analog input shall allow the monitoring of low voltage (0-10 VDC), current (4-20 ma), or resistance signals (thermistor, RTD). Analog input shall be compatible with, and field configurable to commonly available sensing devices. Analog output shall provide a modulating signal for these control devices.
2. Binary inputs shall allow the monitoring of on/off signals from remote devices. Binary inputs shall provide a wetting current of at least 12 milliamps to be compatible with commonly available control devices. Binary outputs shall provide on/off operation, or a pulsed low voltage signal for pulse width modulation control. Outputs shall be selectable for either normally open or normally closed operation.
3. Binary outputs on remote and auxiliary controllers shall have 3-position (on/off/auto) override switches and status lights. Analog outputs on remote and auxiliary controllers shall have status lights and a 2-position (auto/manual) switch and manually adjustable potentiometer for manual override.
4. Each output point shall be provided with a light emitting diode (LED) to indicate status of outputs.

F. Communication Ports:

1. NACs controllers in the DDC systems shall be connected in a system local area network using protocol defined by ASHRAE Standard 135, BACnet protocol.
2. The control supplier shall provide connectors, repeaters, hubs, and routers necessary for inter-network communication.

3. Minimum baud rate between the peer-to-peer controllers in the system LAN shall be maintained at the rate of 10 Mbps. Minimum baud for the low level controllers between UCUs and ACUs, ACUs and NAC's shall be maintained at the rate of 76 Kbps.
4. Provide RS-232 port with DB-9 or RJ-11 connector for communication with each controller that will allow direct connection of standard printers, operator terminals, modems, and portable laptop operator's terminal. Controllers shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers or terminals.
5. Database, such as points; status information, reports, system software, custom programs of any one controller shall be readable by any other controller on the network.

G. Electric Outlet: Provide a single phase, 120 VAC emergency electrical receptacles inside or within 2 meters (6 feet) of the NAC and ACU enclosures for use with test equipment.

2.6 DIRECT DIGITAL CONTROLLER SOFTWARE

A. The software programs specified in this section shall be commercially available, concurrent, multi-tasking operating system and support the use of software application that operates under Microsoft Windows.

B. All points shall be identified by up to 30-character point name and 16-character point descriptor. The same names shall be used at the operator workstation.

C. All control functions shall execute within the stand-alone control units via DDC algorithms. The VA shall be able to customize control strategies and sequences of operations defining the appropriate control loop algorithms and choosing the optimum loop parameters.

D. All CU's shall be capable of being programmed to utilize stored default values for assured fail-safe operation of critical processes. Default values shall be invoked upon sensor failure or, if the primary value is normally provided by the central or another CU, or by loss of bus communication. Individual application software packages shall be structured to assume a fail-safe condition upon loss of input sensors. Loss of an input sensor shall result in output of a sensor-failed message at the ECC workstation. Each ACU and RCU shall have capability for local readouts of all functions. The UCUs shall be read remotely.

E. All modules shall be capable of providing global control strategies for the system based on information from any objects in the system, regardless if the object is directly monitored by the building controller module or by another controller. The software program implementing these strategies shall be completely flexible and user-definable. All software tools necessary for programming shall be provided as part of project software. Any systems utilizing factory pre-programmed global strategies that cannot be modified by field personnel on-site, using a WAN or downloaded through remote communications are not acceptable. Changing global strategies using firmware changes is also unacceptable.

F. All DDC control loops shall be able to utilize any of the following control modes:
   1. Two position (on-off, slow-fast) control.
   2. Proportional control.
   3. Proportional plus integral (PI) control.
   4. Proportional plus integral plus derivative (PID) control. All PID programs shall automatically invoke integral wind up prevention routines whenever the controlled unit is off, under manual control of an automation system or time initiated program.
   5. Automatic tuning of control loops.

G. System Security: Operator access shall be secured using individual password and operator’s name. Passwords shall restrict the operator to the level of object, applications, and system functions assigned to him. A minimum of ten (10) levels of security for operator access shall be provided. DDC Control system password access shall be set up by the controls contractor and follow the following levels. Contractor shall assist Owner’s operators with assigning user names, passwords and password levels. Set up the following password levels to include the specified capabilities:

Access Level Table:

Level #	Name of Access Level:	Allowed actions:
1	Read Only	Read only access. Limit read access to operational user data, and point trends.
3	Basic Operator	Level 1 plus Adjust temps, CFM, start/stop, humidity, etc. of non-critical spaces, adjust existing schedules and override economizer.
5	Advanced AC Operator	Level 3 plus manual override of operational level setpts for AHU and VAV/TU, add & adjust schedules, damper controls, etc. of non-critical spaces. Ability to shutdown software for use of third party software. Required training completed and demonstrated operational skills.
7	Critical Rooms & Equipment	Level 5 plus manual setpoint override of Critical areas and equipment (such as Bone Marrow, SPD, OR's, Pharmacy Compounding, Labs, etc.), operational level setpts, add/adjust schedules, damper controls, etc. Adjustments to Boiler & Chiller Plant setpoints. Required training completed and demonstrated operational skills. Configure system software, to include PID parameters, AHU return/supply air offsets, reset parameters. Modify controller unit programs.
8	Technical Design Level	Level 7 plus build graphics, set critical setpts, high level overrides, design parameters, PID's, AHU return/supply air offsets, reset parameters, add schedules, adjust safeties, setup users access, etc. Security settings and backup schedules. Essentially unrestricted except for viewing or modifying user names, passwords, password levels.
10	Admin Control Level	Level 8 above, plus Admin Control of all frontends (Tridium, Honeywell and Alerton), router settings, switch settings, LAN settings, all manufactures controllers, and all network management functions. View, add, change and delete user names, passwords, password levels

User Access Table:

Persons Name:	User Name:	Cell Phone:	Affiliated Company:	User Password (all lower case):	Access Level:	Comments:

H. Application Software: The CUs shall provide the following programs as a minimum for the purpose of optimizing energy consumption while maintaining comfortable environment for occupants via the sequence of operations provided in specification section 230993. Sequences of Operations for HVAC Controls. Unless the sequence of operations is listed in the project drawings, use the Spec section 23-09-93 sequences of operations for this project. Spec section 23-09-93 also includes details for other programming application requirements. Information in spec section 23-09-93 takes priority over spec section 23-09-23. All application software shall reside and run in the system digital controllers. Editing of the application shall occur at the operator workstation or via a portable workstation, when it is necessary, to access directly the programmable unit. See spec section 230993 for more detail.

1. Economizer: An economizer program shall be provided for VAV systems. This program shall control the position of air handler relief,

return, and outdoors dampers. Economizers: Reset with outside enthalpy Vs Return Air Enthalpy.

2. Event Scheduling: Provide a comprehensive menu driven program to automatically start and stop designated points or a group of points according to a stored time. This program shall provide the capability to individually command a point or group of points. When points are assigned to one common load group it shall be possible to assign variable time advances/delays between each successive start and stop within that group. Scheduling shall be calendar based and advance schedules may be defined up to one year in advance. Advance schedule shall override the day-to-day schedule. The operator shall be able to define the following information:
   a. Time, day.
   b. Commands such as on, off, auto.
   c. Time delays between successive commands.
   d. Manual overriding of each schedule.
   e. Allow operator intervention.
3. Alarm Reporting: The operator shall be able to determine the action to be taken in the event of an alarm. Alarms shall be routed to the appropriate workstations based on time and events. An alarm shall be able to start programs, login the event, print and display the messages. The system shall allow the operator to prioritize the alarms to minimize nuisance reporting and to speed operator’s response to critical alarms. A minimum of six (6) priority levels of alarms shall be provided for each point.
4. Remote Communications: The system shall have the ability to email out in the event of an alarm to a pre-determined set of recipients. The alarm message shall include the name of the calling location, the device that generated the alarm, and the alarm message itself. The operator shall be able to remotely access and operate the system using dial up communications. Remote access shall allow the operator to function the same as local access.
5. Maintenance Management (PM): The program shall monitor equipment status and generate maintenance messages based upon the operators defined equipment run time, starts, and/or calendar date limits. A preventative maintenance alarm shall be printed indicating maintenance requirements based on pre-defined run time. Each preventive message shall include point description, limit criteria

and preventative maintenance instruction assigned to that limit. A minimum of 480-character PM shall be provided for each component of units such as air handling units.

6. Space Temp & CFM Setback: Terminal units, VAV's and FCU's shall have temp set points and CFM occupied/unoccupied capability for nights/weekends/holiday setback. Use Space Temp & CFM setpoints that are easy to understand (i.e. heating stpt, cooling stpt, stpt adjust by +/-, space t-stat stpt) and show controlling method (system or space wall sensor/T-stat). System should have a programmed range for each VAV box where no matter where the occupant sets their desired temp, the space will never get colder than the preset minimum nor will it get hotter than your preset maximum. Night setback shall be used on all administrative space and any clinical spaces where use of night setback will not negatively impact patient safety.
   1) During unoccupied mode, the CFM flowing into the space shall be reduced to a preset CFM valve (adjustable). Some areas may need no or very little flow, as long as the temperature is maintained within the dead-band range. Based on the type of space, consideration shall be given to odor control and flushing the space to prevent order buildup.
   2) Temperatures shall be allowed to fluctuate over a wider range (selectable). The loop shall be expanded to at least twice the normal operating range allowing for both warmer and colder temps than are allowable during occupied hours.
   3) Night setback shall have a simple override that allows both the room occupants (via the wall t-stat control) and controls operator to add periods of occupied time (i.e. 30 min or 1 hour, selectable a DDC frontend) to the room occupied time, after which the room would revert back to the original Night Setback schedule. For after-hours use of the space, the space occupants shall be able to push a button on the wall T-stat and override the unoccupied mode for X minutes/hours.
   4) Program with optimize start/stop
   5) Time Schedules for occupied and unoccupied modes shall be individual terminal units, zone and global. Use a graphical display of an occupied/unoccupied temp range.

2.7 ENGINEERING CONTROL CENTER (ECC)—OPERATOR'S WORKSTATION

A. ECC Project-Specific Software:

1. The Controls Systems Operator Interfaces shall be user friendly, readily understood and shall make maximum use of colors, graphics, icons, embedded images, animation, text based information and data visualization techniques to enhance and simplify the use and understanding of the displays by authorized users at the ECC.
2. User access shall be protected by a flexible and Owner re-definable software-based password access protection. Password protection shall be multi-level and partitionable to accommodate the varied access requirements of the different user groups to which individual users may be assigned. Provide the means to define unique access privileges for each individual authorized user. Provide the means to on-line manage password access control under the control of a project specific Master Password. Provide an audit trail of all user activity on the Controls Systems including all actions and changes.
3. All Graphics shall be reviewed by the VA prior to being deployed throughout the building. The "First" graphic for each AHU, Floor Plans, Terminal Units, and miscellaneous HVAC Equipment Graphics shall be completed with all page transitions/transfers, point overrides, moving graphics, trends, and color changes, before the VA will review for deployment. **An Owners review meeting between the Controls Contractor and the VA shall be coordinated by Controls Contractor prior to deployment for modification suggestions. Graphics will not be deployed until the VA has had a chance to review, comment, and accept the graphics for deployment.** The VA reserves the right to have the Controls Contractor make a change to the accepted graphics after the deployment as the entire system come online.
4. **Section 1**: **Graphic Floor Plan Requirements:** The following items shall be listed on the floor plan graphical drawing for each floor or section of a floor. The items shall be shown as an icon (or text ID) on the floor plan that will bring up another level of graphical and text details. Provide floor plans of all project related spaces and integrate with existing DDC frontend floor plans. Floor plan graphics shall show heating and cooling zones throughout the floors in a range of colors, which provide a visual display of temperature

relative to their respective setpoints. The colors shall be updated dynamically as a zone's actual temperature to setpoint changes:

a. Floor plan backgrounds shall include walls (as single lines), zones (as double lines), stairs and room numbers. If the floor plan is to busy, then divide up the floor plan into different sections.
b. Show locations of key space sensors: T-stat, static pressure station (with reading) and humidistat.
c. Show each VAV or box that serves each area and show the limits of that space boundary. If the graphics are too busy, then divide up into different sections.
d. Use colors and icons to distinguish different equipment items.
e. All floor plans to be vector based to allow for zooming in and out of floor plans.
f. If required in the project drawings, Special Controllers and Special Rooms: Show locations with icons or text on the drawing for Bio-Safety Cabinets, Fume hoods, Differential Pressure, Tissue Culture, Open Lab, Microscopy, and Animal Procedure areas. Selecting the item shall bring up a screen with status details for that space/equipment.
g. Show associated exhaust fans for each major area on each floor plan. If necessary show icon/fan numbers outside of floor footprint with connection line to the related space.
h. Show fire/smoke damper locations and status (open/closed).
i. Set-point adjustment and color band displays should be provided at the room level screen.
j. The floor plan maps shall show heating and cooling zones throughout the building space in a range of colors which provide a visual display of temperature relative to their respective set-point. Colors shall be updated dynamically. Each space shall show (via colors that are user definable) the operational status of the space temp, for example:
   - Light Gray - Unoccupied
   - Non-Gray color - Occupied, see below colors
   - Light Yellow - Space temp is less than 3-deg F above set point

- Dark Yellow - Space temp is 3-deg F or more above set point limits
- Light Blue - Space temp is less than 3-deg F below set point
- Dark Blue - Space temp is 3-deg F or more below set point,
- Red – Space temp is more than 5-deg F above or below set point limits, includes alarm.
- Pink - Communications failure

k. Mouse and Navigation Functions:

1. Double click on zone temp and the operator was taken to graphic for VAV and additional info.
2. Click on any of the data displays for related AHU (i.e. DAT) and operator is taken to AHU graphic.
3. Click on HWS temp to go to heating system equipment, etc.
4. Navigation buttons at bottom let you go to next or previous floor plan, or to whole building over view for quick selection of another floor plan, jump to VAV list screen which would show all VAV's associated with that floor plan screen with more information displayed, list style. i.e. Room number, VAV #, Zone temp, air flow required, air flow actual, DAT for VAV, set point for space temp, position of reheat valve.
5. Clicking on room or VAV number would take you to VAV graphic.

l. Show AHU # and AHU zone boundaries.

5. **<u>Section 2</u>: Screen Information Outside of Floor Plan:** On each floor plan screen, include the following (outside of the floor footprint):

a. Show associated AHU’s serving the selected floor as an icon (with alarm status color and AHU #). Click on icon to display AHU details in a pop-up window.

b. Brief Index of symbols/icons/colors, (or just include in O&M manual).

c. Outside Air Temp and Humidity.

d. Include buttons that will bring up other floors or equipment that are related to the project space. For example the related AHU, EF’s and TSI’s.

6. **<u>Section 3</u>: Special Controllers and Special Rooms:** If the project has special equipment and controls, such as Bio-Safety Cabinets, Fume hoods, Differential Pressure, Tissue Culture, Open Lab, Microscopy, Instrument, and Animal Procedure areas, then follow the below requirements. Selecting these rooms (or equipment) on the

Floor level drawing should bring up a screen with specific details for that space/equipment. This detail screen should include:

1) Graphics showing the inter-relationship of the space and major equipment items, shall include:
   a) Lab enclosure/boundary lines,
   b) Hoods,
   c) Show associated exhaust fans for each Lab area or Hood. If needed show icon/fan number outside of floor footprint with connection line to the related space or hood for the following:
      i) Dedicated fumehood exhaust fan,
      ii) Exhaust valve (CV),
      iii) General exhaust,
   d) Supply/makeup air valve,
   e) Differential Pressure/Offset Controller
   f) Related VFD's, etc.
2) Readings/monitoring points should include:
   a) Alarms,
   b) CFM's,
   c) Balance,
   d) Hood face velocity,
   e) Show air flow direction,
   f) Mode,
   g) Start/stop and fan motor run status (if available)
   h) VFD info, on/off/hand, percent, alarm, etc.
   i) Flow tracking/monitoring,
   j) Temps (discharge air, space),
   k) Damper min & max,
   l) Pressures, etc.

7. **Section 4**: **AHU's screens**: Mechanical system graphics shall show the type of mechanical system components serving any zone through the use of a pictorial representation of components. Selected I/O points being controlled or monitored for each piece of equipment shall be displayed with the appropriate engineering units.
   a. Animation shall be used for rotation or moving mechanical components to enhance usability, such as to show if louvers/valves are open, closed or partially open.

b. Use animation to show fans are running. Also show start/stop command and actual fan run status.

c. VFD info, on/off/hand, percent, alarm, etc.

d. Show discharge air static pressure.

e. Insure AHU controls has capability for auto restart after AC power failure.

f. Show Smoke Detector status on AHU graphics

8. <u>Section 5</u>: Exhaust Fan Summary page:

1) Show location reference for each exhaust fan.

9. **<u>Section 6: DDC Navigation Tree Structural:</u>** The intent of the graphic displays is to ensure the operator is always aware of his position within the system as well as how too logically progress through the graphical hierarchy to select any desired graphic or other source of info. Software shall provide the operator with the capability of returning to any previous graphic by pointing to a graphic tab then pushing a single button. The operator shall be able to navigate from the home page through all screens by clicking on the graphic screen maps, buildings, floor plans, and the hierarchy links:

a. Provides drill down to lower levels (i.e. more details) screens and menus.

b. Menu Tree, should show location within the tree structural, i.e. how far down the tree you are for the current screen. Then you can jump back up to a higher level item.

c. Double click (or as standard on existing system) on zone temp and the operator is taken too graphic for VAV and additional info.

d. The floor plan maps shall be accessible by rolling over the floor on the building map. This will provide the viewer a quick and accurate overview of the building zone conditions. Rolling over any zone will bring up the zone description and temperature in a pop-up flag. Flags are used to keep the zone information legible regardless of how small the zone is depicted on the plan.

e. Click on any of the data displays for related AHU and operator is taken to AHU graphic. Click on HWS temp to go to heating system equipment. Navigation buttons let the operator go to next or previous floor plan, or to whole building over view for quick section of another area floor plan.

f. Clicking on room or VAV number would take you to VAV graphic and details.

g. The VAV list screen shall show all VAV's associated with that floor plan screen. The VAV list should also show Room number, VAV #, Zone temp, air flow required, air flow actual, DAT for VAV, SP for space temp and position of reheat.

B. The system shall be completely field-programmable from the common operator’s keyboard thus allowing hard disk storage of all data automatically. All programs for the CUs shall be able to be downloaded from the hard disk. The software shall provide the following functionality as a minimum:

1. Point database editing, storage and downloading of controller databases.
2. Scheduling and override of building environmental control systems.
3. Collection and analysis of historical data.
4. Alarm reporting, routing, messaging, and acknowledgement.
5. Definition and construction of dynamic color graphic displays.
6. Real-time graphical viewing and control of environment.
7. Scheduling trend reports.
8. Program editing.
9. Operating activity log and system security.
10. Transfer data to third party software.

C. Provide graphical user software, which shall minimize the use of keyboard through the use of the mouse and "point and click" approach to menu selection.

D. The software shall provide a multi-tasking type environment that will allow the user to run several applications simultaneously. The mouse or Alt-Tab keys shall be used to quickly select and switch between multiple applications. The operator shall be able automatically export data to and work in Microsoft Word, Excel, and other Windows based software programs, while concurrently on-line system alarms and monitoring information.

E. Provide functionality such that using the least amount of steps to initiate the desired event may perform any of the following simultaneously:

1. Dynamic color graphics and graphic control.
2. Alarm management.
3. Event scheduling.

4. Dynamic trend definition and presentation.
5. Program and database editing.
6. Each operator shall be required to log on to the system with a user name and password to view, edit or delete the data. System security shall be selectable for each operator, and the password shall be able to restrict the operator's access for viewing and changing the system programs. Each operator shall automatically be logged off the system if no keyboard or mouse activity is detected for a selected time.

F. Trend reports shall be generated on demand or pre-defined schedule and directed to monitor display, printers or disk. As a minimum, the system shall allow the operator to easily obtain the following types of reports:
1. A general list of all selected points in the network.
2. List of all points in the alarm.
3. List of all points in the override status.
4. List of all disabled points.
5. List of all points currently locked out.
6. List of user accounts and password access levels.
7. List of weekly schedules.
8. List of holiday programming.
9. List of limits and dead bands.
10. Custom reports.
11. System diagnostic reports, including, list of digital controllers on the network.
12. List of programs.

G. Scheduling and Override:
1. Provide a calendar type format for time-of-day scheduling and overrides of building control systems. Schedules reside in the ECC. The workstation, digital controllers shall ensure equipment time scheduling when the ECC is off-line. The ECC shall not be required to execute time scheduling. Provide the following spreadsheet graphics as a minimum:
   1) Weekly schedules.
   2) Globe, Zone and TU schedules, minimum of 100 zones.
   3) Scheduling up to 365 days in advance.
   4) Scheduled reports to print at workstation.

5) Also see above section for Space Temp & CFM Setback procedures.

H. Collection and Analysis of Historical Data:

a. Provide trending capabilities that will allow the operator to monitor and store records of system activity over an extended period of time. Points may be trended automatically on time based intervals or change of value, both of which shall be user definable. The trend interval could be five (5) minutes to 120 hours. Trend data may be stored on hard disk for future diagnostic and reporting. Additionally trend data may be archived to network drives or removable disk media for off-site retrieval.

b. Reports may be customized to include individual points or predefined groups of at least six points. Provide additional functionality to allow pre-defined groups of up to 250 trended points to be easily accessible by other industry standard word processing and spreadsheet packages. The reports shall be time and date stamped and shall contain a report title and the name of the facility.

c. System shall have the set up to generate spreadsheet reports to track energy usage and cost based on weekly or monthly interval, equipment run times, equipment efficiency, and/or building environmental conditions.

d. Provide additional functionality that will allow the operator to view real time trend data on trend graph displays. A minimum of 20 points may be graphed regardless of whether they have been predefined for trending. In addition, the user may pause the graph and take snapshots of the screens to be stored on the workstation disk for future reference and trend analysis. Exact point values may be viewed and the graph may be printed. Operator shall be able to command points directly on the trend plot by double clicking on the point.

I. Alarm Management:

a. Alarm routing shall allow the operator to send alarm notification to selected printers or operator workstation based on time of day, alarm severity, or point type.

b. Alarm notification shall be provided via two alarm icons, to distinguish between routine, maintenance type alarms and critical alarms. The critical alarms shall display on the screen at the time of its occurrence, while others shall display by clicking on their icon.

c. Alarm display shall list the alarms with highest priority at the top of the display. The alarm display shall provide selector buttons for display of the associated point graphic and message in English language. The operator shall be able to sort out the alarms.

d. Alarm messages shall be customized for each point to display detailed instructions to the operator regarding actions to take in the event of an alarm.

e. An operator with proper security level access may acknowledge and clear the alarm. All that have not been cleared shall be archived at workstation disk.

J. Remote Communications: The system shall have the ability to dial out in the event of an alarm. Receivers shall include operator workstations, e-mail addresses, and alpha-numeric pagers. The alarm message shall include the name of the calling location, the device that generated the alarm, and the alarm message itself.

K. System Configuration:

a. Network control strategies shall not be restricted to a single digital controller, but shall be able to include data from all other network devices to allow the development of global control strategies.

L. Provide automatic backup and restore of all digital controller databases on the workstation hard disk. In addition to all backup data, all databases shall be performed while the workstation is on-line without disturbing other system operations.

2.8 PORTABLE OPERATOR'S TERMINAL (pot) Provide 1 portable operator's terminals (POT's) that shall be capable of accessing all system data. POT may be connected to any point on the system network or may be connected directly to any controller for programming, setup, and troubleshooting. POT

shall communicate using BACnet protocol. POT may be connected to any point on the system network or it may be connected directly to controllers using the BACnet PTP (Point-To-Point) Data Link/ Physical layer protocol. The terminal shall use the Read (Initiate) and Write (Execute) BACnet Services. POT shall be an IBM-compatible notebook-style PC including all software and hardware required.

A. Hardware: POT shall conform to the BACnet Advanced Workstation (B-AWS) Profile and shall be BTL-Listed as a B-AWS device.
   1. POT shall be commercial standard with supporting 32- or 64-bit hardware (as limited by the direct-digital control system software) and software enterprise server. Internet Explorer v6.0 SP1 or higher, Windows Script Hosting version 5.6 or higher, Windows Message Queuing, Windows Internet Information Services (IIS) v5.0 or higher, minimum 2.8 GHz processor, minimum 500 GB 7200 rpm SATA hard drive with 16 MB cache, minimum 2GB DDR3 SDRAM (minimum 1333 Mhz) memory, 512 MB video card, minimum 16 inch (diagonal) screen, 10-100-1000 Base-TX Ethernet NIC with an RJ45 connector or a 100Base-FX Ethernet NIC with an SC/ST connector, 56,600 bps modem, an ASCII RS-232 interface, and a 16 speed high density DVD-RW+/- optical drive.

B. Software: POT shall include software equal to the software on the ECC.

2.9 BACNET PROTOCOL ANALYZER

A. For ease of troubleshooting and maintenance, provide a BACnet protocol analyzer. Provide its associated fittings, cables and appurtenances, for connection to the communications network. The BACnet protocol analyzer shall be able to, at a minimum: capture and store to a file all data traffic on all network levels; measure bandwidth usage; filter out (ignore) selected traffic.

2.10 NETWORK AND DEVICE NAMING CONVENTION

A. Network Numbers

All BACnet object device instance number assignments shall follow the below protocol. All Nashville VAMC BACnet instance assignments shall follow a seven digit format of ABCCDDD as detailed. Controls Contractor shall propose device number assignments to be used during project submittal phase. Controls contractors shall request permission for any unique numbers that are not addressed below or to use unassigned numbers:

Device Instance Number Format: **A B CC DDD**, Object instances can range from 0 to 4,194,302.

	A = Unique Vendor assignment #	B = Facility Floor #	CC = System #'s	DDD = Equipment Sequence #	
	0 = Legacy/Existing Alerton or Honeywell 1 = Alerton 2 = Honeywell	0 = Basement & Sub-basement, 1 = 1st floor, 2 = 2nd Floor, 3 = 3rd Floor, 4 = 4th Floor, 5 = 5th Floor ACRE & Main Hospital Penthouses, 6 = 6th Floor, 7 = 7th Floor (ACRE Penthouse Floor), 8 = 8th Floor (ACRE Penthouse Roofs).	01 to 69 = AHU Zone #'s,	001 to 099 = AHU equipment device #'s, 101 to 299 = Terminal Units (VAV, FCU & UH) device #'s, 301 to 399 = AHU/TU support devices, Smoke Dampers etc. 401 to 499 = TSI Monitors, 501 to 549= Exhaust Fans, 550 to 560= Variable Frequency Drives 550 to 999 = Unassigned #'s	
			70 = Misc Equipment and Non-AHU zone equipment not connected to an AHU zone.	001 to 099 = General EF's, not associated with an AHU zone, 101 to 199 = Unit Heaters, not associated with an AHU zone, 201 to 209 = Summer Winter System, 251 to 249 = Entry Door heaters/Fans, 301 to 329	

				=Refrigeration Equipment, 401 to 449 = Med Gas System 451 to 499 = Facility (Plant) Air Compressors, 501 to 599 = Coolers and Freezers, 601 to 609 = Sprinkler System	
			81 = Boiler Plant,	001 to 099 = Boilers, 101 to 299 = DA Tank Equipment, 201 to 399 = Plant Condensate Equipment, 301 to 499 = Boiler Economizer, 400 to 999 = Unassigned.	
			82 = Steam Converters, Reheat & Condensate Return Sys,	001 to 099 Steam Converters (CV's) and Reheat, 101 to 199 = Condensate Return System, 201 to 299 = PRV's, 300 to 999 = Unassigned	
			83 = Domestic Hot & Cold Water and RO Water Sys,	001 to 099 = Hot Water Heater System, 101 to 199 = Cold Water System, 201 to 219 = RO Water systems 220 to 999	

				Unassigned	
			85 = Chilled Water System	001 to 099 = Chillers, Water 101 to 149 = Cooling Towers & Condenser, 201 to 249 = Primary Loop 251 to 299 = Secondary/Central Loop system, 301 to 349 = Chillers, Air, 401 to 419 = Plate & Frame HX,	
			86 = Lighting System	Future	
	3 = Unassigned 4 = Unused	9 = Unassigned.	71 to 79 = Unassigned 84 = unassigned 87 to 99 = Unassigned,		

B. Device Names

1. Name the control devices based on facility name, location within a facility, the system or systems that the device monitors and/or controls, or the area served. The intent of the device naming is to be easily recognized. Names can be up to 254 characters in length, without embedded spaces. Provide the shortest descriptive, but unambiguous, name. For example, in building #123 prefix the number with a “B” followed by the building number, if there is only one chilled water pump "CHWP-1", a valid name would be "B123.CHWP. 1.STARTSTOP". If there are two pumps designated "CHWP-1", one in a basement mechanical room (Room 0001) and one in a penthouse mechanical room (Room PH01), the names could be "B123.R0001.CHWP.1. STARTSTOP" or "B123.RPH01.CHWP.1.STARTSTOP". In the case of unitary

controllers, for example a VAV box controller, a name might be "B123.R101.VAV". These names should be used for the value of the "Object_Name" property of the BACnet Device objects of the controllers involved so that the BACnet name and the EMCS name are the same.

2.11 BACNET DEVICES

A. All BACnet Devices – controllers, gateways, routers, actuators and sensors shall conform to BACnet Device Profiles and shall be BACnet Testing Laboratories (BTL) - Listed as conforming to those Device Profiles. Protocol Implementation Conformance Statements (PICSs), describing the BACnet capabilities of the Devices shall be published and available of the Devices through links in the BTL website.

1. BACnet Building Controllers, historically referred to as NACs, shall conform to the BACnet B-BC Device Profile, and shall be BTL-Listed as conforming to the B-BC Device Profile. The Device's PICS shall be submitted.
2. BACnet Advanced Application Controllers shall conform to the BACnet B-AAC Device Profile, and shall be BTL-Listed as conforming to the B-AAC Device Profile. The Device's PICS shall be submitted.
3. BACnet Application Specific Controllers shall conform to the BACnet B-ASC Device Profile, and shall be BTL-Listed as conforming to the B-ASC Device Profile. The Device's PICS shall be submitted.
4. BACnet Smart Actuators shall conform to the BACnet B-SA Device Profile, and shall be BTL-Listed as conforming to the B-SA Device Profile. The Device's PICS shall be submitted.
5. BACnet Smart Sensors shall conform to the BACnet B-SS Device Profile, and shall be BTL-Listed as conforming to the B-SS Device Profile. The Device's PICS shall be submitted.
6. BACnet routers and gateways shall conform to the BACnet B-OTH Device Profile, and shall be BTL-Listed as conforming to the B-OTH Device Profile. The Device's PICS shall be submitted.

2.12 CONTROLLERS

A. General. Provide an adequate number of BTL-Listed B-BC building controllers and an adequate number of BTL-Listed B-AAC advanced application controllers to achieve the performance specified in the Part 1 Article on "System Performance." Each of these controllers shall meet the following requirements.

1. The controller shall have sufficient memory to support its operating system, database, and programming requirements.
2. The building controller shall share data with the ECC and the other networked building controllers. The advanced application controller shall share data with its building controller and the other networked advanced application controllers.
3. The operating system of the controller shall manage the input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
4. Controllers that perform scheduling shall have a real-time clock.
5. The controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall:
   a. assume a predetermined failure mode, and
   b. generate an alarm notification.
6. The controller shall communicate with other BACnet devices on the internetwork using the BACnet Read (Execute and Initiate) and Write (Execute and Initiate) Property services.
7. Communication.
   a. Each controller shall reside on a BACnet network using the ISO 8802-3 (Ethernet) Data Link/Physical layer protocol for its communications. Each building controller also shall perform BACnet routing if connected to a network of custom application and application specific controllers.
   b. The controller shall provide a service communication port using BACnet Data Link/Physical layer protocol for connection to a portable operator’s terminal.
8. Keypad. A local keypad and display shall be provided for each controller. The keypad shall be provided for interrogating and editing data. Provide a system security password shall be available to prevent unauthorized use of the keypad and display.
9. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
10. Memory. The controller shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.

11. The controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Controller operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).

I. Provide BTL-Listed B-ASC application specific controllers for each piece of equipment for which they are constructed. Application specific controllers shall communicate with other BACnet devices on the internetwork using the BACnet Read (Execute) Property service.

1. Each B-ASC shall be capable of stand-alone operation and shall continue to provide control functions without being connected to the network.
2. Each B-ASC will contain sufficient I/O capacity to control the target system.
3. Communication.
   a. Each controller shall reside on a BACnet network using the ISO 8802-3 (Ethernet) Data Link/Physical layer protocol for its communications. Each building controller also shall perform BACnet routing if connected to a network of custom application and application specific controllers.
   b. Each controller shall have a BACnet Data Link/Physical layer compatible connection for a laptop computer or a portable operator’s tool. This connection shall be extended to a space temperature sensor port where shown.
4. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
5. Memory. The application specific controller shall use nonvolatile memory and maintain all BIOS and programming information in the event of a power loss.
6. Immunity to power and noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80%. Operation shall be protected against electrical noise of 5-120 Hz and from keyed radios up to 5 W at 1 m (3 ft).
7. Transformer. Power supply for the ASC must be rated at a minimum of 125% of ASC power consumption and shall be of the fused or current limiting type.

A. Direct Digital Controller Software

1. The software programs specified in this section shall be commercially available, concurrent, multi-tasking operating system and support the use of software application that operates under DOS or Microsoft Windows.
2. All points shall be identified by up to 30-character point name and 16-character point descriptor. The same names shall be used at the ECC.
3. All control functions shall execute within the stand-alone control units via DDC algorithms. The VA shall be able to customize control strategies and sequences of operations defining the appropriate control loop algorithms and choosing the optimum loop parameters.
   a. All controllers shall be capable of being programmed to utilize stored default values for assured fail-safe operation of critical processes. Default values shall be invoked upon sensor failure or, if the primary value is normally provided by the central or another CU, or by loss of bus communication. Individual application software packages shall be structured to assume a fail-safe condition upon loss of input sensors. Loss of an input sensor shall result in output of a sensor-failed message at the ECC.
   b. Power Demand Limiting (PDL): Power demand limiting program shall monitor the building power consumption and limit the consumption of electricity to prevent peak demand charges. PDL shall continuously track the electricity consumption from a pulse input generated at the kilowatt-hour/demand electric meter. PDL shall sample the meter data to continuously forecast the electric demand likely to be used during successive time intervals. If the forecast demand indicates that electricity usage will likely to exceed a user preset maximum allowable level, then PDL shall automatically shed electrical loads. Once the demand load has met, loads that have been shed shall be restored and returned to normal mode. Control system shall be capable of demand limiting by resetting the HVAC system set points to reduce load while maintaining indoor air quality.
   c. Economizer: Night Setback/Morning Warm up Control: The system shall provide the ability to automatically adjust set points for this mode of operation.

d. Optimum Start/Stop (OSS): Optimum start/stop program shall automatically be coordinated with event scheduling. The OSS program shall start HVAC equipment at the latest possible time that will allow the equipment to achieve the desired zone condition by the time of occupancy, and it shall also shut down HVAC equipment at the earliest possible time before the end of the occupancy period and still maintain desired comfort conditions. The OSS program shall consider both outside weather conditions and inside zone conditions. The program shall automatically assign longer lead times for weekend and holiday shutdowns. The program shall poll all zones served by the associated AHU and shall select the warmest and coolest zones. These shall be used in the start time calculation. It shall be possible to assign occupancy start times on a per air handler unit basis. The program shall meet the local code requirements for minimum outdoor air while the building is occupied. Modification of assigned occupancy start/stop times shall be possible via the ECC.

e. Event Information:
   i. Time, day.
   ii. Commands such as on, off, auto.
   iii. Time delays between successive commands.
   iv. Manual overriding of each schedule.

   5) Allow operator intervention.

f. Alarm Reporting: The operator shall be able to determine the action to be taken in the event of an alarm. Alarms shall be routed to the ECC based on time and events. An alarm shall be able to start programs, login the event, print and display the messages. The system shall allow the operator to prioritize the alarms to minimize nuisance reporting and to speed operator’s response to critical alarms. A minimum of six (6) priority levels of alarms shall be provided for each point.

g. Remote Communications: The system shall have the ability to dial out in the event of an alarm to the ECC and alpha-numeric pagers. The alarm message shall include the name of the calling location, the device that generated the alarm, and the alarm message itself. The operator shall be able to remotely access and operate

the system using dial up communications. Remote access shall allow the operator to function the same as local access.

h. Maintenance management (pm): the program shall monitor equipment status and generate maintenance messages based upon the operators defined equipment run time, starts, and/or calendar date limits. A preventative maintenance alarm shall be printed indicating maintenance requirements based on pre-defined run time. Each preventive message shall include point description, limit criteria and preventative maintenance instruction assigned to that limit. A minimum of 480-character pm shall be provided for each component of units such as air handling units.

2.13 SENSORS (AIR, WATER AND STEAM)

A. Sensors' measurements shall be read back to the DDC system, and shall be visible by the ECC.

B. Temperature and Humidity Sensors shall be electronic, vibration and corrosion resistant for wall, immersion, and/or duct mounting. Provide all remote sensors as required for the systems.

1. Temperature Sensors: thermistor type for terminal units and Resistance Temperature Device (RTD) with an integral transmitter type for all other sensors.

a. Duct sensors shall be rigid or averaging type as shown on drawings. Averaging sensor shall be a minimum of 1 linear ft of sensing element for each sq ft of cooling coil face area.

b. Immersion sensors shall be provided with a separable well made of stainless steel, bronze or monel material. Pressure rating of well is to be consistent with the system pressure in which it is to be installed.

c. Space sensors shall be equipped with in-space User set-point adjustment, override switch, numerical temperature display on sensor cover, and communication port. Match room thermostats. Provide a tooled-access cover.

1) Public space sensor: setpoint adjustment shall be only through the ECC or through the DDC system's diagnostic device/laptop. Do not provide in-space User set-point adjustment. Provide an opaque keyed-entry cover if needed to restrict in-space User set-point adjustment.

2) Room sensors shall be provided with digital readout that allow the user to view room temperature, view outside air

temperature, adjust the room setpoint within preset limits and set desired override time. User shall also be able to start and stop unit from the digital sensor. Include all necessary wiring and firmware such that room sensor includes field service mode. Field service mode shall allow a technician to balance VAV zones and access any parameter in zone controller directly from the room sensor. Field service mode shall have the ability to be locked out.

d. Outdoor air temperature sensors shall have watertight inlet fittings and be shielded from direct sunlight.

e. Wire: Twisted, shielded-pair cable.

f. Output Signal: 4-20 ma.

2. Humidity Sensors: Bulk polymer sensing element type.

a. Duct and room sensors shall have a sensing range of 20 to 80 percent with accuracy of ± 2 to ± 5 percent RH, including hysteresis, linearity, and repeatability.

b. Outdoor humidity sensors shall be furnished with element guard and mounting plate and have a sensing range of 0 to 100 percent RH.

c. 4-20 ma continuous output signal.

C. Static Pressure Sensors: Non-directional, temperature compensated.

1. 4-20 ma output signal.

2. 0 to 5 inches wg for duct static pressure range.

3. 0 to 0.25 inch wg for Building static pressure range.

D. Water flow sensors:

1. Type: Insertion vortex type with retractable probe assembly and 2 inch full port gate valve.

a. Pipe size: 3 to 24 inches.

b. Retractor: ASME threaded, non-rising stem type with hand wheel.

c. Mounting connection: 2 inch 150 PSI flange.

d. Sensor assembly: Design for expected water flow and pipe size.

e. Seal: Teflon (PTFE).

2. Controller:

a. Integral to unit.

b. Locally display flow rate and total.

c. Output flow signal to BMCS: Digital pulse type.

3. Performance:

a. Turndown: 20:1

b. Response time: Adjustable from 1 to 100 seconds.

c. Power: 24 volt DC

4. Install flow meters according to manufacturer's recommendations. Where recommended by manufacturer because of mounting conditions, provide flow rectifier.

E. Flow switches:

1. Shall be either paddle or differential pressure type.

a. Paddle-type switches (liquid service only) shall be UL Listed, SPDT snap-acting, adjustable sensitivity with NEMA 4 enclosure.

b. Differential pressure type switches (air or water service) shall be UL listed, SPDT snap acting, NEMA 4 enclosure, with scale range and differential suitable for specified application.

F. Current Switches: Current operated switches shall be self powered, solid state with adjustable trip current as well as status, power, and relay command status LED indication. The switches shall be selected to match the current of the application and output requirements of the DDC systems.

G. NA

2.14 CONTROL CABLES

A. General:

1. Ground cable shields, drain conductors, and equipment to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments. Comply with Sections 27 05 26 and 26 05 26.

2. Cable conductors to provide protection against induction in circuits. Crosstalk attenuation within the System shall be in excess of -80 dB throughout the frequency ranges specified.

3. Minimize the radiation of RF noise generated by the System equipment so as not to interfere with any audio, video, data, computer main distribution frame (MDF), telephone customer service unit (CSU), and electronic private branch exchange (EPBX) equipment the System may service.

4. The as-installed drawings shall identify each cable as labeled, used cable, and bad cable pairs.

5. Label system's cables on each end. Test and certify cables in writing to the VA before conducting proof-of-performance testing. Minimum cable test requirements are for impedance compliance, inductance, capacitance, signal level compliance, opens, shorts,

cross talk, noise, and distortion, and split pairs on all cables in the frequency ranges used. Make available all cable installation and test records at demonstration to the VA. All changes (used pair, failed pair, etc.) shall be posted in these records as the change occurs.

6. Power wiring shall not be run in conduit with communications trunk wiring or signal or control wiring operating at 100 volts or less.
7. All Low Voltage Control Cables shall be "GREEN" in color.

B. Analog control cabling shall be not less than No. 18 AWG solid, with thermoplastic insulated conductors as specified in Section 26 05 21.

C. Copper digital communication cable between the ECC and the B-BC and B-AAC controllers shall be 100BASE-TX Ethernet, Category 5e or 6, not less than minimum 24 American Wire Gauge (AWG) solid, Shielded Twisted Pair (STP) or Unshielded Twisted Pair (UTP), with thermoplastic insulated conductors, enclosed in a thermoplastic outer jacket, as specified in Section 27 15 00.

1. Other types of media commonly used within IEEE Std 802.3 LANs (e.g., 10Base-T and 10Base-2) shall be used only in cases to interconnect with existing media.

D. Optical digital communication fiber, if used, shall be Multimode or Singlemode fiber, 62.5/125 micron for multimode or 10/125 micron for singlemode micron with SC or ST connectors as specified in TIA-568-C.1. Terminations, patch panels, and other hardware shall be compatible with the specified fiber and shall be as specified in Section 27 15 00. Fiber-optic cable shall be suitable for use with the 100Base-FX or the 100Base-SX standard (as applicable) as defined in IEEE Std 802.3.

2.15 THERMOSTATS AND HUMIDISTATS

A. Room thermostats controlling unitary standalone heating and cooling devices not connected to the DDC system shall have three modes of operation (heating - null or dead band - cooling). Thermostats for patient bedrooms shall have capability of being adjusted to eliminate null or dead band. Wall mounted thermostats shall have polished or brushed aluminum finish, setpoint range and temperature display and external adjustment:

1. Electronic Thermostats: Solid-state, microprocessor based, programmable to daily, weekend, and holiday schedules.
   a. Public Space Thermostat: Public space thermostat shall have a thermistor sensor and shall not have a visible means of set point

adjustment. Adjustment shall be via the digital controller to which it is connected.

b. Battery replacement without program loss.

c. Processor: The microprocessor used in the FLG-7350 subbase is freescale Semiconductor MC908AZ60.

d. Terminations All wiring connections are made at the thermostat through wiring at the back of the subbase. Termination of field wiring is provided by terminal block connectors. These terminals accept 18-22AWG wire.

e. BACnet Conformance ASC level device.

f. Binary (Relay) Outputs All relay outputs are rated for 1.5A run and inrush of 7.5A at 30 VAC (0.5 PF); minimum 0.02A run at 20 VAC. Fan and cooling relays are N.O. singlepole, single-throw (SPST) commoned to Rc. Heating relays are N.O. SPST commoned to Rh. On communicating models, the Auxiliary relay is N.O. SPST and is isolated. The heating relays provide 200,000 cycles (30 VAC). The cooling relays provide 100,000 cycles (30 VAC).

g. Analog (Modulating) Outputs The modulating outputs are rated for 0-22mA current outputs (max. load of 500 ohms) with 7 bit or greater resolution.

h. Unit consisting of a thermostat and BACnet subbase, is a BACnet-enabled communicating thermostat.

i. Furnish and install ALERTON’s Model T7350 and FLG-7350 Assembly with modulating output.

B. Strap-on thermostats shall be enclosed in a dirt-and-moisture proof housing with fixed temperature switching point and single pole, double throw switch.

C. Freezestats shall have a minimum of 300 mm (one linear foot) of sensing element for each 0.093 square meter (one square foot) of coil area. A freezing condition at any increment of 300 mm (one foot) anywhere along the sensing element shall be sufficient to operate the thermostatic element. Freezestats shall be manually-reset.

2.16 FINAL CONTROL ELEMENTS AND OPERATORS

A. Fail Safe Operation: Control valves and dampers shall provide "fail safe" operation in either the normally open or normally closed position as required for freeze, moisture, and smoke or fire protection.

B. Power Operated Control Dampers (other than VAV Boxes): Factory fabricated, balanced type dampers. All modulating dampers shall be

opposed blade type and gasketed. Blades for two-position, duct-mounted dampers shall be parallel, airfoil (streamlined) type for minimum noise generation and pressure drop.

1. Leakage: maximum leakage in closed position shall not exceed 7 L/S (15 CFMs) differential pressure for outside air and exhaust dampers and 200 L/S/ square meter (40 CFM/sq. ft.) at 50 mm (2 inches) differential pressure for other dampers.
2. Frame shall be galvanized steel channel with seals as required to meet leakage criteria.
3. Blades shall be galvanized steel or aluminum, 200 mm (8 inch) maximum width, with edges sealed as required.
4. Bearing shall be nylon, bronze sleeve or ball type.
5. Hardware shall be zinc-plated steel. Connected rods and linkage shall be non-slip. Working parts of joints shall be brass, bronze, nylon or stainless steel.
6. Maximum air velocity and pressure drop through free area the dampers:
   a. Smoke damper in air handling unit: 305 meter per minute (1000 fpm).
   b. Duct mounted damper: 600 meter per minute (2000 fpm).
   c. Maximum static pressure loss: 50 Pascal (0.20 inches water gage).

C. Smoke Dampers and Combination Fire/Smoke Dampers: Dampers and operators are specified in Section 23 31 00, HVAC DUCTS AND CASINGS. Control of these dampers is specified under this Section.

D. Control Valves:

1. Valves shall be rated for a minimum of 150 percent of system operating pressure at the valve location but not less than 900 kPa (125 psig).
2. Valves 50 mm (2 inches) and smaller shall be bronze body with threaded or flare connections.
3. Valves 60 mm (2 1/2 inches) and larger shall be bronze or iron body with flanged connections.
4. Brass or bronze seats except for valves controlling media above 100 degrees C (210 degrees F), which shall have stainless steel seats.
5. Flow characteristics:
   a. Three way modulating valves shall be globe pattern. Position versus flow relation shall be linear relation for steam or equal percentage for water flow control.

b. Two-way modulating valves shall be globe pattern. Position versus flow relation shall be linear for steam and equal percentage for water flow control.

c. Two-way 2-position valves shall be ball, gate or butterfly type.

6. Maximum pressure drop:

a. Two position steam control: 20 percent of inlet gauge pressure.

b. Modulating Steam Control: 80 percent of inlet gauge pressure (acoustic velocity limitation).

c. Modulating water flow control, greater of 3 meters (10 feet) of water or the pressure drop through the apparatus.

7. Two position water valves shall be line size.

E. Damper and Valve Operators and Relays:

1. Electronic damper operators: Metal parts shall be aluminum, mill finish galvanized steel, or zinc plated steel or stainless steel. Provide actuator heads which allow for electrical conduit attachment. The motors shall have sufficient closure torque to allow for complete closure of valve or damper under pressure. Provide multiple motors as required to achieve sufficient close-off torque.

a. VAV Box actuator shall be mounted on the damper axle or shall be of the air valve design, and shall provide complete modulating control of the damper. The motor shall have a closure torque of 35-inch pounds minimum with full torque applied at close off to attain minimum leakage.

2. SEE DRAWINGS FOR REQUIRED CONTROL OPERATION.

2.17 AIR FLOW CONTROL

A. Airflow and static pressure shall be controlled via digital controllers with inputs from airflow control measuring stations and static pressure inputs as specified. Controller outputs shall be analog or pulse width modulating output signals. The controllers shall include the capability to control via simple proportional (P) control, proportional plus integral (PI), proportional plus integral plus derivative (PID), and on-off. The airflow control programs shall be factory-tested programs that are documented in the literature of the control manufacturer.

B. Air Flow Measuring Station – Fan Inlet Sensing Probes:

1. Air Flow Sensor Probe:

a. Each air flow measuring probe shall be of the multiple averaging Pitot/Static Sensor Type with sensors distributed for equal-area

averaging of flows. They shall be installed for a total pitot traverse of the fan inlet. Internal Pitot/Static sensors shall be constructed of aluminum with hard anodized finish. Instrument connections shall be ¼" NPT female. The probe shall be similar to Ultraprobe FIAMP, manufactured by Ultratech Industries, a Hamlin Company.

b. Accuracy +/- 2%
c. Temperature: Maximum 400 DegF.
d. Minimum Flow: 400 fpm.
e. Maximum Flow: 12,000 fpm.
f. These sensors shall be coupled with differential pressure sensors of an appropriate differential pressure range that will allow for sensing of airflow over the entire range of the fan and air flow sensors.
g. All Air flow Sensors will need to be calibrated at multiple points across the fan speed ranges to ensure proper calibration. This will need to be completed with a balancer.

2. Air Flow Sensor Grid Array:
   a. Each sensor grid shall consist of a lattice network of sensing holes along the length of the tube that yield an average velocity pressure reading for better accuracy. Each sensor tubes shall be mounted across the ductwork with the pitot/static pressure holes are facing upstream and downstream of the airflow and located so that it is protected on the upstream side. Depending on the size of the duct being measured, multiple tubes may be required to get an accurate reading across the entire area of the duct. When multiple tubes are required the tubes shall be installed in a Hashtag pattern in the duct and all tubes shall be pneumatically tubed together so that on differential pressure sensor is reading the air flow velocity.

These tubes shall be similar to the KELE AMP series – Ampliflow Air Velocity Sensors.

Probe Sensor Tubes	
Area (sq.ft.)	Qty. Tubes
<=1	1
>1 to <4	2
4 to <8	4
8 to <12	6
12 to <16	8
>=16	10

b. These sensors shall be coupled with differential pressure sensors of an appropriate differential pressure range that will allow for sensing of airflow over the entire range of the fan and air flow sensors.

c. All Air flow Sensors will need to be calibrated at multiple points across the fan speed ranges to ensure proper calibration. This will need to be completed with a balancer.

C. Complete installation shall not exhibit more than ± 2.0% error in airflow measurement output for variations in the angle of flow of up to 10 percent in any direction from its calibrated orientation. Repeatability of readings shall be within ± 0.25%.D. Static Pressure Measuring Station: shall consist of one or more static pressure sensors and transmitters along with relays or auxiliary devices as required for a complete functional system. The span of the transmitter shall not exceed two times the design static pressure at the point of measurement. The output of the transmitter shall be true representation of the input pressure with plus or minus 25 Pascal (0.1 inch) W.G. of the true input pressure:

1. Static pressure sensors shall have the same requirements as Airflow Measuring Devices except that total pressure sensors are optional, and only multiple static pressure sensors positioned on an equal area basis connected to a network of headers are required.
2. For systems with multiple major trunk supply ducts, furnish a static pressure transmitter for each trunk duct. The transmitter signal representing the lowest static pressure shall be selected and this shall be the input signal to the controller.

3. The controller shall receive the static pressure transmitter signal and CU shall provide a control output signal to the supply fan capacity control device. The control mode shall be proportional plus integral (PI) (automatic reset) and where required shall also include derivative mode.
4. In systems with multiple static pressure transmitters, provide a switch located near the fan discharge to prevent excessive pressure during abnormal operating conditions. High-limit switches shall be manually-reset.

D. Constant Volume Control:

1. Systems shall consist of an air flow measuring station along with such relays and auxiliary devices as required to produce a complete functional system. The transmitter shall receive its air flow signal and static pressure signal from the flow measuring station and shall have a span not exceeding three times the design flow rate. The CU shall receive the transmitter signal and shall provide an output to the fan volume control device to maintain a constant flow rate. The CU shall provide proportional plus integral (PI) (automatic reset) control mode and where required also inverse derivative mode. Overall system accuracy shall be plus or minus the equivalent of 2 Pascal (0.008 inch) velocity pressure as measured by the flow station.

E. Airflow Synchronization:

1. Systems shall consist of an air flow measuring station for each supply and return duct, the CU and such relays, as required to provide a complete functional system that will maintain a constant flow rate difference between supply and return air to an accuracy of ±10%. In systems where there is no suitable location for a flow measuring station that will sense total supply or return flow, provide multiple flow stations with a differential pressure transmitter for each station. Signals from the multiple transmitters shall be added through the CU such that the resultant signal is a true representation of total flow.
2. The total flow signals from supply and exhaust air shall be the input signals to the CU. This CU shall track the return air fan capacity in proportion to the supply air flow under all conditions.

2.18 SPECIAL CONTROLLERS (IF REQUIRED IN PROJECT DRAWINGS)

A. Laboratory rooms and the fume hoods in those rooms shall be controlled to allow for a variable flow of conditioned air into the room, general exhaust from the room, and exhaust through the fume hood while maintaining a safe face velocity at the hood sash opening and proper space pressurization.

B. **Room Fixed Offset Flow Control:** Laboratory rooms and the fume hoods in those rooms shall be controlled to allow for a variable flow of conditioned air into the room, general exhaust from the room, and exhaust through the fume hood while maintaining a safe face velocity at the hood sash opening and proper space pressurization.

1. **OFFSET Controller:**
   a. Controls supply and General Exhaust for Room Balance.
   b. Controls reheat and supply air volume for temperature control.
   c. Unoccupied mode reduces supply volume.
   d. Controls venturi valves.
   e. Analog and relay outputs for flow.
   f. Analog and relay outputs for pressure.
   g. BACnet Communications.
   h. Alarm Contacts: SPST (NO), Mac Current 5A, Max Voltage 150 VDC, 250 VAC., Min switch load 10ma, 5DC.
   i. Flow Inputs: (4) Supply Flows, (2) General Exhaust Flow, (7) Fume Hood flows.
   j. Electric actuator/venturi valve assembly-See Section 23 3600 for venturi valve specification.
   k. Temperature Input: 1000 Ω platinum RTD.
   l. Digital interface module, cabling, transformer and transformer cabling.
   m. TSI SureFlow Model 8682 Offset Controller or approved substitute.

C. **Fume Hood Exhaust Air Controller:** The air flow through the open face of the hood, regardless of sash position, shall be controlled at a face velocity between 30 to 36 meter per minute (100 fpm and 120 fpm). A velocity sensor controller located in a sampling tube in the side wall of the hood shall control a damper in the hood discharge to maintain the face velocity.

1. Face Velocity Controller:
   a. Maintains constant face velocity with direct face velocity measurements to provide continuous, closed loop control.
   b. Provides audible and visual local alarms.
   c. High and low alarm contacts.
   d. Setback Input.
   e. Emergency Input.
   f. Analog output.
   g. BACnet MSTP Communications.
   h. Damper Min & Max.
   i. Display Range: 0 to 1000 fpm.
   j. Low range alarm: 5 to 980 fpm.
   k. High alarm range: 80 to 1000 fpm.
   l. No Flow Alarm Range: 5 to 1000 fpm.
   m. Alarm Contacts: SPST (NO), Max current 5A, Max voltage: 150 VDC, 250 VAC, Min switch load: 10mA, 5VDC.
   n. Sidewall pressure sensor, cabling, transformer and transformer cabling.
   o. Electric actuator/venturi valve assembly-See Section 23 3600 for venturi valve specification.
   p. TSI SureFlow Model 8650 Face Velocity Controller or approved substitute.

D. **Room Differential Pressure Controller**: The differential pressure in the Animal Procedure and Tissue Culture Rooms shall be maintained by controlling the quantity of air exhausted from or supplied to the room. A sensor-controller shall measure and control the velocity of air flowing into or out of the room through a sampling tube installed in the wall separating the room from the adjacent space, and display the value on its monitor. The sensor controller shall meet the following as a minimum:
   1. Operating range: -0.200000 to +0.20000 inches of water
   2. Resolution: 5 percent of reading
   3. Accuracy: +/- 10 percent of reading +/- 0.00001 inches of water
   4. Analog output: 0-10 VDC or 4-20 ma
   5. Operating temperature range: 32-120 degrees F
   6. Adaptive OFFSET Controller:
      a. Controls supply and General Exhaust for Room Balance.
      b. Controls reheat and supply air volume for temperature control.

c. Unoccupied mode reduces supply volume.
d. Controls venturi valves.
e. Analog and relay outputs for flow.
f. Analog and relay outputs for pressure.
g. BACnet Communications.
h. Alarm Contacts: SPST (NO), Mac Current 5A, Max Voltage 150 VDC, 250 VAC., Min switch load 10ma, 5DC.
i. Flow Inputs: (4) Supply Flows, (2) General Exhaust Flow, (7) Fume Hood flows.
j. Electric actuator/venturi valve assembly-See Section 23 3600 for venturi valve specification.
k. Temperature Input: 1000 Ω platinum RTD
l. Digital interface module, through-the-wall TSI pressure sensor, cabling, transformer and transformer cabling.
m. TSI SureFlow Model 8682 Adaptive Offset Controller or approved substitute.

2.19 FINAL CONTROL ELEMENTS AND OPERATORS

A. Fail Safe Operation: Control valves and dampers shall provide "fail safe" operation in either the normally open or normally closed position as required for freeze, moisture, and smoke or fire protection.

B. Power Operated Control Dampers (other than VAV Boxes): Factory fabricated, balanced type dampers. All modulating dampers shall be opposed blade type and gasketed. Blades for two-position, duct-mounted dampers shall be parallel, airfoil (streamlined) type for minimum noise generation and pressure drop.

1. Leakage: maximum leakage in closed position shall not exceed 7 L/S (15 CFMs) differential pressure for outside air and exhaust dampers and 200 L/S/ square meter (40 CFM/sq. ft.) at 50 mm (2 inches) differential pressure for other dampers.
2. Blades shall be galvanized steel or aluminum, 200 mm (8 inch) maximum width, with edges sealed as required.
3. Bearing shall be nylon, bronze sleeve or ball type.
4. Hardware shall be zinc-plated steel. Connected rods and linkage shall be non-slip. Working parts of joints shall be brass, bronze, nylon or stainless steel.

C. Operators shall be electric as required for proper operation.

1. See drawings for required control operation.

2. Metal parts shall be aluminum, mill finish galvanized steel, or zinc plated steel or stainless steel.
3. Maximum air velocity and pressure drop through free area the dampers:
   a. Smoke damper in air handling unit; 210 meter per minute (700 fpm).
   b. Duct mounted damper; 600 meter per minute (2000 fpm).
   c. Maximum static pressure loss, 50 Pascal (0.20 inches water gage).

D. Smoke Dampers and Combination Fire/Smoke Dampers: Dampers and operators are specified in Section 23 31 00, HVAC DUCTS AND CASINGS. Control of these dampers is specified under this Section.

E. Control Valves:
1. Valves shall be rated for a minimum of 150 percent of system operating pressure at the valve location but not less than 900 kPa (125 psig).
2. Valves 50 mm (2 inches) and smaller shall be bronze body with threaded or flare connections.
3. Valves 60 mm (2 1/2 inches) and larger shall be bronze or iron body with flanged connections.
4. Brass or bronze seats except for valves controlling media above 100 degrees C (210 degrees F), which shall have stainless steel seats.
5. Flow characteristics:
   a. Three way valves shall have a linear relation or equal percentage relation of flow versus value position.
   b. Two-way valves position versus flow relation shall be linear for steam and equal percentage for water flow control.
6. Maximum pressure drop:
   a. Two position steam control: 20 percent of inlet gauge pressure.
   b. Modulating Steam Control: 80 percent of inlet gauge pressure (acoustic velocity limitation).
   c. Modulating water flow control, greater of 3 meters (10 feet) of water or the pressure drop through the apparatus.
   d. Two position water valves shall be line size.

F. Damper and Valve Operators and Relays:
1. Electric damper operator shall provide full modulating control of dampers. A linkage and pushrod shall be furnished for mounting the actuator on the damper frame internally in the duct or externally in

the duct or externally on the duct wall, or shall be furnished with a direct-coupled design.

2. Electronic damper operators: VAV Box actuator shall be mounted on the damper axle or shall be of the air valve design, and shall provide complete modulating control of the damper. The motor shall have a closure torque of 35-inch pounds minimum with full torque applied at close off to attain minimum leakage.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Examine project plans for control devices and equipment locations; and report any discrepancies, conflicts, or omissions to COR for resolution before proceeding for installation.
2. Work Coordination: Section 00 72 00, GENERAL CONDITIONS.
3. Install equipment, piping, and wiring/conduit parallel to or at right angles to building lines.
4. Install all equipment and piping in readily accessible locations. Do not run tubing and conduit concealed under insulation or inside ducts.
5. Mount control devices, tubing and conduit located on ducts and apparatus with external insulation on standoff support to avoid interference with insulation.
6. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.
7. Run tubing and wire connecting devices on or in control cabinets parallel with the sides of the cabinet neatly racked to permit tracing.
8. Install equipment level and plum.

B. Electrical Wiring Installation (by Division 23 0923):

1. Install conduits and wiring in accordance with Specification Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS. Conduits carrying control wiring and cabling shall be dedicated to the control SYSTEMS. Wiring and cabling: these conduits shall not carry power wiring. Provide plastic end sleeves at all conduit terminations to protect wiring from burrs.
2. Install signal and communication cables in conduit and in accordance with Specification Section 26 05 21. Install digital communication cables in conduit and in accordance with Specification Section 27 15

00, Communications Horizontal Cabling and in accordance with Specification Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW).

3. Furnish and install all conduit, wire and connect ALL controls and devices operating below 125-volts in accordance with approved wiring diagrams.
4. Furnish and install ALL conduit and wiring between control panels, pressure sensors, differential room pressure monitors, control motor-actuators, electronic valves, electronic dampers, terminal VAV/constant volume controllers, Fixed Offset Pressure Controllers, Room Pressure Controllers and Venturi Valves, electric fire/smoke dampers and control transformers.
5. Coordinate with Division 26 for spare breakers in emergency electrical panels to power required circuits.
6. Install conduit and wiring between existing network, digital controllers, electrical panels, indicating devices, instrumentation, miscellaneous alarm points, thermostats, and relays as shown on the drawings or as required under this section.
7. Install all electrical work required for a fully functional system and not shown on electrical plans or required by electrical specifications. Where low voltage (less than 50 volt) power is required, provide suitable Class B transformers.
8. Install all system components in accordance with local Building Code and National Electric Code.
   a. Splices: Splices in shielded and coaxial cables shall consist of terminations and the use of shielded cable couplers. Terminations shall be in accessible locations. Cables shall be harnessed with cable ties.
   b. Equipment: Fit all equipment contained in cabinets or panels with service loops, each loop being at least 300 mm (12 inches) long. Equipment for fiber optics system shall be rack mounted, as applicable, in ventilated, self-supporting, code gauge steel enclosure. Cables shall be supported for minimum sag.
   c. Cable Runs: Keep cable runs as short as possible. Allow extra length for connecting to the terminal board. Do not bend flexible coaxial cables in a radius less than ten times the cable outside diameter.

d. Use vinyl tape, sleeves, or grommets to protect cables from vibration at points where they pass around sharp corners, through walls, panel cabinets, etc.

9. Conceal cables, except in mechanical rooms and areas where other conduits and piping are exposed.
10. Permanently label or code each point of all field terminal strips to show the instrument or item served. Color-coded cable with cable diagrams may be used to accomplish cable identification.
11. Grounding: ground electrical systems per manufacturer's written requirements for proper and safe operation.
12. All Low Voltage control cabling shall be "GREEN" in color.

C. Install Sensors and Controls:

1. Temperature Sensors:
   a. Install all sensors and instrumentation according to manufacturer's written instructions. Temperature sensor locations shall be readily accessible, permitting quick replacement and servicing of them without special skills and tools.
   b. Calibrate sensors to accuracy specified, if not factory calibrated.
   c. Use of sensors shall be limited to its duty, e.g., duct sensor shall not be used in lieu of room sensor.
   d. Install room sensors permanently supported on wall frame. They shall be mounted at 1.5 meter (5.0 feet) above the finished floor.
   e. Mount sensors rigidly and adequately for the environment within which the sensor operates. Separate extended-bulb sensors form contact with metal casings and coils using insulated standoffs.
   f. Sensors used in mixing plenum, and hot and cold decks shall be of the averaging of type. Averaging sensors shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip.
   g. All pipe mounted temperature sensors shall be installed in wells.
   h. All wires attached to sensors shall be air sealed in their conduits or in the wall to stop air transmitted from other areas affecting sensor reading.
   i. Permanently mark terminal blocks for identification. Protect all circuits to avoid interruption of service due to short-circuiting or other conditions. Line-protect all wiring that comes from

external sources to the site from lightning and static electricity.

2. Pressure Sensors:
   a. Install duct static pressure sensor tips facing directly downstream of airflow.
   b. Install high-pressure side of the differential switch between the pump discharge and the check valve.
   c. Install snubbers and isolation valves on steam pressure sensing devices.
3. Actuators:
   a. Mount and link damper and valve actuators according to manufacturer’s written instructions.
   b. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed position.
   c. Check operation of valve/actuator combination to confirm that actuator modulates valve smoothly in both open and closed position.
4. Flow Switches:
   a. Install flow switch according to manufacturer’s written instructions.
   b. Mount flow switch a minimum of 5 pipe diameters up stream and 5 pipe diameters downstream or 600 mm (2 feet) whichever is greater, from fittings and other obstructions.
   c. Assure correct flow direction and alignment.

D. Installation of network:
1. Ethernet:
   a. The network shall employ Ethernet LAN architecture, as defined by IEEE 802.3. The Network Interface shall be fully Internet Protocol (IP) compliant allowing connection to currently installed IEEE 802.3, Compliant Ethernet Networks.
   b. The network shall directly support connectivity to a variety of cabling types. As a minimum provide the following connectivity: 100 Base TX (Category 5e cabling) for the communications between the ECC and the B-BC and the B-AAC controllers.

E. Installation of digital controllers and programming:
1. Provide a separate digital control panel for each major piece of equipment, such as air handling unit, pumping unit etc. Points used

for control loop reset such as outdoor air, outdoor humidity, or space temperature could be located on any of the remote control units.

2. Provide sufficient internal memory for the specified control sequences and trend logging. There shall be a minimum of 25 percent of available memory free for future use.
3. System point names shall be modular in design, permitting easy operator interface without the use of a written point index.
4. Provide software programming for the applications intended for the systems specified, and adhere to the strategy algorithms provided.
5. Provide graphics for each piece of equipment and floor plan in the building. This includes each air handling unit, fan, terminal unit, pumping unit etc. These graphics shall show all points dynamically as specified in the point list.

F. Framed Control Drawings:

1. Laminated control drawings including system control schematics, sequences of operation and panel termination drawings, shall be provided in panels and mounted in a suitable frame with a .125" Lexan polycarbonate cover for major pieces of equipment. Drawings should be of sufficient size to be easily read. If size of the drawing requires mounting outside of Panel in the Mechanical room, provide reference in Panel to drawing location in Mechanical Room. Terminal unit drawings shall be located in the central plant equipment panel or mechanical room panel. Include paper copy of points listing in slip folder attached inside panel door

3.2 SYSTEM VALIDATION AND DEMONSTRATION

A. As part of final system acceptance, a system demonstration is required (see below). Prior to start of this demonstration, the contractor is to perform a complete validation of all aspects of the controls and instrumentation system.

B. Validation

1. Prepare and submit for approval a validation test plan including test procedures for the performance verification tests. Test Plan shall address all specified functions of the ECC and all specified sequences of operation. Explain in detail actions and expected results used to demonstrate compliance with the requirements of this specification. Explain the method for simulating the necessary conditions of operation used to demonstrate performance of the

system. Test plan shall include a test check list to be used by the Installer's agent to check and initial that each test has been successfully completed. Deliver test plan documentation for the performance verification tests to the owner's representative 30 days prior to start of performance verification tests. Provide draft copy of operation and maintenance manual with performance verification test.

2. After approval of the validation test plan, installer shall carry out all tests and procedures therein. Installer shall completely check out, calibrate, and test all connected hardware and software to insure that system performs in accordance with approved specifications and sequences of operation submitted. Installer shall complete and submit Test Check List.

C. Demonstration

1. System operation and calibration to be demonstrated by the installer in the presence of the COR on random samples of equipment as dictated by the COR. Should random sampling indicate improper testing, the owner reserves the right to subsequently witness complete calibration of the system at no addition cost to the VA.
2. Demonstrate to authorities that all required safeties and life safety functions are fully functional and complete.
3. Make accessible, personnel to provide necessary adjustments and corrections to systems as directed by balancing agency.
4. The following witnessed demonstrations of field control equipment shall be included:
   a. Observe HVAC systems in shut down condition. Check dampers and valves for normal position.
   b. Test application software for its ability to communicate with digital controllers, operator workstation, and uploading and downloading of control programs.
   c. Demonstrate the software ability to edit the control program off-line.
   d. Demonstrate reporting of alarm conditions for each alarm and ensure that these alarms are received at the assigned location, including operator workstations.
   e. Demonstrate ability of software program to function for the intended applications-trend reports, change in status etc.

f. Demonstrate via graphed trends to show the sequence of operation is executed in correct manner, and that the HVAC systems operate properly through the complete sequence of operation, e.g., seasonal change, occupied/unoccupied mode, and warm-up condition.
g. Demonstrate hardware interlocks and safeties functions, and that the control systems perform the correct sequence of operation after power loss and resumption of power loss.
h. Prepare and deliver to the VA graphed trends of all control loops to demonstrate that each control loop is stable and the set points are maintained.

5. Demonstrate that each control loop responds to set point adjustment and stabilizes within one (1) minute. Control loop trend data shall be instantaneous and the time between data points shall not be greater than one (1) minute.
6. Witnessed demonstration of ECC functions shall consist of:
   a. Running each specified report.
   b. Display and demonstrate each data entry to show site specific customizing capability. Demonstrate parameter changes.
   c. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.
   d. Execute digital and analog commands in graphic mode.
   e. Demonstrate DDC loop precision and stability via trend logs of inputs and outputs (6 loops minimum).
   f. Demonstrate EMS performance via trend logs and command trace.
   g. Demonstrate scan, update, and alarm responsiveness.
   h. Demonstrate spreadsheet/curve plot software, and its integration with database.
   i. Demonstrate on-line user guide, and help function and mail facility.
   j. Demonstrate digital system configuration graphics with interactive upline and downline load, and demonstrate specified diagnostics.
   k. Demonstrate multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
   l. Demonstrate class programming with point options of beep duration, beep rate, alarm archiving, and color banding.

3.3 START-UP AND COMMISSIONING

A. When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line. All testing, calibrating, adjusting and final field tests shall be completed by the installer. Verify that all systems are operable from local controls in the specified failure mode upon panel failure or loss of power.

B. Provide any recommendation for system modification in writing to COTR. Do not make any system modification, including operating parameters and control settings, without prior approval of COTR.

3.4 SPARE PARTS:

A. Contractor shall provide the VA controls related spare parts as shown below:

1. 3 Hot Water valve actuators,
2. 2 Terminal Unit Controllers,
3. 3 Wall Temperature Sensor,
4. 3 Wall Humidity Sensor,
5. Provide 2 spare digital controller (CU) boards and spare I/O boards as required. It shall be possible for trained hospital personnel to replace CU boards and load software via the Laptop computer or the ECC.
6. Provide a minimum of one spare digital controller board of each type and associated parts including batteries to make at least one complete set of DDC control equipment spares.
7. If I/O boards are separate from the CU boards, provide two spare I/O boards for each spare CU board provided above.
8. 4. Provide 2 controllers plus expansion modules that would support 2 full size AHUs, and 4 VAV Terminal Units. Including all sensors.

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SECTION TABLE OF CONTENTS

DIVISION 23 – HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)

SECTION 23 09 93
HVAC CONTROLS SEQUENCE OF OPERATIONS, FOR TVHS

PART 1 - GENERAL

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

--End of Section—

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SECTION 23 09 93
HVAC CONTROLS SEQUENCE OF OPERATIONS, FOR TVHS

PART 1 - GENERAL

1.1 SECTION INCLUDES

A. Air Handling Units

B. Chilled Water System

C. Terminal Units

D. Exhaust Fans

E. Heat Exchangers

1.2 RELATED DOCUMENTS:

A. Drawings and general provisions of Contract, including the General Conditions and other Division-1 Specification Sections, apply to this Section.

B. Section 230911 - Basic Mechanical Requirements

C. Section 230923 – Direct Digital Control (DDC) for HVAC

D. Section 230711 – TAB for HVAC

E. Section 230800 – BAS Commissioning

1.3 SUMMARY: This Section includes control sequences for HVAC systems, subsystems, controls and equipment.

1.4 SUBMITTALS:

A. Refer to Section 230923 and Division 1 for requirements for control shop drawings, product data, Users Manuals, etc.

B. Programming Manuals: Provide DDC system programming manual as well as documentation of site-specific programming prior to the start of Acceptance Phase.

1.5 PROJECT RECORD DOCUMENTS:

A. Within two weeks of the completion of commissioning, provide record documents to represent the final control configuration with actual setpoints and tuning parameters as existed at acceptance.

B. Record documents shall be modified control drawings with the actual installed information. Drawings shall be delivered in both reproducible hard copy and electronic format in AutoCAD drawing files. Provide all supporting files, blocks, fonts, etc. required by the drawings.

C. Provide final points list as described in this spec section and installed with this project.

D. Provide final detailed wiring diagrams with all wire numbers and termination points indicated. On floor plans, show location of all

wiring and cable routing, repeaters, junction boxes, vertical penetrations and controllers. Also show locations of static pressure sensors, T-stats, TU boxes, EF's, AHU sensors, etc.

E. Accurately record final sequences and control logic made after submission of shop drawings.

PART 2 - PRODUCTS, (Not Used)

PART 3 - EXECUTION

3.1 GENERAL

A. Sequences specified herein indicate the functional intent of the systems operation and may not fully detail every aspect of the programming that may be required to obtain the indicated operation. Contractor shall provide all programming necessary to obtain the sequences/system operation indicated.

B. When an air handling unit is not in operation, control devices shall remain in their "off" positions. "Off" positions may differ from the "normal" (meaning failed) position. Except as specified otherwise, "off" and "normal" positions of control devices shall be as follows:

Device	"Off"	"Normal"
Heating coil valves	**closed**	**open**
Cooling coil valves	**closed**	**closed**
Steam coil valves	**closed**	**closed**
Outside air damper	**closed**	**closed**
Return air damper	**open**	**open**
Exhaust/relief air	**closed**	**closed**

C. Variable Frequency Drives: For a VFD dependent on an external input for its output setting (e.g. the VFD gets "Frequency" as an input), loss of that external input shall result in the VFD shall go to its minimum speed setting, and a loss of signal alarm shall be generated. VFD points should also include BACnet info to/from VFD for input speed, actual speed, fault, start, start, KW, energy and belt brake alarm, if used.

D. All PID loop control of VFDs shall be by the Digital Control Panel or DCP Controller serving the VFD. All calculations and adjustments are to be available in the DCP controller.

E. Except as specified otherwise, throttling ranges, proportional bands, and cycle differentials shall be centered on the associated setpoint. All modulating feedback control loops

shall include the capability of having proportional, integral, and derivative (PID) action. Unless the loop is specified "proportional only" or "P+I", Contractor shall apply appropriate elements of integral and derivative gain to each control loop which shall result in stable operation, minimum settling time, and shall maintain the primary variable within the specified maximum allowable variance.

F. Provide a real time clock and schedule controller with sufficient scheduling capability to schedule all required controllers and sequences. Schedule functionality may reside in the controllers. Set up initial schedules in coordination with VA Project COR.

G. Scheduling Terminology: When air handlers are scheduled throughout the day, the following defines the terminology used:

1. **Occupied Period:** period of time when the space is in use and occupied. Unless indicated otherwise, this period is defined as 7:00 AM – 5:00 PM weekdays. Exclude all national holidays. Generally systems will be fully operational throughout this period and ventilation air shall be continuously introduced. Space temperature setpoints will generally be in the "normal" range of 69°-76°F. Setpoints for Medical Clinic areas will be as required for clinical areas (Ref VA HVAC design guide). Coordinate actual setpoints with VA COR.
2. **Unoccupied period:** period of time when the building or zone is not in use and unoccupied. Ventilation air shall not be introduced, except to meet exhaust demand and building pressure requirement.
3. **Preoccupancy Period (Warn-up or Cooldown):** Time prior to the Occupied period when the systems are returning the space temperatures from setback to "normal" or occupied setpoints (warm-up and cool-down). Ventilation air shall not be introduced, except for exhaust demand or unless outside air conditions permit free-cooling. Time period shall be determined by an optimum start strategy unless otherwise specified.

4. **Setback Period**: Setback will typically start with the end of the occupied period and end with the start of the preoccupancy period, however it shall be provided with its own schedule. Generally systems will be off except to maintain a "setback" temperature, economization may be enabled to maintain "setback" cooling setpoint when applicable.

H. Where any sequence or occupancy schedule calls for more than one AHU motorized unit to start simultaneously, the DCP start commands shall be staggered by 5 second (adj.) intervals to minimize inrush current.

I. Wherever a value is indicated as adjustable (adj.), it shall be modifiable, with the proper password level, from the ECC frontend menu. For these points, it is unacceptable to have to modify programming statements to change the setpoint.

J. Where "proof" or "prove operation" of a device (generally controlled by a digital output) is indicated in the sequence, it shall require that the DCP shall, after an adjustable time delay after the device is commanded to operate (feedback delay) , confirm that the device is operational via the status input. If the status point does not confirm operation after the time delay or anytime thereafter for an adjustable time delay (debounce delay) while the device is commanded to run, proving a command status mismatch, an alarm shall be enunciated audibly and displayed graphically.

K. DDC shall provide for adjustable maximum rates of change for increasing and decreasing output from the following analog output points:
   a. Speed control of variable speed drives
   b. Control Reset Loop
   c. Valve Travel Limit

L. Wherever a value is indicated to be dependent on another value (i.e.: setpoint plus 5°F) DCP shall use that equation to determine the value. Simply providing a virtual point that the operator must set is unacceptable. In this case three virtual points shall be provided. One to store the parameter (5°F), one to store the setpoint, and one to store the value which is the result of the equation.

M. Controls contractor shall use control Simulation Software to test out all functions of the Sequence of Operations.

O. Modulated Load Shedding (MLS)

1. Programming shall be used to reduce load on non-critical (i.e. admin spaces, bridges, corridors …) during periods of very high OAT/humidity or Chiller Plant limitations due to equipment outages. MLS shall be implemented on each AHU or Terminal Unit impacted by this project. MLS shall include the following:
2. System shall include Modulated Load Shedding program that includes resets the AHU DAT set point and reset Terminal Unit dead-band temp setpoint based on Central Chilled Water loop Chilled Water Supply temperature and/or OAT. Shedding shall be implemented independently on each and every zone or piece of equipment connected to system.
3. Controls contractor shall install temp sensor on chilled water supply lines at two locations in Chilled Water Plant.
4. Operators shall be able to enable/disable each AHU and Terminal Unit for implementation of modulated load shedding. Provide AHU and Terminal Unit Summary Graphic pages showing load shedding status, set points, overrides, percent of load shed, etc. Operator with level 9 access shall be able to:
   - Enable/Disable each AHU and Terminal Unit for use of MLS,
   - Adjust reset values, with high and low values,
   - Enable/disable reset based on OAT,
5. Enable/Disable Manual Override (time limited implementation, with auto release) of MLS. For example, activating Manual Override would implement modulated load shedding for 4 hours (adj.) and then release to Auto.

P. Controller Diagnostic Software: Controller software shall include diagnostic software that checks memory and communications and reports any malfunctions.

Q. See specification section 23 09 23 for additional DDC details.

3.2 AIR HANDLING UNITS - GENERAL

A. **Logic Strategies**: The Digital Control Panel (DCP) shall fully control the air handlers. Generally the DCP shall energize the AHU (start the fans and activate control loops) as dictated for each air handler. The following indicates when and how the DCP shall energize the AHUs and control various common aspects of them. The following "logic strategies" shall be included by reference with each

air handler with specific clarifications as required for specific AHU:

1. **Scheduled Occupancy: DDC** shall determine the occupancy periods (occupied, unoccupied, preoccupancy, and setback) as defined above. The following details the common control aspects related to the scheduled occupancy.
   a) DCP shall energize the AHU during all occupied periods. Note that the beginning of the occupancy period shall be set sufficiently before the actual start of occupancy to obtain the required building component of ventilation per ASHRAE 62. Specific times shall be as directed by the A-E. Minimum OA flow setpoint shall be as scheduled on the drawings. "Normal" setpoints shall apply.
   b) **Unoccupied Period:** Minimum OA flow shall be: Not more than 50% of heating setpoint CFM, or 0 CFM and the minimum OA damper position shall be 0%. If during the unoccupied period there is a request for occupancy override, the occupancy mode shall become active for an adjustable period. The unoccupied period and the preoccupancy period will typically overlap.
   c) **Setback Period (if used):** The DCP shall de-energize the unit except as required to maintain a setback temperature as indicated in the individual sequences with a 5°F cycle differential. Generally, where setback temperatures apply in multiple zones, the worst zone shall control the system. Setback setpoints generally apply except during preoccupancy. If during the unoccupied period there is a request for occupancy override, the occupancy mode shall become active for an adjustable period.
   d) **Preoccupancy Period (Warn-up or Cooldown):** Use the below info, unless optimal start function is stated in the sequence of operations. The DCP shall energize the AHU continuously during the preoccupancy period. Minimum OA flow shall be 0 CFM

or the minimum OA damper position shall be 0%. "Normal" setpoints shall apply. Preoccupancy duration shall be one of the following methods. Default method shall be Optimized Start. Only use Fixed Method if specifically stated.

1) **Optimized Start:** Uses weather conditions and historical performance to adjust the warm-up or cooldown start time. Includes intelligent and adaptive algorithms to adjust start times.

2) **Fixed:** The duration of the preoccupancy period shall be reset at the DCP based on the outside air temperature as follows:

Outside Air	Preoccupancy Start
> 70˚F	1 to 2 hour early
60˚F to 70˚F	On time start
50˚F to 60˚F	30 minutes early
40˚F to 50˚F	1 to 1.5 hour early
30˚F to 40˚F	2 hour early start
< 30˚F	3 hour early start

3. **VAV Return Fan Capacity Control:** DCP shall control the output of the return fan as follows:

a) **Flow Tracking:** The return air fan shall run to maintain a return flow setpoint of the supply flow minus an offset value. The offset value shall be determined as follows:

1) **Fixed Differential:** It shall be fixed at the design minimum OA value.

2) **Differential Reset from Measured OA to Maintain Fixed OA:** It shall be reset to maintain the measured minimum OA flow at the design value any time the economizer mode is inactive. Whenever it is inactive, it shall be set to the value that existed when the unit became active.

b) **Rescaled Output Capacity Control:** The output for the return fan capacity control shall be rescaled from the output of the to the supply device such that the design minimum OA flow is maintained at both maximum and 50% flow conditions. The balancing contractor shall determine the coordinated output.

4. **National Weather Service Data**:
   All Air Handlers are provided with their own Outside Air Temperature and Humidity Sensors for standalone operation. The local sensors are to be used only when in standalone operation and the local intranet is down. During normal operations and communications, the Outside Air Temperature and Humidity values shall be derived from the National Weather Service via the Internet. It is the responsibility of this contractor to pull the NWS Data through the existing ECC for use for Economizer, Reset, or Summer/Winter switchover.
   If the NWS Data fails to update due to connectivity issues, the Local Outside Air Temperature Sensor and Humidity Sensor shall Automatically take over. Once the NWS Data stream is restored the local controller shall revert back to using the NWS data for sequence decision making. The NWS Data as well as the local OAT and OARH shall be displayed on the Web page graphic, as well as which value is under control on the graphic.
5. **Airside Economizer: DCP** shall modulate the mixing dampers to provide "free cooling" when conditions merit. The free cooling shall generally be staged before any mechanical cooling. While conditions merit, dampers shall be modulated in a DA PID loop to maintain mixed air temperature at setpoint. Economizer logic shall remain enabled during setback cooling where applicable.
6. **Sequenced Heating and Cooling: DCP** shall control the heating and cooling coils and air side economizer as detailed for the particular AHU. Program logic shall directly prohibit the heating and cooling valves as well as the heating valve and economizer damper to be open (or above minimum) simultaneously. This does not apply to cooling and reheat valves that are used simultaneously for dehumidification.
7. **Mixed Air Low Limit Override**: DCP shall override the signal to the OA damper via a proportional only loop to maintain a minimum mixed air temperature of 45°F (adj.).

8. **Freeze Safety:** Upon operation of a freezestat, unit shall be de-energized with the exception of the heating loops. Typically supply and return fans where applicable shall be de-energized via a hardwired interlock, and an indication of the operation shall be sensed by the DCP. DCP shall enunciate appropriate alarm and remove and lock out the start command, which shall initiate "fan failure" alarms. OA dampers shall close, RA dampers shall open, all hydronic valves shall open and heating loops shall remain active.
9. **Control Valve Positioning:**
   All Hot Water and Chilled Water Control Valves shall be stroked from 0% to 100% each day, in the smallest duration possible, before being returned to automatic control. This can be accomplished at a scheduled unoccupied time, or at a particular time interval at a predetermined time. This is to ensure that valves are locked into a controllable range due to limited use or oversizing.
10. **Energy Usage Dashboard:**
    Program an Energy Dashboard to display each energy used by AHU's installed with this project. This includes chilled water, steam, and fan (via info from VFDs) energy. Totalized energy used should be displayed in BTU's, MBTU's or MMBTU's for hour over hour, day of day, month of month and year over year should be displayed in table and graph form. Includes tables, bar charts, and pie charts of energy information. Include reports that can be printed out.

3.3 TERMINAL UNITS - GENERAL

A. **Logic Strategies:** The Digital Control Panel (DCP) shall fully control the terminal units (VAV's, FCU's, etc.). See below VAV sequence of operations and logic strategies for terminal units.

1. **Scheduled Occupancy: DDC** shall determine the occupancy periods (occupied, unoccupied, preoccupancy, and setback) as defined above. The following details the

common control aspects related to the scheduled occupancy.

a) DCP shall energize terminal units during all occupied periods. Note that the beginning of the occupancy period shall be set sufficiently before the actual start of occupancy to obtain required space temperatures before the normal occupied times.

b) **Unoccupied Period:** HVAC Operator with level 9 access shall be able to select between:

- Not more than 50% of heating setpoint CFM (adj.), or
- 0 CFM

c) **Preoccupancy Period (Warn-up or Cooldown):** The DCP shall energize the terminal unit continuously during the preoccupancy period and "Normal" setpoints shall apply. Preoccupancy duration shall be based on optimized start logic that uses weather conditions and each terminal unit's historical performance to adjust the warm-up or cooldown start time. Includes intelligent and adaptive algorithms to adjust start times.

3.4 AHUs with Return Air (AHU- 2, & 3B):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), outside air damper (D-3) and min outside air damper (D-4) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3), min outside air damper (D-4), face and bypass (F&DP) damper shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be

overridden whether stated or not in the sequence via the graphical user interface. :

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
   H. Or the AHU is selected to run 24/7 in lieu of the schedule.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the min OA damper (D-4), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.
   D. Close the humidifier valve whenever the supply fan is off (command or status).
   E. Close the CHW valve.
3. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between

the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-22) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV's with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV's that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-18), shall be maintained by modulating chilled water valve (V-2) and control of F&BP dampers with pre-heat valve (V-1) as discussed below:

i. If the Outside Air temperature is less than the F&BP switchover setpoint of 40°F (adj.) the pre-heat valve (V-1) shall follow one of the following sequences and the F&BP dampers shall be modulated to maintain DAT setpoint.

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valve (V-1) shall open from a minimum of 10% open to a maximum of 100% open. The F&BP dampers shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valve (V-1) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valve (V-1) shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override

shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than or equal to the F&BP switchover setpoint of 40°F (adj.) the F&BP damper will be open to full face with pre-heat valve (V-1) modulated to maintain the DAT setpoint.

iii. Above 50°F (adj.) the pre-heat coil valve (V-1) shall be closed.

iv. Heating control valves shall be modulated via PID control loop to maintain the supply DAT.

v. Pre-heat valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

vi. The Pre-heat valve and F&BP dampers (if present) shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

vii. Adjusting any of the above temperature values shall require Technical Design Level User access.

viii. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. <u>Economizer Mode, Mixed Air Temperature Control:</u>

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-18). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-25) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-5),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-25) and outside air moisture transmitter (MT-26), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6).

Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the

Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-4) to minimum position, return air damper (D-2) shall open and minimum OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3 and D-4) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3 and 4) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler

ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by return air humidity (MT-6), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.
      ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-5) and humidity transmitter (MT-6) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-12). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
   B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.
      i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
      ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.
7. Other Operating Modes:
   A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function

of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the

digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-11) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-12) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-12 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-12 will require manual reset at the device. The OA damper, Minimum OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.
   A. On freezestat trip:
   B. Shut down the supply fan and shut down the return fan.
   C. Close the OA and Minimum OA dampers, close the relief air damper, and open the RA damper.
   D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.
   E. Open preheat coil face and bypass dampers to full face. (Should this be to full Bypass, with no air movement I am thinking about stratification in the plenum)
   F. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   G. Return the unit to normal operation when freezestat is manually reset.
9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
   E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
   F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
   G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-11) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-11) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall

reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)
(2). Previous day,
(3). Week to date,
(4). Previous week,
(5). Year to date,
(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.5 AHUs with 100% Outside Air - AHU-6: (Not in this contract)

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto"

position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" outside air damper (D-1) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" outside air damper (D-1), shall open 100% in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface. :

1. AHU Operational Conditions:
   A. The AHU shall run continuously.
   B. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   C. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-1).
   C. Modulate the preheat coil valve (V-1) to maintain AHU cabinet temperature at 50° F as sensed by the PHT sensor (TT-12).
   D. Close the humidifier valve whenever the supply fan is off (command or status).
   E. Close the CHW valve (V-2).
3. Airflow Control,
   A. Occupied Mode:
      i. The supply shall run continuously. The supply fans speed shall be modulated to maintain the supply CFM (adj.). The fan shall set to maintain a constant airflow. The outside air (OA) damper shall open to maintain minimum ventilation requirements.
      ii. High pressure sensor (PSH-16) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will

require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

4. Temperature control:

A. Steam Pre-Heating (non-freeze type): Operate preheat coil, and cooling coil in sequence to maintain supply discharge air temperature (DAT) setpoint. DAT sensed by temperature sensor (TT-5), shall be maintained by modulating chilled water valve (V-2) and pre-heat valve (V-1) as discussed below:

i. If the OA temperature is less than 40°F (adj.) the Pre Heat Valve (V-1) will be open to 100% to maintain the DAT setpoint.

ii. If the OA temperature is greater than 40°F (adj.), but less than 55°F (adj.), the Pre Heat Valve (V-1) will be modulated between 0% and 100% to maintain the DAT setpoint.

iii. If the OA temperature is greater than 55°F (adj.) the Pre Heat Valve (V-1) will be closed and the Chilled Water Valve (V-2) will modulate between 0% and 100% to maintain the DAT setpoint.

iv. Pre-heat valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously.

v. Discharge Air Temperature Control Loop shall be controlled via a PID Control Loop to maintain the supple air temperature.

vi. Adjusting any of the above temperature values shall require Technical Design Level User access.

vii. Low Preheat Fault Alarm: If the preheat is enabled and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. Supply Air Temperature Reset:

i. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions, but shall be overridden if more than one zone served begins to overheat.. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by the Space Humidity (MT-19), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall modulate open.
      II. The space dew point setpoint is 45 DegF.
      iii. Space humidity shall be maintained at setpoint of 45 DegF dew point (adj.) via DCP by modulating control valve (V-3) to maintain the desired humidity. The dry bulb transmitter (TT-18) and humidity transmitter (MT-19) in the space shall be used to calculate space dew point.
      iv. The DCP shall override this control to maintain duct supply humidity no higher than 90% as sensed by duct humidity sensor (MT-2).
      v. DCP shall close valve V-3 whenever the supply fan is off.
      vi. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
6. Other Operating Modes:
   A. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.
7. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-12) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-11) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-11 shall be hardwired to the supply fan and shall be shut down in hand, auto or bypass mode. TSL-11 will require manual reset at the device. The OA damper shall be closed.
   A. On freezestat trip:
   B. Shut down the supply fan.
   C. Close the OA damper.

D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the PHT sensor.

E. Open CHW valve to 20% for minimum flow.

F. Return the unit to normal operation when freezestat is manually reset.

8. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

A. Fan Failure: Commanded on, but the status is off.

B. Fan in Hand: Commanded off, but the status is on.

C. Fan VFD Fault.

D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.

E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.

F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.

G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Belt Break Alarm (if applicable)

9. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply duct shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply fan shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply fan shall restart when smoke detector circuit is reset.

10. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-12) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above

72°F, as sensed by pre-heat temperature sensor (TT-12) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply CFM airflow. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface (if Applicable): ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

3.6 AHUs with Return Air (AHU-7):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), outside air damper (D-3) and min outside air damper (D-4) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the

DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3), min outside air damper (D-4), face and bypass (F&DP) damper shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface. :

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
   H. Or the AHU is selected to run 24/7 in lieu of the schedule.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the min OA damper (D-4), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.
   D. Close the humidifier valve whenever the supply fan is off (command or status).

E. Close the CHW valve.

3. Airflow Control,

A. Occupied Mode:

i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-22) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-18), shall be maintained by modulating chilled water valve (V-2) and control of F&BP dampers with pre-heat valve (V-1) as discussed below:

i. If the Outside Air temperature is less than the F&BP switchover setpoint of 40°F (adj.) the pre-heat valve (V-1) shall follow one of the following sequences and the F&BP dampers shall be modulated to maintain DAT setpoint.

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valve (V-1) shall open from a minimum of 10% open to a maximum of 100% open. The F&BP dampers shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valve (V-1) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valve (V-1) shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than or equal to the F&BP switchover setpoint of 40°F (adj.) the F&BP damper will be open to full face with pre-heat valve (V-1) modulated to maintain the DAT setpoint.

iii. Above 50°F (adj.) the pre-heat coil valve (V-1) shall be closed.

iv. Heating control valves shall be modulated via PID control loop to maintain the supply DAT.

v. Pre-heat valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

vi. The Pre-heat valve and F&BP dampers (if present) shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

vii. Adjusting any of the above temperature values shall require Technical Design Level User access.

viii. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. <u>Economizer Mode, Mixed Air Temperature Control:</u>

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air

temperature setpoint as sensed by the temperature sensor (TT-18). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-25) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-5),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-25) and outside air moisture transmitter (MT-26), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-4) to minimum position, return air damper (D-2) shall open and minimum OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3 and D-4) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3 and 4) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal

units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. <u>Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:</u>

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and

humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:

A. Humidity control with Humidifier:

I. When the DCP is not calling for humidity, sensed by return air humidity (MT-6), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.

ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-5) and humidity transmitter (MT-6) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-12). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.

i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.

ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.

7. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU

shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-11) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-12) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-12 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-12 will require manual reset at the device. The OA damper, Minimum OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.
   A. On freezestat trip:
   B. Shut down the supply fan and shut down the return fan.
   C. Close the OA and Minimum OA dampers, close the relief air damper, and open the RA damper.
   D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.
   E. Open preheat coil face and bypass dampers to full face. (Should this be to full Bypass, with no air movement I am thinking about stratification in the plenum)
   F. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   G. Return the unit to normal operation when freezestat is manually reset.
9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded.

Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.

E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.

F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.

G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-11) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-11) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.7 AHUs with Return Air (AHU- 9):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), outside air damper (D-3) and min outside air damper (D-4) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3), min outside air damper (D-4), face and bypass (F&DP) damper shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface. :

1. <u>AHU Operational Conditions:</u>

A. Run the AHU in occupied mode to satisfy occupied status for any zone.

B. Index the AHU to unoccupied mode and do one of the following:

i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.

ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.

C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.

D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start

calculations.

E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.

F. Run the return fan any time the supply fan runs.

G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.

H. Or the AHU is selected to run 24/7 in lieu of the schedule.

2. AHU Shutdown:

A. On command or schedule.

B. Close the OA damper (D-3), close the min OA damper (D-4), close the exhaust/relief damper (D-1), and open the RA damper (D-2).

C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.

D. Close the humidifier valve whenever the supply fan is off (command or status).

E. Close the CHW valve.

3. Airflow Control,

A. Occupied Mode:

i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-2) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV's with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV's that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-4), shall be maintained by modulating chilled water valve (V-2) and control of F&BP dampers with pre-heat valves (V-1A, & 1B) as discussed below:

i. If the Outside Air temperature is less than the F&BP switchover setpoint of 40°F (adj.) the pre-heat valves (V-1A & 1B) shall follow one of the following sequences and the F&BP dampers shall be modulated to maintain DAT setpoint.

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valves (V-1A & 1B) shall open from a minimum of 10% open to a maximum of 100% open. The F&BP dampers shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valves (V-1A, & 1B) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valves (V-1A, & 1B) shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than or equal to the F&BP switchover setpoint of 40°F (adj.) the F&BP damper will be open to full face with pre-heat valves (V-1A, & 1B) modulated to maintain the DAT setpoint.

iii. Above 50°F (adj.) the pre-heat coil valves (V-1A, & 1B) shall be closed.

iv. Heating control valves shall be modulated via PID control loop to maintain the supply DAT.

v. The AHU has 1/3 and 2/3 Steam valves, then adjust control strategy to operate the 1/3 valve first to maintain DAT Setpoint, If the 1/3 steam valve has reached 100% open for 10 minutes and DAT setpoint is not maintained, then switch to modulate the 2/3 steam valve to maintain DAT setpoint, and closing the 1/3 valve. If the 2/3 steam valve has reached 100% open for 10 minutes and DAT setpoint is not maintained, then add the 1/3 valve in and modulate the 1/3 steam valve to maintain DAT setpoint.

vi. Pre-heat valves (V-1A, & 1B) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

vii. The Pre-heat valve and F&BP dampers shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

viii. Adjusting any of the above temperature values shall require Technical Design Level User access.

ix. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. <u>Economizer Mode, Mixed Air Temperature Control:</u>

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-18). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-8) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-29),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-8) and outside air moisture transmitter (MT-8), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-29) and return air moisture transmitter (MT-30). Enthalpy comparison mode (above) shall have an

enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-4) to minimum position, return air damper (D-2) shall open and minimum OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3 and D-4) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled,

but with OA dampers (D-3 and 4) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably

require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by return air humidity (MT-30), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.
      ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-29) and humidity transmitter (MT-30) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-1). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
   B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.
      i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-29) and return air moisture transmitter (MT-30) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
      ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.
7. Other Operating Modes:
   A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air

temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-21) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-16) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-16 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-16 will require manual reset at the device. The OA damper, Minimum OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.
   A. On freezestat trip:
   B. Shut down the supply fan and shut down the return fan.
   C. Close the OA and Minimum OA dampers, close the relief air damper, and open the RA damper.
   D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.
   E. Open preheat coil face and bypass dampers to full face. (Should this be to full Bypass, with no air movement I am thinking about stratification in the plenum)
   F. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   G. Return the unit to normal operation when freezestat is manually reset.
9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
   E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
   F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
   G. High duct static pressure trip.
   H. Freezestat trip.
   I. High DAT: If the DAT is 10 F greater than set point, provide a

warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-17) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-17) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired

setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)
(2). Previous day,
(3). Week to date,
(4). Previous week,
(5). Year to date,
(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.8 AHUs with Return Air (AHU- 20):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), outside air damper (D-

3) and min outside air damper (D-4) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3), min outside air damper (D-4) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface. :

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
   H. Or the AHU is selected to run 24/7 in lieu of the schedule.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the min OA damper (D-4), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Close the humidifier valve (V-3 & V-4) whenever the supply fan is

off (command or status).

D. Close the CHW valve (V-2).

3. Airflow Control,

A. Occupied Mode:

i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the total supply air (SA) CFM of both air flow measuring stations and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-22) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units.

Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of 0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-18). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-25) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-5),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-25) and outside air moisture transmitter (MT-26), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6). Enthalpy comparison mode (above) shall have an

enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-4) to minimum position, return air damper (D-2) shall open and minimum OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

B. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer is either disabled or fully open.

iv. AND the supply fan status is on.

v. The CHW valve shall open to 50% on activation of the freezestat with fans off.

C. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3 and D-4) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3 and 4) closed, until the zone

unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

D. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process

shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by return air humidity (MT-6), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.
      ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-5) and humidity transmitter (MT-6) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-12). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
   B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.
      i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
      ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.
7. Other Operating Modes:
   A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature

control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by mixed air temperature sensor (TT-7) falls below 44°F, an alarm signal shall indicate

at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-XX) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-XX shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-XX will require manual reset at the device. The OA damper, Minimum OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

A. On freezestat trip:
B. Shut down the supply fan and shut down the return fan.
C. Close the OA and Minimum OA dampers, close the relief air damper, and open the RA damper.
D. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
E. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

A. Fan Failure: Commanded on, but the status is off.
B. Fan in Hand: Commanded off, but the status is on.
C. Fan VFD Fault.
D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
G. High duct static pressure trip.
H. Freezestat trip.
I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.
J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.
K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is

initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by mixed air temperature sensor (TT-7) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by mixed air temperature sensor (TT-7) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.
IS SPACE PRESSURE CONTROL REQUIRED FOR AHU-24 – SPACE PRESSURE POINT ARE NOT LISTED FOR M4.XX

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration

and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)
(2). Previous day,
(3). Week to date,
(4). Previous week,
(5). Year to date,
(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.9 AHUs with Return Air (AHU-21):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), and outside air damper (D-3) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), and outside air

damper (D-3) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
   H. Or the AHU is selected to run 24/7 in lieu of the schedule.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Close the humidifier valve (V-3 & V-4) whenever the supply fan is off (command or status).
   D. Close the CHW valve (V-2).
3. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan

shall modulate to maintain a constant airflow difference between the total supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-XX) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV's with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV's that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches

4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of 0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-31). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-29) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-28),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-29) and outside air moisture transmitter (MT-30), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled.

After the startup time delay the outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, economizer dampers shall modulate open beyond the position required for minimum ventilation air.

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-3) to minimum position, and return air damper (D-2) shall modulate to maintain the minimum OA CFM setpoint.

B. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer is either disabled or fully open.

iv. AND the supply fan status is on.

v. The CHW valve shall open to 50% on activation of the freezestat with fans off.

C. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA damper (D-3) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

D. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads.

The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. <u>Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:</u>

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled

(i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. <u>Humidity Control:</u>

A. <u>Humidity control with Humidifier:</u>

I. When the DCP is not calling for humidity, sensed by return air humidity (MT-29), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.

ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-28) and humidity transmitter (MT-29) in return air shall be used to calculate return air humidity. The DCP shall override this control

to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-14). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.

i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.

ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.

7. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply

fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-10) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-10 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-10 will require manual reset at the device. The OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

A. On freezestat trip:

B. Shut down the supply fan and shut down the return fan.

C. Close the OA dampers, close the relief air damper, and open the RA damper.

D. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.

E. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
   E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
   F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
   G. High duct static pressure trip.
   H. Freezestat trip.
   I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.
   J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.
   K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.
   L. Duct static high limit trip.
   M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:
   A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut “off” and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.
   B. Exhaust fans serving area of the supply fan shall continue to run.
   C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.
   D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by mixed air temperature sensor (TT-15) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.
IS SPACE PRESSURE CONTROL REQUIRED FOR AHU-24 – SPACE PRESSURE POINT ARE NOT LISTED FOR M4.XX

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.10 AHUs with Return Air (AHU-23):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), and outside air damper (D-3) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:

A. Run the AHU in occupied mode to satisfy occupied status for any zone.

B. Index the AHU to unoccupied mode and do one of the following:

i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.

ii. Continue to run in unoccupied mode at a reduced static

pressure setpoint.

C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.

D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.

E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.

F. Run the return fan any time the supply fan runs.

G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.

H. Or the AHU is selected to run 24/7 in lieu of the schedule.

2. AHU Shutdown:

A. On command or schedule.

B. Close the OA damper (D-3), close the exhaust/relief damper (D-1), and open the RA damper (D-2).

C. Close the humidifier valve (V-3 & V-4) whenever the supply fan is off (command or status).

D. Close the CHW valve (V-2).

3. Airflow Control,

A. Occupied Mode:

i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the total supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-13) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV's with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV's that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) OR the true position of the VAV damper is greater than 95% open then OR the new space temperature sensor is above or below unoccupied H/Csetpoints the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of 0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-31). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-29) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-28),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-29) and outside air moisture transmitter (MT-30), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve

mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, economizer dampers shall modulate open beyond the position required for minimum ventilation air.

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-3) to minimum position, the return air damper (D-2) shall open, and shall modulate to maintain the minimum OA CFM setpoint.

B. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer is either disabled or fully open.

iv. AND the supply fan status is on.

v. The CHW valve shall open to 50% on activation of the freezestat with fans off.

C. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

D. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. <u>Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:</u>

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:

A. Humidity control with Humidifier:

I. When the DCP is not calling for humidity, sensed by return air humidity (MT-29), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.

ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-28) and humidity transmitter (MT-29) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-14). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.

i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29) sensor, shall override the cooling sequence above to maintain a

maximum of 60% RH (adj.) for the area served by the air handling unit.

ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.

7. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-10) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-10 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-10 will require manual reset at the device. The OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

   A. On freezestat trip:

   B. Shut down the supply fan and shut down the return fan.

   C. Close the OA damper, close the relief air damper, and open the RA damper.

   D. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.

   E. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

   A. Fan Failure: Commanded on, but the status is off.

   B. Fan in Hand: Commanded off, but the status is on.

   C. Fan VFD Fault.

   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.

E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.

F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.

G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by mixed air temperature sensor (TT-15) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.11 AHUs with Return Air (AHU- 24):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), and outside air damper (D-3) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. <u>AHU Operational Conditions:</u>

A. Run the AHU in occupied mode to satisfy occupied status for any zone.

B. Index the AHU to unoccupied mode and do one of the following:

i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.

ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.

C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.

D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.

E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.

F. Run the return fan any time the supply fan runs.

G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.

H. Or the AHU is selected to run 24/7 in lieu of the schedule.

2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Close the humidifier valve (V-3 & V-4) whenever the supply fan is off (command or status).
   D. Close the CHW valve (V-2).
3. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the total supply air (SA) CFM of both air flow measuring stations and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.
      ii. High pressure sensor (PSH-13) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.
      iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.
   B. Unoccupied Mode:
      i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.
      ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:
         (1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are

satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of 0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-31). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-29) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-28),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-29) and outside air moisture

transmitter (MT-30), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, economizer dampers shall modulate open beyond the position required for minimum ventilation air.

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-3) to minimum position, the return air damper (D-2) shall open, and shall modulate to maintain the minimum OA CFM setpoint.

B. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer is either disabled or fully open.

iv. AND the supply fan status is on.

v. The CHW valve shall open to 50% on activation of the freezestat with fans off.

C. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

D. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process

shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by return air humidity (MT-29), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.
      ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-28) and humidity transmitter (MT-29) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-14). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
   B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.
      i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
      ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.
7. Other Operating Modes:
   A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature

control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) falls below 44°F, an alarm signal shall

indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-10) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-10 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-10 will require manual reset at the device. The OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

A. On freezestat trip:
B. Shut down the supply fan and shut down the return fan.
C. Close the OA damper, close the relief air damper, and open the RA damper.
D. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
E. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

A. Fan Failure: Commanded on, but the status is off.
B. Fan in Hand: Commanded off, but the status is on.
C. Fan VFD Fault.
D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
G. High duct static pressure trip.
H. Freezestat trip.
I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.
J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.
K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is

initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by mixed air temperature sensor (TT-15) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure. Pressure relationship will be setup with RA Return Fan Capacity Control per specification section 23 09 90, PARA 3.2,A3, and TAB.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration

and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)
(2). Previous day,
(3). Week to date,
(4). Previous week,
(5). Year to date,
(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.12 AHUs with Return Air (AHU-28 & 29):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), outside air damper (D-3) and min outside air damper (D-4) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper

(D-2), outside air damper (D-3), and min outside air damper (D-4) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan wall any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan wall runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
   H. Or the AHU is selected to run 24/7 in lieu of the schedule.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the min OA damper (D-4), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.
   D. Close the humidifier valve whenever the supply fan wall is off (command or status).
   E. Close the CHW valve.

3. Airflow Control,

A. Occupied Mode:

i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-XX) located at the supply fan wall discharge shall prevent the supply fans from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan wall and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-5), shall be maintained by modulating chilled water valve (V-2) and control of pre-heat valve (V-1) as discussed below:

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valve (V-1) shall open from a minimum of 10% open to a maximum of 100% open, and shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valve (V-1) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valves (V-1)

shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than 50°F (adj.) the pre-heat coil valves (V-1) shall be closed.

iii. Heating control valve shall be modulated via PID control loop to maintain the supply DAT.

iv. Pre-heat valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

v. The Pre-heat valve shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

vi. Adjusting any of the above temperature values shall require Technical Design Level User access.

vii. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. <u>Economizer Mode, Mixed Air Temperature Control:</u>

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-5). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-26) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-XX),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-26) and outside air moisture transmitter (MT-27), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-XX) and return air moisture transmitter (MT-24).

Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan wall status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the

Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-4) to minimum position, return air damper (D-2) shall open and minimum OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan wall status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3 and D-4) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied

cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3 and 4) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan wall energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan wall energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably

require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by return air humidity (MT-24), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.
      ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-XX) and humidity transmitter (MT-24) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by SA duct humidity sensor (MT-24). DCP shall close valve V-3 whenever the supply fan wall is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
   B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.
      i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-XX) and return air moisture transmitter (MT-24) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
      ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.
7. Other Operating Modes:
   A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air

temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan wall shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan wall shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-14) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-13) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-13 shall be hardwired to the supply fan wall and return fan and both shall be shut down in hand, auto or bypass mode. TSL-13 will require manual reset at the device. The OA damper, Minimum OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.
   A. On freezestat trip:
   B. Shut down the supply fan wall and shut down the return fan.
   C. Close the OA and Minimum OA dampers, close the relief air damper, and open the RA damper.
   D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.
   E. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   F. Return the unit to normal operation when freezestat is manually reset.
9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
   E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
   F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
   G. High duct static pressure trip.
   H. Freezestat trip.
   I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.
   J. Low DAT: If the DAT is 10 F less than set point, provide a warning.

If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan wall shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-14) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-14) the supply fan wall and return fan shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)
(2). Previous day,
(3). Week to date,
(4). Previous week,
(5). Year to date,
(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.13 AHUs with 100% Outside Air – AHU-36:

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" outside air damper (D-1) shall be fully closed. The DCP shall send the controller occupied/unoccupied, and heat mode schedules. The discharge air temperature (DAT) setpoint shall be set at

the DCP. When the unit is "on" outside air damper (D-1), and face and bypass (D-2) damper shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, and valves shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy the space temperature setpoint.
   B. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   C. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-1), and position the Face and Bypass damper (D-2) to full bypass.
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the DAT sensor.
3. Temperature control:
   A. Occupied Control Mode for Steam Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point and Space Temperature Setpoint. DAT sensed by temperature sensor (TT-18), shall be maintained by control of F&BP (D-2) dampers with heating valves (V-1) as discussed below, while the space temperature shall be controlled by modulating the Supply Fan VFD Speed Control.:
      i. When the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 25°F (adj.) the pre-heat valve (V-1) shall open from a minimum of 15% open to a maximum of 100% open. The F&BP (D-2) dampers shall be modulated to maintain the DAT setpoint, while satisfying the Space Temperature Setpoint by modulating Supply Fan VFD Speed from 50% to 100% fan speed.

ii. If the OA temperature is greater than or equal to the F&BP switchover setpoint of 40°F (adj.) the F&BP damper (D-2) will be open to full face with heating valve (V-1) modulated from 15% to 100% to maintain the DAT setpoint, while satisfying the Space Temperature Setpoint from 50% to 100% fan speed.

iii. Above 50°F (adj.) the heating coil valve (V-1) shall be closed.

iv. Heating control valves shall be modulated via PID control loop to maintain the supply DAT.

v. The heating valve and F&BP dampers shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat. (If required)

vi. Adjusting any of the above temperature values shall require Technical Design Level User access.

vii. Low Heating Fault Alarm: If the heat is enabled and DAT is 10°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

viii. TAB process shall determine the final DAT limits and OAT limits.

ix. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

4. Freeze protection: If the air temperature as sensed by discharge temperature sensor (TT-18) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-XX) (If required) the supply and fan shall shut down and a critical alarm shall indicate at the digital control panel and ECC. TSL-XX shall be hardwired to the supply fan and shall be shut down in hand, auto or bypass mode. TSL-XX will require manual reset at the device. The OA damper shall be closed and the Face and Bypass damper will be at full bypass position.

A. On freezestat trip.

B. Shut down the supply fan.

C. Close the OA damper.

D. Open the heating valve and then modulate to maintain 55 °F as sensed by the DAT sensor.

E. Open heating coil face and bypass dampers to full bypass position.

F. Return the unit to normal operation when freezestat is manually reset.

5. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D.
   E. Freezestat trip. (If required)
   F. High DAT: If the DAT is 20 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.
   G. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.
   H. Low Space Temperature: If the space temperature is below 40 F, provide a warning. If the space temperature is below 32 F, initiate an alarm.
   I. Belt Break Alarm (if applicable)

6. Misc Control:
   A. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain space temperature setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.
      i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:
         (1). Day to date (total for the day)
         (2). Previous day,
         (3). Week to date,
         (4). Previous week,
         (5). Year to date,

(6). Previous year.

Proof: DCP shall prove supply fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

3.14 AHUs with Return Air (AHU-39, 40, & 41):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), and outside air damper (D-3) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), and outside air damper (D-3) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:

A. Run the AHU in occupied mode to satisfy occupied status for any zone.

B. Index the AHU to unoccupied mode and do one of the following:

i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.

ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.

C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.

D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.

E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.

F. Run the return fan any time the supply fan runs.

G. If ECC is not present, or communication is lost with the ECC

frontend the controller shall operate using default modes and setpoints.

H. Or the AHU is selected to run 24/7 in lieu of the schedule.

2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.
   D. Close the humidifier valve whenever the supply fan is off (command or status).
   E. Close the CHW valve.
3. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.
      ii. High pressure sensor (PSH-25) located at the supply fan discharge shall prevent the supply fans from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.
      iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.
   B. Unoccupied Mode:
      i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.
      ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU

shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-31), shall be maintained by modulating chilled water valve (V-2) and control of pre-heat valve (V-1) as discussed below:

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valve (V-1) shall open from a minimum of 10% open to a maximum of 100% open, and shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valve (V-1) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valves (V-1) shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than 50°F (adj.) the pre-heat coil valves (V-1) shall be closed.

iii. Heating control valve shall be modulated via PID control loop to maintain the supply DAT.

iv. Pre-heat valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

v. The Pre-heat valve shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

vi. Adjusting any of the above temperature values shall require Technical Design Level User access.

vii. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-31). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-29) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-28),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-29) and outside air moisture transmitter (MT-30), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, economizer dampers shall modulate open beyond the position required for minimum ventilation air.

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, return air damper (D-2) shall open and OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA damper (D-3) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating

capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA damper (D-3) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed

and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. <u>Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:</u>

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and

humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:

A. Humidity control with Humidifier:

I. When the DCP is not calling for humidity, sensed by return air humidity (MT-29), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.

ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-28) and humidity transmitter (MT-29) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by SA duct humidity sensor (MT-29). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.

i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.

ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.

7. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU

shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-31) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-10) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-10 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-10 will require manual reset at the device. The OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

   A. On freezestat trip:
   B. Shut down the supply fan and shut down the return fan.
   C. Close the OA, close the relief air damper, and open the RA damper.
   D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.
   E. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   F. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.

E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.

F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.

G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-31) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-31) the supply fan and return fan shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.15 AHUs with 100% Return Air AHU-47:

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/cool mode schedules. The discharge air temperature (DAT) setpoints shall be set at the DCP. When the unit is "on" hot water valve (V-1) and the chilled water valve (V-2) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on valves shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

7. AHU Operational Conditions:
   A. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   B. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   C. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
8. AHU Shutdown:
   A. On command or schedule.
   B. Modulate the heating coil valve to maintain AHU cabinet temperature at 50° F as sensed by the DAT sensor (TT-37).
   C. Close the CHW valve.
9. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply fan shall run continuously.
   B. Unoccupied Mode:
      i. During unoccupied periods the supply fan shall stop running.
10. Temperature control:
   A. Occupied Control Mode for Heating: Operate heating coil, and cooling coil valves in sequence to maintain supply discharge air

temperature (DAT) set point and space temperature setpoint. DAT sensed by temperature sensor (TT-31). Space Temperature setpoint shall be maintained by modulating chilled water valve (V-2) with hot water valve (V-1) as discussed below:

i. Hot water control valve shall be modulated via PID control loop to maintain the supply DAT and the space temperature setpoint.

ii. Hot Water valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously.

iii. Adjusting any of the above temperature values shall require Technical Design Level User access.

B. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or space temperature cooling request).

ii. AND the supply fan status is on.

iii. AND the preheating is disabled.

C. Unoccupied temperature mode:

i. When the space temperature drops below its unoccupied heating set point, start and run the AHU with DAT temperature control until the space unoccupied setpoint of 60°F (adj.) is satisfied.

ii. When the space temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation until the space unoccupied setpoint of 80°F (adj.) is satisfied.

1. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall

start and the heating valve shall open. When the space temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. When the space temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint.

E. Occupancy Override: When the Occupancy Override button on the room T-stat is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

2. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

A. Fan Failure: Commanded on, but the status is off.

B. Fan in Hand: Commanded off, but the status is on.

C. Filter Change Required: Time exceeded. A filter change alarm shall occur when a user definable limit (adj.) is exceeded.

D. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

E. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

F. Belt Break Alarm (if applicable)

3. Misc Control:

Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm

3.16 AHUs with Return Air (AHU-50, 51, & 52):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), and outside air damper (D-3) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), and outside air damper (D-3) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and

setpoints.

H. Or the AHU is selected to run 24/7 in lieu of the schedule.

2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.
   D. Close the humidifier valve whenever the supply fan is off (command or status).
   E. Close the CHW valve.
3. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.
      ii. High pressure sensor (PSH-25) located at the supply fan discharge shall prevent the supply fans from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.
      iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.
   B. Unoccupied Mode:
      i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.
      ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU

shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-31), shall be maintained by modulating chilled water valve (V-2) and control of pre-heat valve (V-1A, & 1B) as discussed below:

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valve (V-1A, & 1B) shall open from a minimum of 10% open to a maximum of 100% open, and shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valve (V-1A, & 1B) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valves (V-1A, & 1B) shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than 50°F (adj.) the pre-heat coil valves (V-1A, & 1B) shall be closed.

iii. Heating control valve shall be modulated via PID control loop to maintain the supply DAT.

iv. The AHU has 1/3 and 2/3 Steam valves, then adjust control strategy to operate the 1/3 valve first to maintain DAT Setpoint, If the 1/3 steam valve has reached 100% open for 10 minutes and DAT setpoint is not maintained, then switch to modulate the 2/3 steam valve to maintain DAT setpoint, and closing the 1/3 valve. If the 2/3 steam valve has reached 100% open for 10 minutes and DAT setpoint is not maintained, then add the 1/3 valve in and modulate the 1/3 steam valve to maintain DAT setpoint.

v. Pre-heat valve (V-1A, & 1B) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

vi. The Pre-heat valve shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

vii. Adjusting any of the above temperature values shall require Technical Design Level User access.

viii. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-31). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-29) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-28),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-29) and outside air moisture transmitter (MT-30), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically

driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, economizer dampers shall modulate open beyond the position required for minimum ventilation air.

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, return air damper (D-2) shall open and OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. <u>Temperature control, Chilled Water Cooling Mode:</u> The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA damper (D-3) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA damper (D-3) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. <u>Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:</u>

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed,

the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:

A. Humidity control with Humidifier:

I. When the DCP is not calling for humidity, sensed by return air humidity (MT-29), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.

ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-28) and humidity transmitter (MT-29) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by SA duct humidity sensor (MT-29). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.

i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.

ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.

7. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-31) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-10) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-10 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-10 will require manual reset at the device. The OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

A. On freezestat trip:

B. Shut down the supply fan and shut down the return fan.

C. Close the OA, close the relief air damper, and open the RA damper.

D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.

E. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.

F. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or

more.

A. Fan Failure: Commanded on, but the status is off.

B. Fan in Hand: Commanded off, but the status is on.

C. Fan VFD Fault.

D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.

E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.

F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.

G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-31) raises above 65°F, an alarm signal

shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-31) the supply fan and return fan shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.
    A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.
    B. Duct static pressure reset as described in Static Pressure Reset section.
    C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.17 VAV Terminal Unit with AHU Interface

A. General: All settings and set points are to be adjustable (by operator with appropriate access) and are to be displayed on graphic along with measured and commanded values.

B. VAV'S shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller or via the Engineering Control Center (ECC) frontend:

1. Terminal Operational Conditions
    A. Index the terminal to occupied mode based on daily, weekly and holiday schedule, on activation of an override button, on activation of occupancy sensor, or on a manual command from operator.
    B. Index the terminal to unoccupied mode whenever it is not indexed to occupied mode.
2. Terminal Shutdown
    A. When a zone occupancy is indexed to unoccupied,
        i. Close the terminal damper and hot water reheat coil valve completely, or
        ii. Close the terminal damper to a preset minimum position and allow the hot water reheat coil valve to modulate to maintain an unoccupied heating setpoint, or
        iii. Modulate the damper to maintain the unoccupied airflow set point and allow the hot water reheat coil valve to modulate to maintain an unoccupied heating setpoint.
3. Occupied Temperature, Ventilation, and Humidity Control
    A. Program zone cooling and heating temperature set points, with a deadband of at least 2°F (adj.) in between.
    B. Modulate damper position to maintain terminal air flow set point.

C. Maintain the zone cooling temperature set point by resetting the terminal airflow set point between cooling minimum and maximum settings

D. As zone temperature drops to heating set point, modulate airflow set point between heating minimum and maximum.

E. Modulate the terminal hot water reheat coil valve to maintain the zone temperature at the zone heating temperature set point.

i. Modulate airflow to maintain terminal SAT high limit of 90°F (adj.) as sensed by VAV Supply air temp (SAT) sensor.

F. Allow zone set point temperature override of +/- 2°F (adj. by frontend operator), applied to the space zone setpoint, as adjusted at the space sensor:

i. Maintain the temperature override value until manually changed, or

ii. Maintain the temperature override value for a period of X hours,

iii. Maintain the temperature override value until the next unoccupied cycle, or

iv. Maintain the temperature override value until a time of HH:MM each day.

G. When zone occupancy status is overridden to occupied, control as for occupied for the scheduled override time.

H. Signal AHU (or allow AHU to poll VAV's) space temp, damper position and hot water valve position, occupancy mode for determining AHU duct static pressure reset and AHU Discharge Air Temperature reset. High level frontend user shall have ability to disregard select rouge VAV zones.

4. Unoccupied Temperature Control:

A. Activation of timed override switch on zone/space thermostats shall only reset zone heating/cooling and CFM setpoints to "occupied" values, but shall not affect otherwise.

B. Zone/Space occupancy schedule shall be user defined from the frontend graphical interface and shall normally automatically select the Occupied or Unoccupied operating mode of Terminal Unit. All Terminal Units/VAV's shall have temperature set points and CFM occupied/unoccupied setback capability for nights/weekends/holiday setback.

C. During unoccupied mode, the CFM flowing into the space shall be reduced to a preset CFM value (adjustable). Some areas will require no CFM, as long as the temperature is maintained within the dead-band range. Other areas shall provide min CFM for odor control or flushing the space to prevent odor buildup. Other areas shall be setback to no more than 50% of the designed occupied air flow.

D. Provide a graphical switch to allow frontend user to change between flowing the VAV continuously in unoccupied mode or shut off and activate VAV only when needed to maintain space temperature.

E. Program unoccupied zone cooling and heating temperature set points shall be set to 66 °F Unoccupied heating and 76 °F Unoccupied Cooling Setpoints.

F. When a zone's unoccupied heating set point is satisfied, modulate the heating valve closed and reduce the airflow set point to unoccupied minimum to prevent overheating.

G. When the temperature of any zone rises above its unoccupied cooling set point

   (1). Signal the AHU controller to operate for unoccupied cooling.

   (2). Operate the terminal unit as for occupied cooling, until the unoccupied cooling set point is satisfied.

H. When a zone's unoccupied cooling set point is satisfied, reduce the airflow set point to unoccupied minimum or off to prevent overcooling.

I. Occupancy Override: When the Occupancy Override button on the T-stat is depressed momentarily, the Terminal Unit shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours (adj.).

J. Optimal Start: The DCP shall monitor environmental conditions and calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity). Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to bring zone to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

K. Morning warm-up mode: During optimal start, if the space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated

L. Morning pre-cool mode: During optimal start, if space temperature is above the occupied cooling setpoint a morning pre-cool mode shall be activated. When the space temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

M. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs.

5. Occupied Standby Mode, with Occupancy Sensors: When an occupancy sensor is used in combination with a time-of-day schedule, the sensor is used to indicate if the zone is unoccupied although the DDC frontend has scheduled it as occupied. This combination is used to switch the zone to an "occupied standby" mode.

   A. In Occupied Standby Mode, the temperature setpoints are raised or lowered by 1°F to 2°F (adj.), and the ventilation requirement for that space/zone is reduced to very low minimum level (adj.).

   B. When the occupancy sensor indicates that the zone is again occupied, these settings are switched back to normal occupied mode.

   C. If included in contract drawings, the same HVAC occupancy sensors will control some of the lights in that zone and shut off lighting when unoccupied. This is used in class rooms and conference rooms.

6. Max Cool Mode

   Max Cool mode is used to temporality increase VAV cooling value to 100% and quickly adjust room conditions to within normal occupied setpoints. This is used for conference rooms where the number of people entering the room changes quickly, causing large variation in the space. Allow wall T-stat override button to be used to implement Max Cool and set the Max Cool time for Conference/class rooms during occupied periods.

   Max Cool does not activate if space temp is within normal occupied range. Max Cool will cancel when the Max Cool time expires or temperature is in occupied range.

7. Alarms

   A. High Space Temperature: If the space temperature is 5°F above set point.

B. Low Space Temperature: If the space temperature is 5°F below set point.

C. Low Zone Airflow: If the zone airflow is 20% below set point.

D. High Zone Airflow: If the zone airflow is 20% above set point

E. High SAT: If SAT is 10°F greater than set point (as applicable).

F. Leaking heating valve: If SAT is 10°F greater than AHU DAT, with heating valve commanded closed for more than 30 minutes (adj). An alarm shall be generated, enunciated audibly and displayed graphically.

8. Frontend Graphics: Frontend graphics shall be modified to show Floor Plan View, VAV Operations, VAV Summary and VAV Occupancy Summary, as shown below:

A. Floor Plan View: Shall include:

i. Floor plans with room #'s and room names,

ii. Space zones, with single-line ductwork and Supply/return grills

iii. VAV locations,

iv. T-stat locations,

v. Each VAV shall graphically represent the space temperature and its reference to the zone setpoint. If the space temperature is 2°F (adj.) over setpoint the zone temperature shall change color tint to red. If the space temperature is 2°F (adj.) below setpoint the zone temperature shall change color tint to blue. If the space temperature is within 0.5°F (adj.) of setpoint the zone temperature shall change color tint to green. A gradient color for any value in between will be used to indicate how far the space temperature is off setpoint. A legend indicating this will be on each floor plan.

vi. Each VAV Graphic shall include direct links to the next and last VAV, link to the AHU serving the VAV box, Link to the Floor Plan, Link to the home page. The goal is to minimize the number of clicks it takes to navigate the system. From the home page you should be able to get to a summary page of the equipment within 3 to 4 clicks. For Example Home Page (0), Floor Plan Overview (1), Floor Plan Area Zoom if needed (2), VAV Box (3).

B. VAV Operations: Shall have animated and colored graphics, all setpoints, VAV functions, menu for quick trending setup, alarms and status's.

C. VAV Summary Page shall show:

i. Name of area of building,

ii. Related AHU, Duct Pressure, and AHU Supply Air Temperature,

iii. VAV #,

iv. Room #,

v. Room name,

vi. Occupancy status, and ability to change occupancy mode on this page,

vii. Space temp, with colors for over/under setpoint conditions,

viii. Space setpoint, and ability to change temp setpoint on this page

ix. Actual CFM and Desired CFM,

x. Min and Max CFM's,

xi. Damper position,

xii. Hot water valve position,

xiii. Supply air temp,

xiv. Related exhaust fan (if available): status, CFM and/or exhaust damper position

D. Occupancy Mode Summary shall include:

i. Name of area of building,

ii. VAV number,

iii. Room name,

iv. Occupancy status with color,

v. Current Mode: occupied, unoccupied, Occupied Standby Mode, Occupancy Override, Off and Optimal Start/Stop modes.

vi. Occupancy Selection dropdown menu,

3.18 VAV Terminal Unit without AHU Interface

A. General: All settings and set points are to be adjustable (by operator with appropriate access) and are to be displayed on graphic along with measured and commanded values.

B. VAV'S shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller or via the Engineering Control Center (ECC) frontend:

1. Terminal Operational Conditions

a. Index the terminal to occupied mode based on daily, weekly and holiday schedule, on activation of an override button, on activation of occupancy sensor, or on a manual command from operator.

b. Index the terminal to unoccupied mode whenever it is not

indexed to occupied mode.

2. Terminal Shutdown
   a. When a zone occupancy is indexed to unoccupied,
      i. Close the terminal damper and hot water reheat coil valve completely, or
      ii. Close the terminal damper to a preset minimum position and allow the hot water reheat coil valve to modulate to maintain an unoccupied heating setpoint, or
      iii. Modulate the damper to maintain the unoccupied airflow set point and allow the hot water reheat coil valve to modulate to maintain an unoccupied heating setpoint.
3. Occupied Temperature, Ventilation, and Humidity Control
   a. Program zone cooling and heating temperature set points, with a deadband of at least 2°F (adj.) in between.
   b. Modulate damper position to maintain terminal air flow set point.
   c. Maintain the zone cooling temperature set point by resetting the terminal airflow set point between cooling minimum and maximum settings
   d. As zone temperature drops to heating set point, modulate airflow set point between heating minimum and maximum.
   e. Modulate the terminal hot water reheat coil valve to maintain the zone temperature at the zone heating temperature set point.
      i. Modulate airflow to maintain terminal SAT high limit of 90°F (adj.) as sensed by VAV Supply air temp (SAT) sensor.
   f. Allow zone set point temperature override of +/- 2°F (adj. by frontend operator), applied to the space zone setpoint, as adjusted at the space sensor:
      i. Maintain the temperature override value until manually changed, or
      ii. Maintain the temperature override value for a period of X hours,
      iii. Maintain the temperature override value until the next unoccupied cycle, or
      iv. Maintain the temperature override value until a time of HH:MM each day.

g. When zone status is overridden to occupied, control as for occupied for the scheduled override time.

4. Unoccupied Temperature Control:
   a. Activation of timed override switch on zone/space thermostats shall only reset zone heating/cooling and CFM setpoint to "occupied" values, but shall not affect otherwise.
   b. Zone/Space occupancy schedule shall be user defined from the frontend graphical interface and shall normally automatically select the Occupied or Unoccupied operating mode of Terminal Unit. All Terminal Units/VAV's shall have temp set points and CFM occupied/unoccupied setback capability for nights/weekends/holiday setback.
   c. During unoccupied mode, the CFM flowing into the space shall be reduced to a preset CFM value (adjustable). Some areas will require no CFM, as long as the temperature is maintained within the dead-band range. Other areas shall provide min CFM for odor control or flushing the space to prevent odor buildup. Other areas shall be setback to no more than 50% of the designed occupied air flow.
   d. Provide a graphical switch to allow frontend user to change between flowing the VAV continuously in unoccupied mode or shut off and activate VAV only when needed to maintain space temperature.
   e. Program unoccupied zone cooling and heating temperature set points shall be set to 66 °F Unoccupied heating and 76 °F Unoccupied Cooling Setpoints.
   f. When a zone's unoccupied heating set point is satisfied, modulate the heating valve closed and reduce the airflow set point to unoccupied minimum to prevent overheating.
   g. When the temperature of any zone rises above its unoccupied cooling set point
      i. Operate the terminal unit as for occupied cooling, until the unoccupied cooling set point is satisfied.
   h. When a zone's unoccupied cooling set point is satisfied, reduce the airflow set point to unoccupied minimum or off to prevent overcooling.

i. Occupancy Override: When the Occupancy Override button on the T-stat is depressed momentarily, the Terminal Unit shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours(adj.).

J. Optimal Start: The DCP shall monitor environmental conditions and calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity). Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to bring zone to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

K. Morning warm-up mode: During optimal start, if the space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated

L. Morning pre-cool mode: During optimal start, if space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When the space temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

m. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs.

5. Max Cool Mode

Max Cool mode is used to temporality increase VAV cooling value to 100% and quickly adjust room conditions to within normal occupied setpoints. This is used for conference rooms where the number of people entering the room changes quickly, causing large variation in the space. Allow wall T-stat override button to be used to implement Max Cool and set the Max Cool time for Conference/class rooms during occupied periods.

Max Cool does not activate if space temp is within normal occupied range. Max Cool will cancel when the Max Cool time expires or temperature is in occupied range.

6. Alarms
   a. High Space Temperature: If the space temperature is 5°F above set point.
   b. Low Space Temperature: If the space temperature is 5°F below set point.
   c. Low Zone Airflow: If the zone airflow is 20% below set point.
   d. High Zone Airflow: If the zone airflow is 20% above set point
   e. High SAT: If SAT is 10°F greater than set point (as applicable).
   f. Leaking heating valve: If SAT is 10°F greater than AHU DAT, with heating valve commanded closed for more than 30 minutes (adj). An alarm shall be generated, enunciated audibly and displayed graphically.
7. Frontend Graphics: Frontend graphics shall be modified to show Floor Plan View, VAV Operations, VAV Summary and VAV Occupancy Summary, as shown below:
   a. Floor Plan View: Shall include:
      i. Floor plans with room #'s and room names,
      ii. Space zones, with single-line ductwork and Supply/return grills
      iii. VAV locations,
      iv. T-stat locations,
      v. Each VAV shall graphically represent the space temperature and its reference to the zone setpoint. If the space temperature is 2°F (adj.) over setpoint the zone temperature shall change color tint to red. If the space temperature is 2°F (adj.) below setpoint the zone temperature shall change color tint to blue. If the space temperature is within 0.5°F (adj.) of setpoint the zone temperature shall change color tint to green. A gradient color for any value in between will be used to indicate how far the space temperature is off setpoint. A legend indicating this will be on each floor plan.
      vi. Each VAV Graphic shall include direct links to the next and last VAV, link to the AHU serving the VAV box, Link to the Floor Plan, Link to the home page. The goal is

to minimize the number of clicks it takes to navigate the system. From the home page you should be able to get to a summary page of the equipment within 3 to 4 clicks. For Example Home Page (0), Floor Plan Overview (1), Floor Plan Area Zoom if needed (2), VAV Box (3).

b. VAV Operations: Shall have animated and colored graphics, all setpoints, VAV functions, menu for quick trending setup, alarms and status's.

c. VAV Summary Page shall show:

   i. Name of area of building,
   ii. VAV #,
   iii. Room #,
   iv. Room name,
   v. Occupancy status, and ability to change occupancy mode on this page,
   vi. Space temp, with colors for over/under setpoint conditions,
   vii. Space setpoint, and ability to change temp setpoint on this page
   viii. Actual CFM and Desired CFM,
   ix. Min and Max CFM's,
   x. Damper position,
   xi. Hot water valve position,
   xii. Supply air temp,
   xiii. Related exhaust fan (if available): status, CFM and/or exhaust damper position

d. Occupancy Mode Summary shall include:

   i. Name of area of building,
   ii. VAV number,
   iii. Room name,
   iv. Occupancy status with color,
   v. Current Mode: occupied, unoccupied, Occupied Standby Mode, Occupancy Override, Off and Optimal Start/Stop modes.
   vi. Occupancy Selection dropdown menu,

3.19 Building Pressurization:

A. Building pressurization monitors (BPM) shall be located in Public Corridors, Patient Corridors and Exterior walls as shown on drawings and set for 0.01” WG positive pressure.

1. If BPM is indicating positive pressurization status, the exhaust fan shall be energized or speed increased and vary flow as required to satisfy BPMs.
2. If BPM is indicating negative pressurization status, the outside air intake fan shall be energized or speed increased and vary the flow as required to satisfy BPM’s.

3.20 FAN COIL UNITS:

A. **General:** Control shall include scheduled occupancy with optimum preoccupancy, occupancy override, and reheat control as specified below. Schedule shall be the same as the parent AHU.

B. **Space Temperature Control:** Three setpoints shall apply. Normal (72°F adj.)), setback heating (65°F (adj.)), and setback cooling (80°F). These three values shall be the only values changed by the operator to adjust space temperatures. All other deadbands, differentials, etc. shall be calculated in the program logic (unless another means is provided to prohibit overlap of the heating and cooling loops and ensure a dead band such as function block templates that restrict the setpoint input). During the normal periods, separate heating and cooling setpoints shall be calculated.

1. **Normal space cooling setpoint:** shall be the normal space temperature plus 2°F (adj.)
2. **Normal space heating setpoint:** shall be the normal space temperature minus 2°F (adj.)

C. **Fan:** Fan shall be enabled and run continuously during occupied mode. During unoccupied mode, fan shall be de-energized except as required to maintain setback temperature setpoints for both heating and cooling with a cycle differential of 3°f (adj.). BAS shall prove fan operation with a current sensor and use the status indication to accumulate runtime.

D. **Valves:** Heating and cooling control valves shall cycle as required to maintain space temperature setpoint for the associated mode (heating or cooling). Programming shall be implemented to prevent overlap of the heating and cooling valves.

E. **Heating Request:** This unit shall issue a "heating request" to the HW system as follows:

1. Whenever the heating output is at 100%, or
2. Whenever the space temperature falls below the throttling range of the heating loop.

F. **Cooling Request:** This unit shall issue a "cooling request" to the CHW system as follows:

1. Whenever the cooling output is at 100% (full cooling), or
2. Whenever the space temperature rises above the throttling range of the cooling loop.

3.21 ELECTRIC UNIT HEATER:

A. **General:** BAS shall enable the unit heater and provide monitoring and diagnostic information for management purposes.

B. **Fan Control:** BAS shall control the starting and stopping of the unit heater as follows:

1. **Start/Stop:** BAS shall command the operation of the unit heater and it shall run continuously when enabled per occupancy schedule.
2. **Proof:** BAS shall prove fan operation with a current sensor and use the status indication to accumulate runtime. Upon a command status mismatch plus 20 second time delay, the BAS shall generate an alarm, enunciate the alarm, and display it graphically.

C. **Enable Heater:** Unit heater shall be energized whenever space temperature falls below the active heating setpoint.

D. **Disable Heater:** Unit heater shall be de-energized whenever space temperature rises below the active heating setpoint deadband.

E. **Setpoint:** The heating setpoint in unoccupied areas shall be set to 55 °F (adjustable from the graphic screen). The cooling setpoint in occupied areas shall be set to 68 °F (adjustable from the graphic screen).

--End of Section—

SECTION 23 09 93
HVAC CONTROLS SEQUENCE OF OPERATIONS, FOR TVHS

PART 1 - GENERAL

1.1 SECTION INCLUDES

A. Air Handling Units

B. Chilled Water System

C. Terminal Units

D. Exhaust Fans

E. Heat Exchangers

1.2 RELATED DOCUMENTS:

A. Drawings and general provisions of Contract, including the General Conditions and other Division-1 Specification Sections, apply to this Section.

B. Section 230911 - Basic Mechanical Requirements

C. Section 230923 – Direct Digital Control (DDC) for HVAC

D. Section 230711 – TAB for HVAC

E. Section 230800 – BAS Commissioning

1.3 SUMMARY: This Section includes control sequences for HVAC systems, subsystems, controls and equipment.

1.4 SUBMITTALS:

A. Refer to Section 230923 and Division 1 for requirements for control shop drawings, product data, Users Manuals, etc.

B. Programming Manuals: Provide DDC system programming manual as well as documentation of site-specific programming prior to the start of Acceptance Phase.

1.5 PROJECT RECORD DOCUMENTS:

A. Within two weeks of the completion of commissioning, provide record documents to represent the final control configuration with actual setpoints and tuning parameters as existed at acceptance.

B. Record documents shall be modified control drawings with the actual installed information. Drawings shall be delivered in both reproducible hard copy and electronic format in AutoCAD drawing files. Provide all supporting files, blocks, fonts, etc. required by the drawings.

C. Provide final points list as described in this spec section and installed with this project.

D. Provide final detailed wiring diagrams with all wire numbers and termination points indicated. On floor plans, show location of all

wiring and cable routing, repeaters, junction boxes, vertical penetrations and controllers. Also show locations of static pressure sensors, T-stats, TU boxes, EF's, AHU sensors, etc.

E. Accurately record final sequences and control logic made after submission of shop drawings.

PART 2 - PRODUCTS, (Not Used)

PART 3 - EXECUTION

3.1 GENERAL

A. Sequences specified herein indicate the functional intent of the systems operation and may not fully detail every aspect of the programming that may be required to obtain the indicated operation. Contractor shall provide all programming necessary to obtain the sequences/system operation indicated.

B. When an air handling unit is not in operation, control devices shall remain in their "off" positions. "Off" positions may differ from the "normal" (meaning failed) position. Except as specified otherwise, "off" and "normal" positions of control devices shall be as follows:

Device	"Off"	"Normal"
Heating coil valves	**closed**	**open**
Cooling coil valves	**closed**	**closed**
Steam coil valves	**closed**	**closed**
Outside air damper	**closed**	**closed**
Return air damper	**open**	**open**
Exhaust/relief air	**closed**	**closed**

C. Variable Frequency Drives: For a VFD dependent on an external input for its output setting (e.g. the VFD gets "Frequency" as an input), loss of that external input shall result in the VFD shall go to its minimum speed setting, and a loss of signal alarm shall be generated. VFD points should also include BACnet info to/from VFD for input speed, actual speed, fault, start, start, KW, energy and belt brake alarm, if used.

D. All PID loop control of VFDs shall be by the Digital Control Panel or DCP Controller serving the VFD. All calculations and adjustments are to be available in the DCP controller.

E. Except as specified otherwise, throttling ranges, proportional bands, and cycle differentials shall be centered on the associated setpoint. All modulating feedback control loops

shall include the capability of having proportional, integral, and derivative (PID) action. Unless the loop is specified "proportional only" or "P+I", Contractor shall apply appropriate elements of integral and derivative gain to each control loop which shall result in stable operation, minimum settling time, and shall maintain the primary variable within the specified maximum allowable variance.

F. Provide a real time clock and schedule controller with sufficient scheduling capability to schedule all required controllers and sequences. Schedule functionality may reside in the controllers. Set up initial schedules in coordination with VA Project COR.

G. Scheduling Terminology: When air handlers are scheduled throughout the day, the following defines the terminology used:

1. **Occupied Period:** period of time when the space is in use and occupied. Unless indicated otherwise, this period is defined as 7:00 AM – 5:00 PM weekdays. Exclude all national holidays. Generally systems will be fully operational throughout this period and ventilation air shall be continuously introduced. Space temperature setpoints will generally be in the "normal" range of 69°-76°F. Setpoints for Medical Clinic areas will be as required for clinical areas (Ref VA HVAC design guide). Coordinate actual setpoints with VA COR.
2. **Unoccupied period:** period of time when the building or zone is not in use and unoccupied. Ventilation air shall not be introduced, except to meet exhaust demand and building pressure requirement.
3. **Preoccupancy Period (Warn-up or Cooldown):** Time prior to the Occupied period when the systems are returning the space temperatures from setback to "normal" or occupied setpoints (warm-up and cool-down). Ventilation air shall not be introduced, except for exhaust demand or unless outside air conditions permit free-cooling. Time period shall be determined by an optimum start strategy unless otherwise specified.

4. **Setback Period**: Setback will typically start with the end of the occupied period and end with the start of the preoccupancy period, however it shall be provided with its own schedule. Generally systems will be off except to maintain a "setback" temperature, economization may be enabled to maintain "setback" cooling setpoint when applicable.

H. Where any sequence or occupancy schedule calls for more than one AHU motorized unit to start simultaneously, the DCP start commands shall be staggered by 5 second (adj.) intervals to minimize inrush current.

I. Wherever a value is indicated as adjustable (adj.), it shall be modifiable, with the proper password level, from the ECC frontend menu. For these points, it is unacceptable to have to modify programming statements to change the setpoint.

J. Where "proof" or "prove operation" of a device (generally controlled by a digital output) is indicated in the sequence, it shall require that the DCP shall, after an adjustable time delay after the device is commanded to operate (feedback delay) , confirm that the device is operational via the status input. If the status point does not confirm operation after the time delay or anytime thereafter for an adjustable time delay (debounce delay) while the device is commanded to run, proving a command status mismatch, an alarm shall be enunciated audibly and displayed graphically.

K. DDC shall provide for adjustable maximum rates of change for increasing and decreasing output from the following analog output points:
   a. Speed control of variable speed drives
   b. Control Reset Loop
   c. Valve Travel Limit

L. Wherever a value is indicated to be dependent on another value (i.e.: setpoint plus 5°F) DCP shall use that equation to determine the value. Simply providing a virtual point that the operator must set is unacceptable. In this case three virtual points shall be provided. One to store the parameter (5°F), one to store the setpoint, and one to store the value which is the result of the equation.

M. Controls contractor shall use control Simulation Software to test out all functions of the Sequence of Operations.

O. Modulated Load Shedding (MLS)

1. Programming shall be used to reduce load on non-critical (i.e. admin spaces, bridges, corridors …) during periods of very high OAT/humidity or Chiller Plant limitations due to equipment outages. MLS shall be implemented on each AHU or Terminal Unit impacted by this project. MLS shall include the following:
2. System shall include Modulated Load Shedding program that includes resets the AHU DAT set point and reset Terminal Unit dead-band temp setpoint based on Central Chilled Water loop Chilled Water Supply temperature and/or OAT. Shedding shall be implemented independently on each and every zone or piece of equipment connected to system.
3. Controls contractor shall install temp sensor on chilled water supply lines at two locations in Chilled Water Plant.
4. Operators shall be able to enable/disable each AHU and Terminal Unit for implementation of modulated load shedding. Provide AHU and Terminal Unit Summary Graphic pages showing load shedding status, set points, overrides, percent of load shed, etc. Operator with level 9 access shall be able to:
   - Enable/Disable each AHU and Terminal Unit for use of MLS,
   - Adjust reset values, with high and low values,
   - Enable/disable reset based on OAT,
5. Enable/Disable Manual Override (time limited implementation, with auto release) of MLS. For example, activating Manual Override would implement modulated load shedding for 4 hours (adj.) and then release to Auto.

P. Controller Diagnostic Software: Controller software shall include diagnostic software that checks memory and communications and reports any malfunctions.

Q. See specification section 23 09 23 for additional DDC details.

3.2 AIR HANDLING UNITS - GENERAL

A. **Logic Strategies**: The Digital Control Panel (DCP) shall fully control the air handlers. Generally the DCP shall energize the AHU (start the fans and activate control loops) as dictated for each air handler. The following indicates when and how the DCP shall energize the AHUs and control various common aspects of them. The following "logic strategies" shall be included by reference with each

air handler with specific clarifications as required for specific AHU:

1. **Scheduled Occupancy: DDC** shall determine the occupancy periods (occupied, unoccupied, preoccupancy, and setback) as defined above. The following details the common control aspects related to the scheduled occupancy.
   a) DCP shall energize the AHU during all occupied periods. Note that the beginning of the occupancy period shall be set sufficiently before the actual start of occupancy to obtain the required building component of ventilation per ASHRAE 62. Specific times shall be as directed by the A-E. Minimum OA flow setpoint shall be as scheduled on the drawings. "Normal" setpoints shall apply.
   b) **Unoccupied Period:** Minimum OA flow shall be: Not more than 50% of heating setpoint CFM, or 0 CFM and the minimum OA damper position shall be 0%. If during the unoccupied period there is a request for occupancy override, the occupancy mode shall become active for an adjustable period. The unoccupied period and the preoccupancy period will typically overlap.
   c) **Setback Period (if used):** The DCP shall de-energize the unit except as required to maintain a setback temperature as indicated in the individual sequences with a 5°F cycle differential. Generally, where setback temperatures apply in multiple zones, the worst zone shall control the system. Setback setpoints generally apply except during preoccupancy. If during the unoccupied period there is a request for occupancy override, the occupancy mode shall become active for an adjustable period.
   d) **Preoccupancy Period (Warn-up or Cooldown):** Use the below info, unless optimal start function is stated in the sequence of operations. The DCP shall energize the AHU continuously during the preoccupancy period. Minimum OA flow shall be 0 CFM

or the minimum OA damper position shall be 0%. "Normal" setpoints shall apply. Preoccupancy duration shall be one of the following methods. Default method shall be Optimized Start. Only use Fixed Method if specifically stated.

1) **Optimized Start:** Uses weather conditions and historical performance to adjust the warm-up or cooldown start time. Includes intelligent and adaptive algorithms to adjust start times.

2) **Fixed:** The duration of the preoccupancy period shall be reset at the DCP based on the outside air temperature as follows:

Outside Air	Preoccupancy Start
> 70˚F	1 to 2 hour early
60˚F to 70˚F	On time start
50˚F to 60˚F	30 minutes early
40˚F to 50˚F	1 to 1.5 hour early
30˚F to 40˚F	2 hour early start
< 30˚F	3 hour early start

3. **VAV Return Fan Capacity Control:** DCP shall control the output of the return fan as follows:

a) **Flow Tracking:** The return air fan shall run to maintain a return flow setpoint of the supply flow minus an offset value. The offset value shall be determined as follows:

1) **Fixed Differential:** It shall be fixed at the design minimum OA value.

2) **Differential Reset from Measured OA to Maintain Fixed OA:** It shall be reset to maintain the measured minimum OA flow at the design value any time the economizer mode is inactive. Whenever it is inactive, it shall be set to the value that existed when the unit became active.

b) **Rescaled Output Capacity Control:** The output for the return fan capacity control shall be rescaled from the output of the to the supply device such that the design minimum OA flow is maintained at both maximum and 50% flow conditions. The balancing contractor shall determine the coordinated output.

4. **National Weather Service Data**:
   All Air Handlers are provided with their own Outside Air Temperature and Humidity Sensors for standalone operation. The local sensors are to be used only when in standalone operation and the local intranet is down. During normal operations and communications, the Outside Air Temperature and Humidity values shall be derived from the National Weather Service via the Internet. It is the responsibility of this contractor to pull the NWS Data through the existing ECC for use for Economizer, Reset, or Summer/Winter switchover.
   If the NWS Data fails to update due to connectivity issues, the Local Outside Air Temperature Sensor and Humidity Sensor shall Automatically take over. Once the NWS Data stream is restored the local controller shall revert back to using the NWS data for sequence decision making. The NWS Data as well as the local OAT and OARH shall be displayed on the Web page graphic, as well as which value is under control on the graphic.
5. **Airside Economizer: DCP** shall modulate the mixing dampers to provide "free cooling" when conditions merit. The free cooling shall generally be staged before any mechanical cooling. While conditions merit, dampers shall be modulated in a DA PID loop to maintain mixed air temperature at setpoint. Economizer logic shall remain enabled during setback cooling where applicable.
6. **Sequenced Heating and Cooling: DCP** shall control the heating and cooling coils and air side economizer as detailed for the particular AHU. Program logic shall directly prohibit the heating and cooling valves as well as the heating valve and economizer damper to be open (or above minimum) simultaneously. This does not apply to cooling and reheat valves that are used simultaneously for dehumidification.
7. **Mixed Air Low Limit Override**: DCP shall override the signal to the OA damper via a proportional only loop to maintain a minimum mixed air temperature of 45°F (adj.).

8. **Freeze Safety:** Upon operation of a freezestat, unit shall be de-energized with the exception of the heating loops. Typically supply and return fans where applicable shall be de-energized via a hardwired interlock, and an indication of the operation shall be sensed by the DCP. DCP shall enunciate appropriate alarm and remove and lock out the start command, which shall initiate "fan failure" alarms. OA dampers shall close, RA dampers shall open, all hydronic valves shall open and heating loops shall remain active.
9. **Control Valve Positioning:**
   All Hot Water and Chilled Water Control Valves shall be stroked from 0% to 100% each day, in the smallest duration possible, before being returned to automatic control. This can be accomplished at a scheduled unoccupied time, or at a particular time interval at a predetermined time. This is to ensure that valves are locked into a controllable range due to limited use or oversizing.
10. **Energy Usage Dashboard:**
    Program an Energy Dashboard to display each energy used by AHU's installed with this project. This includes chilled water, steam, and fan (via info from VFDs) energy. Totalized energy used should be displayed in BTU's, MBTU's or MMBTU's for hour over hour, day of day, month of month and year over year should be displayed in table and graph form. Includes tables, bar charts, and pie charts of energy information. Include reports that can be printed out.

3.3 TERMINAL UNITS - GENERAL

A. **Logic Strategies:** The Digital Control Panel (DCP) shall fully control the terminal units (VAV's, FCU's, etc.). See below VAV sequence of operations and logic strategies for terminal units.

1. **Scheduled Occupancy: DDC** shall determine the occupancy periods (occupied, unoccupied, preoccupancy, and setback) as defined above. The following details the

common control aspects related to the scheduled occupancy.

a) DCP shall energize terminal units during all occupied periods. Note that the beginning of the occupancy period shall be set sufficiently before the actual start of occupancy to obtain required space temperatures before the normal occupied times.

b) **Unoccupied Period:** HVAC Operator with level 9 access shall be able to select between:

- Not more than 50% of heating setpoint CFM (adj.), or
- 0 CFM

c) **Preoccupancy Period (Warn-up or Cooldown):** The DCP shall energize the terminal unit continuously during the preoccupancy period and "Normal" setpoints shall apply. Preoccupancy duration shall be based on optimized start logic that uses weather conditions and each terminal unit's historical performance to adjust the warm-up or cooldown start time. Includes intelligent and adaptive algorithms to adjust start times.

3.4 AHUs with Return Air (AHU- 2, & 3B):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), outside air damper (D-3) and min outside air damper (D-4) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3), min outside air damper (D-4), face and bypass (F&DP) damper shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be

overridden whether stated or not in the sequence via the graphical user interface. :

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
   H. Or the AHU is selected to run 24/7 in lieu of the schedule.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the min OA damper (D-4), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.
   D. Close the humidifier valve whenever the supply fan is off (command or status).
   E. Close the CHW valve.
3. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between

the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-22) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV's with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV's that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-18), shall be maintained by modulating chilled water valve (V-2) and control of F&BP dampers with pre-heat valve (V-1) as discussed below:

i. If the Outside Air temperature is less than the F&BP switchover setpoint of 40°F (adj.) the pre-heat valve (V-1) shall follow one of the following sequences and the F&BP dampers shall be modulated to maintain DAT setpoint.

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valve (V-1) shall open from a minimum of 10% open to a maximum of 100% open. The F&BP dampers shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valve (V-1) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valve (V-1) shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override

shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than or equal to the F&BP switchover setpoint of 40°F (adj.) the F&BP damper will be open to full face with pre-heat valve (V-1) modulated to maintain the DAT setpoint.

iii. Above 50°F (adj.) the pre-heat coil valve (V-1) shall be closed.

iv. Heating control valves shall be modulated via PID control loop to maintain the supply DAT.

v. Pre-heat valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

vi. The Pre-heat valve and F&BP dampers (if present) shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

vii. Adjusting any of the above temperature values shall require Technical Design Level User access.

viii. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. <u>Economizer Mode, Mixed Air Temperature Control:</u>

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-18). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-25) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-5),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-25) and outside air moisture transmitter (MT-26), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6).

Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the

Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-4) to minimum position, return air damper (D-2) shall open and minimum OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3 and D-4) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3 and 4) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler

ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by return air humidity (MT-6), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.
      ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-5) and humidity transmitter (MT-6) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-12). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
   B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.
      i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
      ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.
7. Other Operating Modes:
   A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function

of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the

digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-11) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-12) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-12 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-12 will require manual reset at the device. The OA damper, Minimum OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.
   A. On freezestat trip:
   B. Shut down the supply fan and shut down the return fan.
   C. Close the OA and Minimum OA dampers, close the relief air damper, and open the RA damper.
   D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.
   E. Open preheat coil face and bypass dampers to full face. (Should this be to full Bypass, with no air movement I am thinking about stratification in the plenum)
   F. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   G. Return the unit to normal operation when freezestat is manually reset.
9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
   E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
   F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
   G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-11) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-11) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall

reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)
(2). Previous day,
(3). Week to date,
(4). Previous week,
(5). Year to date,
(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.5 AHUs with 100% Outside Air - AHU-6: (Not in this contract)

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto"

position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" outside air damper (D-1) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" outside air damper (D-1), shall open 100% in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface. :

1. AHU Operational Conditions:
   A. The AHU shall run continuously.
   B. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   C. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-1).
   C. Modulate the preheat coil valve (V-1) to maintain AHU cabinet temperature at 50° F as sensed by the PHT sensor (TT-12).
   D. Close the humidifier valve whenever the supply fan is off (command or status).
   E. Close the CHW valve (V-2).
3. Airflow Control,
   A. Occupied Mode:
      i. The supply shall run continuously. The supply fans speed shall be modulated to maintain the supply CFM (adj.). The fan shall set to maintain a constant airflow. The outside air (OA) damper shall open to maintain minimum ventilation requirements.
      ii. High pressure sensor (PSH-16) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will

require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

4. Temperature control:

A. Steam Pre-Heating (non-freeze type): Operate preheat coil, and cooling coil in sequence to maintain supply discharge air temperature (DAT) setpoint. DAT sensed by temperature sensor (TT-5), shall be maintained by modulating chilled water valve (V-2) and pre-heat valve (V-1) as discussed below:

i. If the OA temperature is less than 40°F (adj.) the Pre Heat Valve (V-1) will be open to 100% to maintain the DAT setpoint.

ii. If the OA temperature is greater than 40°F (adj.), but less than 55°F (adj.), the Pre Heat Valve (V-1) will be modulated between 0% and 100% to maintain the DAT setpoint.

iii. If the OA temperature is greater than 55°F (adj.) the Pre Heat Valve (V-1) will be closed and the Chilled Water Valve (V-2) will modulate between 0% and 100% to maintain the DAT setpoint.

iv. Pre-heat valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously.

v. Discharge Air Temperature Control Loop shall be controlled via a PID Control Loop to maintain the supple air temperature.

vi. Adjusting any of the above temperature values shall require Technical Design Level User access.

vii. Low Preheat Fault Alarm: If the preheat is enabled and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. Supply Air Temperature Reset:

i. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions, but shall be overridden if more than one zone served begins to overheat.. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Humidity Control:

A. Humidity control with Humidifier:

I. When the DCP is not calling for humidity, sensed by the Space Humidity (MT-19), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall modulate open.

II. The space dew point setpoint is 45 DegF.

iii. Space humidity shall be maintained at setpoint of 45 DegF dew point (adj.) via DCP by modulating control valve (V-3) to maintain the desired humidity. The dry bulb transmitter (TT-18) and humidity transmitter (MT-19) in the space shall be used to calculate space dew point.

iv. The DCP shall override this control to maintain duct supply humidity no higher than 90% as sensed by duct humidity sensor (MT-2).

v. DCP shall close valve V-3 whenever the supply fan is off.

vi. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

6. Other Operating Modes:

A. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

7. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-12) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-11) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-11 shall be hardwired to the supply fan and shall be shut down in hand, auto or bypass mode. TSL-11 will require manual reset at the device. The OA damper shall be closed.

A. On freezestat trip:

B. Shut down the supply fan.

C. Close the OA damper.

D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the PHT sensor.

E. Open CHW valve to 20% for minimum flow.

F. Return the unit to normal operation when freezestat is manually reset.

8. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

A. Fan Failure: Commanded on, but the status is off.

B. Fan in Hand: Commanded off, but the status is on.

C. Fan VFD Fault.

D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.

E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.

F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.

G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Belt Break Alarm (if applicable)

9. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply duct shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply fan shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply fan shall restart when smoke detector circuit is reset.

10. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-12) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above

72°F, as sensed by pre-heat temperature sensor (TT-12) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply CFM airflow. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface (if Applicable): ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

3.6 AHUs with Return Air (AHU-7):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), outside air damper (D-3) and min outside air damper (D-4) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the

DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3), min outside air damper (D-4), face and bypass (F&DP) damper shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface. :

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
   H. Or the AHU is selected to run 24/7 in lieu of the schedule.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the min OA damper (D-4), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.
   D. Close the humidifier valve whenever the supply fan is off (command or status).

E. Close the CHW valve.

3. Airflow Control,

A. Occupied Mode:

i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-22) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-18), shall be maintained by modulating chilled water valve (V-2) and control of F&BP dampers with pre-heat valve (V-1) as discussed below:

i. If the Outside Air temperature is less than the F&BP switchover setpoint of 40°F (adj.) the pre-heat valve (V-1) shall follow one of the following sequences and the F&BP dampers shall be modulated to maintain DAT setpoint.

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valve (V-1) shall open from a minimum of 10% open to a maximum of 100% open. The F&BP dampers shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valve (V-1) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valve (V-1) shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than or equal to the F&BP switchover setpoint of 40°F (adj.) the F&BP damper will be open to full face with pre-heat valve (V-1) modulated to maintain the DAT setpoint.

iii. Above 50°F (adj.) the pre-heat coil valve (V-1) shall be closed.

iv. Heating control valves shall be modulated via PID control loop to maintain the supply DAT.

v. Pre-heat valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

vi. The Pre-heat valve and F&BP dampers (if present) shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

vii. Adjusting any of the above temperature values shall require Technical Design Level User access.

viii. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. <u>Economizer Mode, Mixed Air Temperature Control:</u>

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air

temperature setpoint as sensed by the temperature sensor (TT-18). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-25) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-5),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-25) and outside air moisture transmitter (MT-26), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-4) to minimum position, return air damper (D-2) shall open and minimum OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3 and D-4) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3 and 4) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal

units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. <u>Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:</u>

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and

humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:

A. Humidity control with Humidifier:

I. When the DCP is not calling for humidity, sensed by return air humidity (MT-6), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.

ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-5) and humidity transmitter (MT-6) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-12). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.

i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.

ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.

7. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU

shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-11) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-12) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-12 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-12 will require manual reset at the device. The OA damper, Minimum OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.
   A. On freezestat trip:
   B. Shut down the supply fan and shut down the return fan.
   C. Close the OA and Minimum OA dampers, close the relief air damper, and open the RA damper.
   D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.
   E. Open preheat coil face and bypass dampers to full face. (Should this be to full Bypass, with no air movement I am thinking about stratification in the plenum)
   F. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   G. Return the unit to normal operation when freezestat is manually reset.
9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded.

Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.

E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.

F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.

G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-11) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-11) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.7 AHUs with Return Air (AHU- 9):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), outside air damper (D-3) and min outside air damper (D-4) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3), min outside air damper (D-4), face and bypass (F&DP) damper shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface. :

1. <u>AHU Operational Conditions:</u>

A. Run the AHU in occupied mode to satisfy occupied status for any zone.

B. Index the AHU to unoccupied mode and do one of the following:

i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.

ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.

C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.

D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start

calculations.

E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.

F. Run the return fan any time the supply fan runs.

G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.

H. Or the AHU is selected to run 24/7 in lieu of the schedule.

2. AHU Shutdown:

A. On command or schedule.

B. Close the OA damper (D-3), close the min OA damper (D-4), close the exhaust/relief damper (D-1), and open the RA damper (D-2).

C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.

D. Close the humidifier valve whenever the supply fan is off (command or status).

E. Close the CHW valve.

3. Airflow Control,

A. Occupied Mode:

i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-2) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV's with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV's that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-4), shall be maintained by modulating chilled water valve (V-2) and control of F&BP dampers with pre-heat valves (V-1A, & 1B) as discussed below:

i. If the Outside Air temperature is less than the F&BP switchover setpoint of 40°F (adj.) the pre-heat valves (V-1A & 1B) shall follow one of the following sequences and the F&BP dampers shall be modulated to maintain DAT setpoint.

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valves (V-1A & 1B) shall open from a minimum of 10% open to a maximum of 100% open. The F&BP dampers shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valves (V-1A, & 1B) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valves (V-1A, & 1B) shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than or equal to the F&BP switchover setpoint of 40°F (adj.) the F&BP damper will be open to full face with pre-heat valves (V-1A, & 1B) modulated to maintain the DAT setpoint.

iii. Above 50°F (adj.) the pre-heat coil valves (V-1A, & 1B) shall be closed.

iv. Heating control valves shall be modulated via PID control loop to maintain the supply DAT.

v. The AHU has 1/3 and 2/3 Steam valves, then adjust control strategy to operate the 1/3 valve first to maintain DAT Setpoint, If the 1/3 steam valve has reached 100% open for 10 minutes and DAT setpoint is not maintained, then switch to modulate the 2/3 steam valve to maintain DAT setpoint, and closing the 1/3 valve. If the 2/3 steam valve has reached 100% open for 10 minutes and DAT setpoint is not maintained, then add the 1/3 valve in and modulate the 1/3 steam valve to maintain DAT setpoint.

vi. Pre-heat valves (V-1A, & 1B) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

vii. The Pre-heat valve and F&BP dampers shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

viii. Adjusting any of the above temperature values shall require Technical Design Level User access.

ix. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. <u>Economizer Mode, Mixed Air Temperature Control:</u>

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-18). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-8) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-29),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-8) and outside air moisture transmitter (MT-8), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-29) and return air moisture transmitter (MT-30). Enthalpy comparison mode (above) shall have an

enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-4) to minimum position, return air damper (D-2) shall open and minimum OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3 and D-4) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled,

but with OA dampers (D-3 and 4) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably

require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by return air humidity (MT-30), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.
      ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-29) and humidity transmitter (MT-30) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-1). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
   B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.
      i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-29) and return air moisture transmitter (MT-30) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
      ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.
7. Other Operating Modes:
   A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air

temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-21) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-16) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-16 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-16 will require manual reset at the device. The OA damper, Minimum OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.
   A. On freezestat trip:
   B. Shut down the supply fan and shut down the return fan.
   C. Close the OA and Minimum OA dampers, close the relief air damper, and open the RA damper.
   D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.
   E. Open preheat coil face and bypass dampers to full face. (Should this be to full Bypass, with no air movement I am thinking about stratification in the plenum)
   F. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   G. Return the unit to normal operation when freezestat is manually reset.
9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
   E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
   F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
   G. High duct static pressure trip.
   H. Freezestat trip.
   I. High DAT: If the DAT is 10 F greater than set point, provide a

warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-17) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-17) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired

setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)
(2). Previous day,
(3). Week to date,
(4). Previous week,
(5). Year to date,
(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.8 AHUs with Return Air (AHU- 20):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), outside air damper (D-

3) and min outside air damper (D-4) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3), min outside air damper (D-4) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface. :

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
   H. Or the AHU is selected to run 24/7 in lieu of the schedule.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the min OA damper (D-4), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Close the humidifier valve (V-3 & V-4) whenever the supply fan is

off (command or status).

D. Close the CHW valve (V-2).

3. Airflow Control,

A. Occupied Mode:

i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the total supply air (SA) CFM of both air flow measuring stations and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-22) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units.

Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of 0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-18). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-25) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-5),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-25) and outside air moisture transmitter (MT-26), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6). Enthalpy comparison mode (above) shall have an

enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-4) to minimum position, return air damper (D-2) shall open and minimum OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

B. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer is either disabled or fully open.

iv. AND the supply fan status is on.

v. The CHW valve shall open to 50% on activation of the freezestat with fans off.

C. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3 and D-4) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3 and 4) closed, until the zone

unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

D. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process

shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by return air humidity (MT-6), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.
      ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-5) and humidity transmitter (MT-6) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-12). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
   B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.
      i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-5) and return air moisture transmitter (MT-6) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
      ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.
7. Other Operating Modes:
   A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature

control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by mixed air temperature sensor (TT-7) falls below 44°F, an alarm signal shall indicate

at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-XX) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-XX shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-XX will require manual reset at the device. The OA damper, Minimum OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

A. On freezestat trip:
B. Shut down the supply fan and shut down the return fan.
C. Close the OA and Minimum OA dampers, close the relief air damper, and open the RA damper.
D. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
E. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

A. Fan Failure: Commanded on, but the status is off.
B. Fan in Hand: Commanded off, but the status is on.
C. Fan VFD Fault.
D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
G. High duct static pressure trip.
H. Freezestat trip.
I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.
J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.
K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is

initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by mixed air temperature sensor (TT-7) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by mixed air temperature sensor (TT-7) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.
IS SPACE PRESSURE CONTROL REQUIRED FOR AHU-24 – SPACE PRESSURE POINT ARE NOT LISTED FOR M4.XX

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration

and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)
(2). Previous day,
(3). Week to date,
(4). Previous week,
(5). Year to date,
(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.9 AHUs with Return Air (AHU-21):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), and outside air damper (D-3) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), and outside air

damper (D-3) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
   H. Or the AHU is selected to run 24/7 in lieu of the schedule.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Close the humidifier valve (V-3 & V-4) whenever the supply fan is off (command or status).
   D. Close the CHW valve (V-2).
3. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan

shall modulate to maintain a constant airflow difference between the total supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-XX) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV's with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV's that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches

4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of 0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-31). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-29) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-28),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-29) and outside air moisture transmitter (MT-30), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled.

After the startup time delay the outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, economizer dampers shall modulate open beyond the position required for minimum ventilation air.

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-3) to minimum position, and return air damper (D-2) shall modulate to maintain the minimum OA CFM setpoint.

B. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer is either disabled or fully open.

iv. AND the supply fan status is on.

v. The CHW valve shall open to 50% on activation of the freezestat with fans off.

C. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA damper (D-3) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

D. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads.

The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. <u>Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:</u>

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled

(i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. <u>Humidity Control:</u>

A. <u>Humidity control with Humidifier:</u>

I. When the DCP is not calling for humidity, sensed by return air humidity (MT-29), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.

ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-28) and humidity transmitter (MT-29) in return air shall be used to calculate return air humidity. The DCP shall override this control

to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-14). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.

i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.

ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.

7. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply

fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-10) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-10 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-10 will require manual reset at the device. The OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

A. On freezestat trip:

B. Shut down the supply fan and shut down the return fan.

C. Close the OA dampers, close the relief air damper, and open the RA damper.

D. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.

E. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
   E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
   F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
   G. High duct static pressure trip.
   H. Freezestat trip.
   I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.
   J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.
   K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.
   L. Duct static high limit trip.
   M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:
   A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut “off” and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.
   B. Exhaust fans serving area of the supply fan shall continue to run.
   C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.
   D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by mixed air temperature sensor (TT-15) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.
IS SPACE PRESSURE CONTROL REQUIRED FOR AHU-24 – SPACE PRESSURE POINT ARE NOT LISTED FOR M4.XX

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.10 AHUs with Return Air (AHU-23):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), and outside air damper (D-3) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:

A. Run the AHU in occupied mode to satisfy occupied status for any zone.

B. Index the AHU to unoccupied mode and do one of the following:

i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.

ii. Continue to run in unoccupied mode at a reduced static

pressure setpoint.

C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.

D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.

E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.

F. Run the return fan any time the supply fan runs.

G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.

H. Or the AHU is selected to run 24/7 in lieu of the schedule.

2. AHU Shutdown:

A. On command or schedule.

B. Close the OA damper (D-3), close the exhaust/relief damper (D-1), and open the RA damper (D-2).

C. Close the humidifier valve (V-3 & V-4) whenever the supply fan is off (command or status).

D. Close the CHW valve (V-2).

3. Airflow Control,

A. Occupied Mode:

i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the total supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-13) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV's with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV's that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) OR the true position of the VAV damper is greater than 95% open then OR the new space temperature sensor is above or below unoccupied H/Csetpoints the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of 0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-31). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-29) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-28),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-29) and outside air moisture transmitter (MT-30), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve

mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, economizer dampers shall modulate open beyond the position required for minimum ventilation air.

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-3) to minimum position, the return air damper (D-2) shall open, and shall modulate to maintain the minimum OA CFM setpoint.

B. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer is either disabled or fully open.

iv. AND the supply fan status is on.

v. The CHW valve shall open to 50% on activation of the freezestat with fans off.

C. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

D. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. <u>Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:</u>

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:

A. Humidity control with Humidifier:

I. When the DCP is not calling for humidity, sensed by return air humidity (MT-29), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.

ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-28) and humidity transmitter (MT-29) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-14). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.

i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29) sensor, shall override the cooling sequence above to maintain a

maximum of 60% RH (adj.) for the area served by the air handling unit.

ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.

7. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-10) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-10 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-10 will require manual reset at the device. The OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

   A. On freezestat trip:
   B. Shut down the supply fan and shut down the return fan.
   C. Close the OA damper, close the relief air damper, and open the RA damper.
   D. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   E. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.

E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.

F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.

G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by mixed air temperature sensor (TT-15) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.11 AHUs with Return Air (AHU- 24):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), and outside air damper (D-3) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), outside air damper (D-3) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. <u>AHU Operational Conditions:</u>

A. Run the AHU in occupied mode to satisfy occupied status for any zone.

B. Index the AHU to unoccupied mode and do one of the following:

i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.

ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.

C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.

D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.

E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.

F. Run the return fan any time the supply fan runs.

G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.

H. Or the AHU is selected to run 24/7 in lieu of the schedule.

2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Close the humidifier valve (V-3 & V-4) whenever the supply fan is off (command or status).
   D. Close the CHW valve (V-2).
3. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the total supply air (SA) CFM of both air flow measuring stations and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.
      ii. High pressure sensor (PSH-13) located at the supply fan discharge shall prevent the supply fan from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.
      iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.
   B. Unoccupied Mode:
      i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.
      ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:
         (1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are

satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of 0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-31). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-29) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-28),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-29) and outside air moisture

transmitter (MT-30), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, economizer dampers shall modulate open beyond the position required for minimum ventilation air.

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-3) to minimum position, the return air damper (D-2) shall open, and shall modulate to maintain the minimum OA CFM setpoint.

B. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer is either disabled or fully open.

iv. AND the supply fan status is on.

v. The CHW valve shall open to 50% on activation of the freezestat with fans off.

C. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

D. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process

shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by return air humidity (MT-29), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.
      ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-28) and humidity transmitter (MT-29) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by duct humidity sensor (MT-14). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
   B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.
      i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
      ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.
7. Other Operating Modes:
   A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature

control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) falls below 44°F, an alarm signal shall

indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-10) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-10 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-10 will require manual reset at the device. The OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

A. On freezestat trip:
B. Shut down the supply fan and shut down the return fan.
C. Close the OA damper, close the relief air damper, and open the RA damper.
D. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
E. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

A. Fan Failure: Commanded on, but the status is off.
B. Fan in Hand: Commanded off, but the status is on.
C. Fan VFD Fault.
D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
G. High duct static pressure trip.
H. Freezestat trip.
I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.
J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.
K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is

initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by mixed air temperature sensor (TT-15) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by mixed air temperature sensor (TT-15) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure. Pressure relationship will be setup with RA Return Fan Capacity Control per specification section 23 09 90, PARA 3.2,A3, and TAB.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration

and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)
(2). Previous day,
(3). Week to date,
(4). Previous week,
(5). Year to date,
(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.12 AHUs with Return Air (AHU-28 & 29):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), outside air damper (D-3) and min outside air damper (D-4) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper

(D-2), outside air damper (D-3), and min outside air damper (D-4) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan wall any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan wall runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
   H. Or the AHU is selected to run 24/7 in lieu of the schedule.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the min OA damper (D-4), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.
   D. Close the humidifier valve whenever the supply fan wall is off (command or status).
   E. Close the CHW valve.

3. Airflow Control,

A. Occupied Mode:

i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.

ii. High pressure sensor (PSH-XX) located at the supply fan wall discharge shall prevent the supply fans from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan wall and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.

iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.

B. Unoccupied Mode:

i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.

ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-5), shall be maintained by modulating chilled water valve (V-2) and control of pre-heat valve (V-1) as discussed below:

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valve (V-1) shall open from a minimum of 10% open to a maximum of 100% open, and shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valve (V-1) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valves (V-1)

shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than 50°F (adj.) the pre-heat coil valves (V-1) shall be closed.

iii. Heating control valve shall be modulated via PID control loop to maintain the supply DAT.

iv. Pre-heat valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

v. The Pre-heat valve shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

vi. Adjusting any of the above temperature values shall require Technical Design Level User access.

vii. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. <u>Economizer Mode, Mixed Air Temperature Control:</u>

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-5). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-26) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-XX),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-26) and outside air moisture transmitter (MT-27), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-XX) and return air moisture transmitter (MT-24).

Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan wall status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the

Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, close the OA damper (D-4) to minimum position, return air damper (D-2) shall open and minimum OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan wall status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA dampers (D-3 and D-4) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied

cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA dampers (D-3 and 4) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan wall energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan wall energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably

require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:
   A. Humidity control with Humidifier:
      I. When the DCP is not calling for humidity, sensed by return air humidity (MT-24), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.
      ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-XX) and humidity transmitter (MT-24) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by SA duct humidity sensor (MT-24). DCP shall close valve V-3 whenever the supply fan wall is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.
   B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.
      i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-XX) and return air moisture transmitter (MT-24) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
      ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.
7. Other Operating Modes:
   A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air

temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan wall shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan wall shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-14) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-13) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-13 shall be hardwired to the supply fan wall and return fan and both shall be shut down in hand, auto or bypass mode. TSL-13 will require manual reset at the device. The OA damper, Minimum OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.
   A. On freezestat trip:
   B. Shut down the supply fan wall and shut down the return fan.
   C. Close the OA and Minimum OA dampers, close the relief air damper, and open the RA damper.
   D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.
   E. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   F. Return the unit to normal operation when freezestat is manually reset.
9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.
   E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.
   F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.
   G. High duct static pressure trip.
   H. Freezestat trip.
   I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.
   J. Low DAT: If the DAT is 10 F less than set point, provide a warning.

If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan wall shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-14) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-14) the supply fan wall and return fan shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)
(2). Previous day,
(3). Week to date,
(4). Previous week,
(5). Year to date,
(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.13 AHUs with 100% Outside Air – AHU-36:

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" outside air damper (D-1) shall be fully closed. The DCP shall send the controller occupied/unoccupied, and heat mode schedules. The discharge air temperature (DAT) setpoint shall be set at

the DCP. When the unit is "on" outside air damper (D-1), and face and bypass (D-2) damper shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, and valves shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy the space temperature setpoint.
   B. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   C. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-1), and position the Face and Bypass damper (D-2) to full bypass.
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the DAT sensor.
3. Temperature control:
   A. Occupied Control Mode for Steam Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point and Space Temperature Setpoint. DAT sensed by temperature sensor (TT-18), shall be maintained by control of F&BP (D-2) dampers with heating valves (V-1) as discussed below, while the space temperature shall be controlled by modulating the Supply Fan VFD Speed Control.:
      i. When the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 25°F (adj.) the pre-heat valve (V-1) shall open from a minimum of 15% open to a maximum of 100% open. The F&BP (D-2) dampers shall be modulated to maintain the DAT setpoint, while satisfying the Space Temperature Setpoint by modulating Supply Fan VFD Speed from 50% to 100% fan speed.

ii. If the OA temperature is greater than or equal to the F&BP switchover setpoint of 40°F (adj.) the F&BP damper (D-2) will be open to full face with heating valve (V-1) modulated from 15% to 100% to maintain the DAT setpoint, while satisfying the Space Temperature Setpoint from 50% to 100% fan speed.

iii. Above 50°F (adj.) the heating coil valve (V-1) shall be closed.

iv. Heating control valves shall be modulated via PID control loop to maintain the supply DAT.

v. The heating valve and F&BP dampers shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat. (If required)

vi. Adjusting any of the above temperature values shall require Technical Design Level User access.

vii. Low Heating Fault Alarm: If the heat is enabled and DAT is 10°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

viii. TAB process shall determine the final DAT limits and OAT limits.

ix. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

4. Freeze protection: If the air temperature as sensed by discharge temperature sensor (TT-18) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-XX) (If required) the supply and fan shall shut down and a critical alarm shall indicate at the digital control panel and ECC. TSL-XX shall be hardwired to the supply fan and shall be shut down in hand, auto or bypass mode. TSL-XX will require manual reset at the device. The OA damper shall be closed and the Face and Bypass damper will be at full bypass position.

A. On freezestat trip.

B. Shut down the supply fan.

C. Close the OA damper.

D. Open the heating valve and then modulate to maintain 55 °F as sensed by the DAT sensor.

E. Open heating coil face and bypass dampers to full bypass position.

F. Return the unit to normal operation when freezestat is manually reset.

5. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.
   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D.
   E. Freezestat trip. (If required)
   F. High DAT: If the DAT is 20 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.
   G. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.
   H. Low Space Temperature: If the space temperature is below 40 F, provide a warning. If the space temperature is below 32 F, initiate an alarm.
   I. Belt Break Alarm (if applicable)

6. Misc Control:
   A. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain space temperature setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.
      i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:
         (1). Day to date (total for the day)
         (2). Previous day,
         (3). Week to date,
         (4). Previous week,
         (5). Year to date,

(6). Previous year.

Proof: DCP shall prove supply fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

3.14 AHUs with Return Air (AHU-39, 40, & 41):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), and outside air damper (D-3) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), and outside air damper (D-3) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:

A. Run the AHU in occupied mode to satisfy occupied status for any zone.

B. Index the AHU to unoccupied mode and do one of the following:

i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.

ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.

C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.

D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.

E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.

F. Run the return fan any time the supply fan runs.

G. If ECC is not present, or communication is lost with the ECC

frontend the controller shall operate using default modes and setpoints.

H. Or the AHU is selected to run 24/7 in lieu of the schedule.

2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.
   D. Close the humidifier valve whenever the supply fan is off (command or status).
   E. Close the CHW valve.
3. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.
      ii. High pressure sensor (PSH-25) located at the supply fan discharge shall prevent the supply fans from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.
      iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.
   B. Unoccupied Mode:
      i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.
      ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU

shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-31), shall be maintained by modulating chilled water valve (V-2) and control of pre-heat valve (V-1) as discussed below:

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valve (V-1) shall open from a minimum of 10% open to a maximum of 100% open, and shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valve (V-1) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valves (V-1) shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than 50°F (adj.) the pre-heat coil valves (V-1) shall be closed.

iii. Heating control valve shall be modulated via PID control loop to maintain the supply DAT.

iv. Pre-heat valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

v. The Pre-heat valve shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

vi. Adjusting any of the above temperature values shall require Technical Design Level User access.

vii. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-31). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-29) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-28),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-29) and outside air moisture transmitter (MT-30), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, economizer dampers shall modulate open beyond the position required for minimum ventilation air.

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, return air damper (D-2) shall open and OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA damper (D-3) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating

capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA damper (D-3) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed

and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. <u>Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:</u>

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed, the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and

humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:

A. Humidity control with Humidifier:

I. When the DCP is not calling for humidity, sensed by return air humidity (MT-29), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.

ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-28) and humidity transmitter (MT-29) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by SA duct humidity sensor (MT-29). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.

i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.

ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.

7. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU

shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-31) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-10) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-10 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-10 will require manual reset at the device. The OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

   A. On freezestat trip:
   B. Shut down the supply fan and shut down the return fan.
   C. Close the OA, close the relief air damper, and open the RA damper.
   D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.
   E. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.
   F. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

   A. Fan Failure: Commanded on, but the status is off.
   B. Fan in Hand: Commanded off, but the status is on.
   C. Fan VFD Fault.
   D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.

E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.

F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.

G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-31) raises above 65°F, an alarm signal shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-31) the supply fan and return fan shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.

A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.

B. Duct static pressure reset as described in Static Pressure Reset section.

C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.15 AHUs with 100% Return Air AHU-47:

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/cool mode schedules. The discharge air temperature (DAT) setpoints shall be set at the DCP. When the unit is "on" hot water valve (V-1) and the chilled water valve (V-2) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on valves shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

7. AHU Operational Conditions:
   A. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   B. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   C. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and setpoints.
8. AHU Shutdown:
   A. On command or schedule.
   B. Modulate the heating coil valve to maintain AHU cabinet temperature at 50° F as sensed by the DAT sensor (TT-37).
   C. Close the CHW valve.
9. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply fan shall run continuously.
   B. Unoccupied Mode:
      i. During unoccupied periods the supply fan shall stop running.
10. Temperature control:
   A. Occupied Control Mode for Heating: Operate heating coil, and cooling coil valves in sequence to maintain supply discharge air

temperature (DAT) set point and space temperature setpoint. DAT sensed by temperature sensor (TT-31). Space Temperature setpoint shall be maintained by modulating chilled water valve (V-2) with hot water valve (V-1) as discussed below:

i. Hot water control valve shall be modulated via PID control loop to maintain the supply DAT and the space temperature setpoint.

ii. Hot Water valve (V-1) and Chilled Water valve (V-2) shall not be open simultaneously.

iii. Adjusting any of the above temperature values shall require Technical Design Level User access.

B. Temperature control, Chilled Water Cooling Mode: The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or space temperature cooling request).

ii. AND the supply fan status is on.

iii. AND the preheating is disabled.

C. Unoccupied temperature mode:

i. When the space temperature drops below its unoccupied heating set point, start and run the AHU with DAT temperature control until the space unoccupied setpoint of 60°F (adj.) is satisfied.

ii. When the space temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation until the space unoccupied setpoint of 80°F (adj.) is satisfied.

1. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall

start and the heating valve shall open. When the space temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. When the space temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint.

E. Occupancy Override: When the Occupancy Override button on the room T-stat is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

2. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or more.

A. Fan Failure: Commanded on, but the status is off.

B. Fan in Hand: Commanded off, but the status is on.

C. Filter Change Required: Time exceeded. A filter change alarm shall occur when a user definable limit (adj.) is exceeded.

D. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

E. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

F. Belt Break Alarm (if applicable)

3. Misc Control:

Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm

3.16 AHUs with Return Air (AHU-50, 51, & 52):

A. General: AHU shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller and via the Engineering Control Center (ECC) frontend. H-O-A switch shall be kept in the "auto" position "hand" and "off" positions shall be used only for maintenance. When the unit is "off" exhaust air damper (D-1), and outside air damper (D-3) shall be fully closed. The DCP shall send the controller occupied/unoccupied, morning warm-up/pre-cool, and heat/ cool mode schedules. The discharge air temperature (DAT) setpoints, and duct static pressure setpoint shall be set at the DCP. When the unit is "on" exhaust air damper (D-1), return air damper (D-2), and outside air damper (D-3) shall modulate in accordance with the below sequences. All setpoints and outputs shall be able to be adjusted or overridden via the graphics, given proper password privileges. All overrides on dampers, valves and VFDs shall return to safe position when the AHU is off. All physical outputs shall have the ability to be overridden whether stated or not in the sequence via the graphical user interface.

1. AHU Operational Conditions:
   A. Run the AHU in occupied mode to satisfy occupied status for any zone.
   B. Index the AHU to unoccupied mode and do one of the following:
      i. Shut AHU down when all zone terminal units have unoccupied status and are satisfied.
      ii. Continue to run in unoccupied mode at a reduced static pressure setpoint.
   C. For scheduled startup, the AHU controller shall calculate when optimal start occurs.
   D. The AHU shall be commanded to start when the Zone VAV has determined a need to start based upon its optimal start calculations.
   E. Run the supply fan any time the unit is commanded to run, unless shut down on safeties.
   F. Run the return fan any time the supply fan runs.
   G. If ECC is not present, or communication is lost with the ECC frontend the controller shall operate using default modes and

setpoints.

H. Or the AHU is selected to run 24/7 in lieu of the schedule.

2. AHU Shutdown:
   A. On command or schedule.
   B. Close the OA damper (D-3), close the exhaust/relief damper (D-1), and open the RA damper (D-2).
   C. Modulate the preheat coil valve to maintain AHU cabinet temperature at 50° F as sensed by the MAT sensor.
   D. Close the humidifier valve whenever the supply fan is off (command or status).
   E. Close the CHW valve.
3. Airflow Control,
   A. Occupied Mode:
      i. During occupied periods the supply and return fans shall run continuously. The supply fans speed shall be modulated to maintain the duct static pressure setpoint 1.25” W.C. (adj.). The return fan shall modulate to maintain a constant airflow difference between the supply air (SA) CFM and the return air CFM. The outside air (OA) damper shall open to maintain minimum ventilation requirements.
      ii. High pressure sensor (PSH-25) located at the supply fan discharge shall prevent the supply fans from developing over 3"w.c. (adj.) of static pressure. If static pressure at PSH exceeds 3" W.C. the supply air fan shall stop. PSH shall be hardwired to the supply fan and unit shall be shut down in hand, auto or bypass mode. PSH will require manual reset at the device.
      iii. The High pressure sensor shall be set using a Cleveland Controls Model PVG-1 pressure /vacuum generator. This device will be turned over to the owner at the completion of the project.
   B. Unoccupied Mode:
      i. If AHU has all VAV terminal units that are not required to maintain flow during unoccupied mode (i.e. all VAV’s with 0 CFM air flow), then the AHU shall shut down when all zone terminal units have unoccupied status and are satisfied.
      ii. If AHU has VAV terminal units that are required to maintain a reduced flow during unoccupied mode (i.e. VAV’s that reduce flow to no more than 50% of design occupied heating air flow), then the AHU

shall continue to run in unoccupied mode and index up or down based on the below sequences:

(1). The Supply air CFM shall reset as each terminal unit switches to unoccupied mode. When all space temperatures are satisfied and the true position of the VAV damper is less the 90% open then the duct static pressure shall incrementally reset down by 0.10" W.C. every 5 minutes until the VFD has reached its lowest operating setpoint initially set at to provide minimum air flow to the terminal units. Lowest operating VFD setpoint shall be determined during the TAB process.

(2). During the unoccupied mode, when any terminal unit calls for cooling or heating (setpoints as set by ECC) or the true position of the VAV damper is greater than 95% open then the supply and return fan shall incrementally increase by 0.10" W.C. every 5 minutes or until the space temperature reaches 4.0°F (adj.) differential from unoccupied setpoint the fans shall reset down.

iii. Technical Design Level User shall be able to select between the above two unoccupied modes on the ECC frontend.

C. Duct Static Pressure Reset: The Duct Static Pressure Reset control loop shall have an enabled/disabled control function on a Technical Design Level User access page. Also the Duct Static Pressure reset shall not be enabled while DAT Reset control loop is enabled.

i. Incrementally reset the duct static pressure set point down when all VAV box dampers are less than 90% open. Incrementally reset the duct static pressure set point up when any VAV box damper is greater than 95% open.

ii. Maintain duct static pressure set point between a minimum of0.8 inches W.C. (adj.) and a maximum of 1.8 inches W.C (adj.).

4. Temperature control:

A. Occupied Control Mode for Steam Pre-Heating (non-freeze type): Operate preheat coil, economizer dampers, and cooling coil in sequence to maintain Supply discharge air temperature (DAT) set point. DAT sensed by temperature sensor (TT-31), shall be maintained by modulating chilled water valve (V-2) and control of pre-heat valve (V-1A, & 1B) as discussed below:

(1). For recirculation applications with minimum Outside Air, when the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40°F to 10°F (adj.) the pre-heat valve (V-1A, & 1B) shall open from a minimum of 10% open to a maximum of 100% open, and shall be modulated to maintain DAT setpoint.

(a). Pre-heat Reset Override: If DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous, the pre-heat valve (V-1A, & 1B) shall be indexed open 10% more and continue increasing until 100%. Once DAT is at DAT setpoint for 5 minutes (adj.), the Pre-heat valves (V-1A, & 1B) shall be indexed closed by 10% and continue decreasing until the valve position is at the normal Pre-heat reset valve percentage and then the Pre-heat Reset Override shall be released and return to normal Pre-heat Reset operation. During Override and normal Reset operation, the Pre-heat valve shall go no lower than 10% open. Also see alarm condition below.

ii. If the OA temperature is greater than 50°F (adj.) the pre-heat coil valves (V-1A, & 1B) shall be closed.

iii. Heating control valve shall be modulated via PID control loop to maintain the supply DAT.

iv. The AHU has 1/3 and 2/3 Steam valves, then adjust control strategy to operate the 1/3 valve first to maintain DAT Setpoint, If the 1/3 steam valve has reached 100% open for 10 minutes and DAT setpoint is not maintained, then switch to modulate the 2/3 steam valve to maintain DAT setpoint, and closing the 1/3 valve. If the 2/3 steam valve has reached 100% open for 10 minutes and DAT setpoint is not maintained, then add the 1/3 valve in and modulate the 1/3 steam valve to maintain DAT setpoint.

v. Pre-heat valve (V-1A, & 1B) and Chilled Water valve (V-2) shall not be open simultaneously. Also, Mechanical heating and cooling should be locked out when OAT is between 50 (adj.) and 54 (Adj.) degrees.

vi. The Pre-heat valve shall fully open to coil for freeze protection whenever:

(1). Discharge air temperature (DAT) drops below 40°F (adj.).

(2). Or on activation of the freezestat.

vii. Adjusting any of the above temperature values shall require Technical Design Level User access.

viii. Low Preheat Fault Alarm: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT setpoint for more than 5 minutes (adj.) continuous. An alarm shall be generated, enunciated audibly and displayed graphically.

B. Economizer Mode, Mixed Air Temperature Control:

i. When the economizer is enabled, the controller shall modulate the economizer outside air damper (D-3), relief/exhaust air damper (D-1), and return dampers (D-2) in sequence to maintain the mixed air temperature setpoint 4°F (adj.) less than the discharge air temperature setpoint as sensed by the temperature sensor (TT-31). The economizer shall be enabled whenever:

(1). Outside air temperature dry bulb (TT-29) is 2 °F (adj.) less than the return/exhaust dry bulb temperature sensor (TT-28),

(2). AND the OA enthalpy, as calculated by outside air temperature sensor (TT-29) and outside air moisture transmitter (MT-30), is lower (by -2 BTU/Lb.) than the return air enthalpy, as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29). Enthalpy comparison mode (above) shall have an enable/disable control button on the frontend AHU set point page,

(3). The worst case of the above two conditions shall serve as the economizer changeover set point,

(4). AND the supply fan status is on.

(5). The preheat control output has been off continuously for at least 10 minutes (adj.).

(6). When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), there will be a 5 minute delay before any economizer function is enabled. After the startup time delay the outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a startup delay or a delayed ramp open period. This is to prevent the economizer damper from automatically

driving open too quickly while trying to satisfy DAT setpoint and tripping and re-tripping the freezestat.

ii. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint. Logic shall prohibit opening of heating valve and economizer damper simultaneously:

(1). First, economizer dampers shall modulate open beyond the position required for minimum ventilation air.

(2). The Economizer dampers OA Damper and Return Air Damper, shall modulate opposite of each other in unison. The Economizer PID control loop will modulate the OAD from 10 to 100% Open while driving the Return Damper 10 to 100 % Closed, as the economizer loop calls for more OA to satisfy the DAT Setpoint. As DAT falls below DAT Setpoint the reverse shall happen. The Economizer PID control loop will modulate the OAD from 10 to 100% Closed while driving the Return Damper 10 to 100 % Open, as the economizer loop calls for more RA to satisfy the DAT Setpoint.

(3). On further rise in DAT, modulate economizer dampers open to 100% OA before modulating the Chilled water valve (V-2) to maintain DAT set point.

(4). As OA conditions (temperature or enthalpy) rises above the economizer changeover set point conditions, the economizer shall be disabled, return air damper (D-2) shall open and OA damper (D-3) shall modulate to maintain the minimum OA CFM setpoint.

C. <u>Temperature control, Chilled Water Cooling Mode:</u> The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:

i. DAT exceeds effective DAT setpoint (or general cooling request).

ii. AND outside air temperature is greater than either than the effective DAT setpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).

iii. AND the economizer (if present) is either disabled or fully open.

iv. AND the supply fan status is on.

v. AND the preheating is disabled.

vi. The CHW valve shall open to 50% on activation of the freezestat with fans off.

D. Unoccupied temperature mode:

i. When the temperature of any zone drops below its unoccupied heating set point, start and run the AHU with DAT temperature control and with the OA damper (D-3) closed, until the zone unoccupied set point is satisfied.

(1). If zones demanding heat do not have terminal heating capability, operate the AHU with a DAT set point of 85°F.

(2). If zones demanding heat have terminal heating capability (heating coil), operate the AHU with a minimum DAT of 65°F (adj.).

(3). If zones demanding heat have independent heating capability (fan powered VAV box with heating coil or baseboard radiation) operate zone heat without operating AHU.

ii. When the temperature of any zone rises above its unoccupied cooling set point, start and run the AHU, with temperature control as for occupied operation, with economizer enabled, but with OA damper (D-3) closed, until the zone unoccupied set points are satisfied.

(1). If OAT is below 50°F, execute the unoccupied heating sequence for morning warm-up, as required to bring all zones up to normal occupied temperature set points at the start of the scheduled occupancy period.

(2). If OAT is above 55°F, execute the unoccupied cooling sequence for morning cool-down as required to bring all zones down to normal occupied temperature set points at the start of the scheduled occupancy period.

E. Supply Air Temperature Reset:

I. The supply air temperature setpoint shall be reset to the optimal setpoint communicated by the DCP. The DCP shall reset the DAT setpoint based on the current outside air conditions and VAV loads. The DCP shall override DAT setpoint if the outdoor dew point is higher than 60°F (adj.) or indoor humidity is higher than 60% RH (adj.), as sensed by return air humidity. Limit the maximum cooling coil DAT set point reset as required to maintain the space relative humidity high limit set point. Optimal DAT setpoint shall be reset as follows. Reset the DAT set point between 55° F (adj.) and 64° F (adj.):

(1). As OAT drops from 68°F to 40°F (adj.), AHU's that serve VAV zones with a high internal heat load will require a lower OAT upper limit and may require a lower DAT lower limit, or

(2). As RAT drops from 72F to 68°F (adj.) or

(3). By polling Terminal Unit every 5 minutes (Adj). A call for cooling shall be indicated when the re-heat valve is closed and the damper is at 75% (Adj.) open. When zero terminal units call for cooling the DAT shall be increased by 0.5°f (adj.). If more than two (adj.) Terminal Units call for cooling, decrease the supply air temperature by the multiple of 0.3°f x (# of cooling requests-2(adj.)). Include ability for high level operator to disregard select rouge zones.

ii. Technical Design Level User shall be able to select between the above three modes of reset on the ECC frontend.

iii. TAB process shall determine the final DAT limits and OAT limits.

iv. The DAT reset control loop shall have enable/disable control button on the ECC frontend for high level operator use. DAT reset loop shall not be active at same time as Static Pressure reset loop.

v. If the supply air temperature drops below the minimum limit, a low temperature alarm shall be indicated. If the supply air temperature rises above the maximum limit, an alarm shall be indicated.

5. <u>Outside Temperature Changeover Point for Static Pressure and Discharge Air Temperature (DAT) Resets:</u>

A. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other. Therefore, to minimize negative interaction during colder outside conditions the DAT reset strategy is enabled and the static pressure reset strategy is disabled (i.e. maintain fixed static pressure setpoint). During warmer outside conditions the discharge air temperature reset strategy is disabled (i.e. maintain fixed discharge air temperature setpoint) and the static pressure reset strategy is enabled.

i. Colder Conditions: The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling or over heating zones and maximize energy savings in the chilled water and heating plants. This is done by using DAT reset strategy. While supply fan energy savings will be sacrificed,

the energy saved at the central plant should outweigh the lost fan energy savings. Fan energy usage will be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. TAB process shall be used to determine the optimum static pressure setpoints.

ii. Warmer Conditions: Holding a constant discharge air temperature (DAT) during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

B. To implement this control strategy, use a separate independent control loop for each reset strategy that become enabled and disabled based on outside air temperature. The initial outdoor air temperature changeover setpoint shall be between 65F and 70F. Below this range, the economizer will be able to offset more chiller load at the higher discharge air temperature setpoint during cooler ambient conditions. Above this range, most zones will probably require minimal reheat, and humidity control will be improved by maintaining a fixed discharge air temperature setpoint. TAB process shall determine the optimum outside air temperature changeover point (Adj.).

6. Humidity Control:

A. Humidity control with Humidifier:

I. When the DCP is not calling for humidity, sensed by return air humidity (MT-29), 2-way "on-off" control valve (V-3) shall remain closed. When the DCP is calling for humidity (V-3) shall remain open.

ii. Return air humidity shall be maintained at setpoint of 35% relative humidity (adj.) via DCP by modulating control valve (V-4) to maintain the desired humidity. The dry bulb transmitter (TT-28) and humidity transmitter (MT-29) in return air shall be used to calculate return air humidity. The DCP shall override this control to maintain duct humidity no higher than 80% as sensed by SA duct humidity sensor (MT-29). DCP shall close valve V-3 whenever the supply fan is off. Valve V-4 shall be interlocked with a temperature switch to keep the humidifier off until condensate temperature approaches steam temperature.

B. Dehumidification Mode: Dehumidification mode is used only when required by VA HVAC Design Manual space humidity requirements. Include enable/disable control at ECC frontend.

i. Return Air Relative Humidity (RH), as calculated by return air temperature sensor (TT-28) and return air moisture transmitter (MT-29) sensor, shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.

ii. If return RH is greater than maximum setpoint and current reset DAT setpoint is above initial, then reset to initial DAT setpoint. If after 15 minutes (adj.) RH is still greater than maximum setpoint with initial DAT setpoint, then continue to incrementally reset down to minimum low offset.

7. Other Operating Modes:

A. Optimal Start: The DCP shall monitor calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity. Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to start the AHU at the required time to bring all zones to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

B. Morning warm-up mode: During optimal start, if the average space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated the supply fan shall start and the heating valve shall open. The OA damper D-3 shall remain closed. When the space average temperature reaches the occupied heating setpoint, the unit shall transition to occupied mode.

C. Morning pre-cool mode: During optimal start, if the average space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When morning warm-up is initiated the supply fan shall start and the chilled water valve V-2 shall modulate open and maintain DAT setpoint. The OA damper D-3 shall open if economizing is enabled and remain closed if economizing is disabled. When the space average temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

D. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs. When the optimal stop mode is active the unit controller shall maintain the space temperature to the space temperature offset setpoint. Outside air damper shall remain enabled to provide minimum ventilation.

E. Occupancy Override: When the Occupancy Override button on any of the room/zone/terminal unit T-stats is depressed momentarily, the AHU shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours. When an occupied request is received from a space sensor, the AHU shall transition from its current occupancy mode to occupied override mode and the unit shall maintain the space temperature to the occupied setpoints.

F. Emergency constant speed operation: Upon failure of either VFD, the supply and return fans shall be started/stopped manually at the digital control panel or the ECC through the by-pass starter. Fans shall then be operated at constant speed.

8. Freeze protection: If the air temperature as sensed by pre-heat temperature sensor (TT-31) falls below 44°F, an alarm signal shall indicate at the ECC. If this temperature falls below 40°F, as sensed by the Temperature Switch, Low (TSL-10) the supply and return fans shall shut down and a critical alarm shall indicate at the digital control panel and ECP. TSL-10 shall be hardwired to the supply fan and return fan and both shall be shut down in hand, auto or bypass mode. TSL-10 will require manual reset at the device. The OA damper, and Relief Air damper shall all be closed and the Return Air damper will be opened.

A. On freezestat trip:

B. Shut down the supply fan and shut down the return fan.

C. Close the OA, close the relief air damper, and open the RA damper.

D. Open the preheat valve and then modulate to maintain 55 °F as sensed by the MAT sensor.

E. Open CHW valve to 20%, and enable CHW pump (if applicable) for minimum flow.

F. Return the unit to normal operation when freezestat is manually reset.

9. Alarms: An alarm shall be generated, enunciated audibly and displayed graphically when the adverse condition continues for 15 seconds (adj.) or

more.

A. Fan Failure: Commanded on, but the status is off.

B. Fan in Hand: Commanded off, but the status is on.

C. Fan VFD Fault.

D. Filter Change Required: Filter static pressure or time exceeded. Differential pressure across the Pre-Filter and Final Filters shall cause a filter change alarm when differential pressure exceeds a user definable limit (adj.). TAB process to define initial set points.

E. Low duct static pressure: If the duct static pressure is 10% (adj.) below set point.

F. High duct static pressure: If the duct static pressure is 10% (adj.) above set point.

G. High duct static pressure trip.

H. Freezestat trip.

I. High DAT: If the DAT is 10 F greater than set point, provide a warning. If the DAT is 15 F greater than set point, initiate an audible and graphical alarm at the Graphical User Interface.

J. Low DAT: If the DAT is 10 F less than set point, provide a warning. If the DAT is 15'F less than set point, initiate an alarm.

K. Low MAT: If the MAT falls to within 5 F of the MAT low limit set point, provide a warning. If the MAT falls to the low limit MAT set point such that the MAT low limit sequence described above is initiated, activate an alarm.

L. Duct static high limit trip.

M. Belt Break Alarm (if applicable)

10. Automatic smoke shutdown/restart:

A. When smoke is detected by duct smoke detector (SD), the supply and return fans shall shut "off" and an alarm signal shall be transmitted to the fire alarm system. All smoke dampers in the supply and return ducts shall close.

B. Exhaust fans serving area of the supply fan shall continue to run.

C. Supply and return fans shall restart and smoke dampers shall open when fire alarm circuit is reset.

D. Supply and return fans shall restart when smoke detector circuit is reset.

11. Misc Control:

A. Loss of cooling protection: If the air temperature as sensed by pre-heat temperature sensor (TT-31) raises above 65°F, an alarm signal

shall indicate at the DCP and ECP. If this temperature rises above 72°F, as sensed by pre-heat temperature sensor (TT-31) the supply fan and return fan shall shut down and a critical alarm shall indicate at the digital control panel and ECC.

B. Proof: DCP shall prove supply and return fan operation and use the status indication to accumulate runtime. Upon failure of the fan, DCP shall enunciate an alarm.

C. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall modulate the Return Fan VFD Speed to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall reduce the VFD Speed Signal reducing return air flow, increasing space pressure. If the building pressure increases above the desired setpoint, the controller shall increase the VFD Speed Signal increasing return air flow, decreasing space pressure.

D. VFD Control: When fan is energized, DCP shall control speed of VFD to maintain supply duct static pressure setpoint. On start and stop, VFD shall ramp to speed and slow down within adjustable acceleration and deceleration limits. The supply fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system TAB and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

i. VFD BACnet Interface: ECC frontend shall monitor the VFD via a BACnet interface. All available information shall be accessible via the interface for display on the VFD graphics. Frontend shall also accumulate energy consumption of the fan motor (KWH) in daily, monthly and yearly basis. ECC Frontend shall display KWH values for the following:

(1). Day to date (total for the day)

(2). Previous day,

(3). Week to date,

(4). Previous week,

(5). Year to date,

(6). Previous year.

12. Zone VAV Air Terminal Unit Interface: At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.
    A. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.
    B. Duct static pressure reset as described in Static Pressure Reset section.
    C. Discharge air temperature setpoint –optimized as described in the Discharge Air Temperature Reset section.

3.17 VAV Terminal Unit with AHU Interface

A. General: All settings and set points are to be adjustable (by operator with appropriate access) and are to be displayed on graphic along with measured and commanded values.

B. VAV'S shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller or via the Engineering Control Center (ECC) frontend:

1. Terminal Operational Conditions
    A. Index the terminal to occupied mode based on daily, weekly and holiday schedule, on activation of an override button, on activation of occupancy sensor, or on a manual command from operator.
    B. Index the terminal to unoccupied mode whenever it is not indexed to occupied mode.
2. Terminal Shutdown
    A. When a zone occupancy is indexed to unoccupied,
        i. Close the terminal damper and hot water reheat coil valve completely, or
        ii. Close the terminal damper to a preset minimum position and allow the hot water reheat coil valve to modulate to maintain an unoccupied heating setpoint, or
        iii. Modulate the damper to maintain the unoccupied airflow set point and allow the hot water reheat coil valve to modulate to maintain an unoccupied heating setpoint.
3. Occupied Temperature, Ventilation, and Humidity Control
    A. Program zone cooling and heating temperature set points, with a deadband of at least 2°F (adj.) in between.
    B. Modulate damper position to maintain terminal air flow set point.

C. Maintain the zone cooling temperature set point by resetting the terminal airflow set point between cooling minimum and maximum settings

D. As zone temperature drops to heating set point, modulate airflow set point between heating minimum and maximum.

E. Modulate the terminal hot water reheat coil valve to maintain the zone temperature at the zone heating temperature set point.

i. Modulate airflow to maintain terminal SAT high limit of 90°F (adj.) as sensed by VAV Supply air temp (SAT) sensor.

F. Allow zone set point temperature override of +/- 2°F (adj. by frontend operator), applied to the space zone setpoint, as adjusted at the space sensor:

i. Maintain the temperature override value until manually changed, or

ii. Maintain the temperature override value for a period of X hours,

iii. Maintain the temperature override value until the next unoccupied cycle, or

iv. Maintain the temperature override value until a time of HH:MM each day.

G. When zone occupancy status is overridden to occupied, control as for occupied for the scheduled override time.

H. Signal AHU (or allow AHU to poll VAV's) space temp, damper position and hot water valve position, occupancy mode for determining AHU duct static pressure reset and AHU Discharge Air Temperature reset. High level frontend user shall have ability to disregard select rouge VAV zones.

4. Unoccupied Temperature Control:

A. Activation of timed override switch on zone/space thermostats shall only reset zone heating/cooling and CFM setpoints to "occupied" values, but shall not affect otherwise.

B. Zone/Space occupancy schedule shall be user defined from the frontend graphical interface and shall normally automatically select the Occupied or Unoccupied operating mode of Terminal Unit. All Terminal Units/VAV's shall have temperature set points and CFM occupied/unoccupied setback capability for nights/weekends/holiday setback.

C. During unoccupied mode, the CFM flowing into the space shall be reduced to a preset CFM value (adjustable). Some areas will require no CFM, as long as the temperature is maintained within the dead-band range. Other areas shall provide min CFM for odor control or flushing the space to prevent odor buildup. Other areas shall be setback to no more than 50% of the designed occupied air flow.

D. Provide a graphical switch to allow frontend user to change between flowing the VAV continuously in unoccupied mode or shut off and activate VAV only when needed to maintain space temperature.

E. Program unoccupied zone cooling and heating temperature set points shall be set to 66 °F Unoccupied heating and 76 °F Unoccupied Cooling Setpoints.

F. When a zone's unoccupied heating set point is satisfied, modulate the heating valve closed and reduce the airflow set point to unoccupied minimum to prevent overheating.

G. When the temperature of any zone rises above its unoccupied cooling set point

   (1). Signal the AHU controller to operate for unoccupied cooling.

   (2). Operate the terminal unit as for occupied cooling, until the unoccupied cooling set point is satisfied.

H. When a zone's unoccupied cooling set point is satisfied, reduce the airflow set point to unoccupied minimum or off to prevent overcooling.

I. Occupancy Override: When the Occupancy Override button on the T-stat is depressed momentarily, the Terminal Unit shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours (adj.).

J. Optimal Start: The DCP shall monitor environmental conditions and calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity). Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to bring zone to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

K. Morning warm-up mode: During optimal start, if the space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated

L. Morning pre-cool mode: During optimal start, if space temperature is above the occupied cooling setpoint a morning pre-cool mode shall be activated. When the space temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

M. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs.

5. Occupied Standby Mode, with Occupancy Sensors: When an occupancy sensor is used in combination with a time-of-day schedule, the sensor is used to indicate if the zone is unoccupied although the DDC frontend has scheduled it as occupied. This combination is used to switch the zone to an "occupied standby" mode.

   A. In Occupied Standby Mode, the temperature setpoints are raised or lowered by 1°F to 2°F (adj.), and the ventilation requirement for that space/zone is reduced to very low minimum level (adj.).

   B. When the occupancy sensor indicates that the zone is again occupied, these settings are switched back to normal occupied mode.

   C. If included in contract drawings, the same HVAC occupancy sensors will control some of the lights in that zone and shut off lighting when unoccupied. This is used in class rooms and conference rooms.

6. Max Cool Mode

   Max Cool mode is used to temporality increase VAV cooling value to 100% and quickly adjust room conditions to within normal occupied setpoints. This is used for conference rooms where the number of people entering the room changes quickly, causing large variation in the space. Allow wall T-stat override button to be used to implement Max Cool and set the Max Cool time for Conference/class rooms during occupied periods.

   Max Cool does not activate if space temp is within normal occupied range. Max Cool will cancel when the Max Cool time expires or temperature is in occupied range.

7. Alarms

   A. High Space Temperature: If the space temperature is 5°F above set point.

B. Low Space Temperature: If the space temperature is 5°F below set point.

C. Low Zone Airflow: If the zone airflow is 20% below set point.

D. High Zone Airflow: If the zone airflow is 20% above set point

E. High SAT: If SAT is 10°F greater than set point (as applicable).

F. Leaking heating valve: If SAT is 10°F greater than AHU DAT, with heating valve commanded closed for more than 30 minutes (adj). An alarm shall be generated, enunciated audibly and displayed graphically.

8. Frontend Graphics: Frontend graphics shall be modified to show Floor Plan View, VAV Operations, VAV Summary and VAV Occupancy Summary, as shown below:

A. Floor Plan View: Shall include:

i. Floor plans with room #'s and room names,

ii. Space zones, with single-line ductwork and Supply/return grills

iii. VAV locations,

iv. T-stat locations,

v. Each VAV shall graphically represent the space temperature and its reference to the zone setpoint. If the space temperature is 2°F (adj.) over setpoint the zone temperature shall change color tint to red. If the space temperature is 2°F (adj.) below setpoint the zone temperature shall change color tint to blue. If the space temperature is within 0.5°F (adj.) of setpoint the zone temperature shall change color tint to green. A gradient color for any value in between will be used to indicate how far the space temperature is off setpoint. A legend indicating this will be on each floor plan.

vi. Each VAV Graphic shall include direct links to the next and last VAV, link to the AHU serving the VAV box, Link to the Floor Plan, Link to the home page. The goal is to minimize the number of clicks it takes to navigate the system. From the home page you should be able to get to a summary page of the equipment within 3 to 4 clicks. For Example Home Page (0), Floor Plan Overview (1), Floor Plan Area Zoom if needed (2), VAV Box (3).

B. VAV Operations: Shall have animated and colored graphics, all setpoints, VAV functions, menu for quick trending setup, alarms and status's.

C. VAV Summary Page shall show:

i. Name of area of building,

ii. Related AHU, Duct Pressure, and AHU Supply Air Temperature,

iii. VAV #,

iv. Room #,

v. Room name,

vi. Occupancy status, and ability to change occupancy mode on this page,

vii. Space temp, with colors for over/under setpoint conditions,

viii. Space setpoint, and ability to change temp setpoint on this page

ix. Actual CFM and Desired CFM,

x. Min and Max CFM's,

xi. Damper position,

xii. Hot water valve position,

xiii. Supply air temp,

xiv. Related exhaust fan (if available): status, CFM and/or exhaust damper position

D. Occupancy Mode Summary shall include:

i. Name of area of building,

ii. VAV number,

iii. Room name,

iv. Occupancy status with color,

v. Current Mode: occupied, unoccupied, Occupied Standby Mode, Occupancy Override, Off and Optimal Start/Stop modes.

vi. Occupancy Selection dropdown menu,

3.18 VAV Terminal Unit without AHU Interface

A. General: All settings and set points are to be adjustable (by operator with appropriate access) and are to be displayed on graphic along with measured and commanded values.

B. VAV'S shall be normally started and stopped remotely at the Digital Control Panel (DCP) controller or via the Engineering Control Center (ECC) frontend:

1. Terminal Operational Conditions

a. Index the terminal to occupied mode based on daily, weekly and holiday schedule, on activation of an override button, on activation of occupancy sensor, or on a manual command from operator.

b. Index the terminal to unoccupied mode whenever it is not

indexed to occupied mode.

2. Terminal Shutdown
   a. When a zone occupancy is indexed to unoccupied,
      i. Close the terminal damper and hot water reheat coil valve completely, or
      ii. Close the terminal damper to a preset minimum position and allow the hot water reheat coil valve to modulate to maintain an unoccupied heating setpoint, or
      iii. Modulate the damper to maintain the unoccupied airflow set point and allow the hot water reheat coil valve to modulate to maintain an unoccupied heating setpoint.
3. Occupied Temperature, Ventilation, and Humidity Control
   a. Program zone cooling and heating temperature set points, with a deadband of at least 2°F (adj.) in between.
   b. Modulate damper position to maintain terminal air flow set point.
   c. Maintain the zone cooling temperature set point by resetting the terminal airflow set point between cooling minimum and maximum settings
   d. As zone temperature drops to heating set point, modulate airflow set point between heating minimum and maximum.
   e. Modulate the terminal hot water reheat coil valve to maintain the zone temperature at the zone heating temperature set point.
      i. Modulate airflow to maintain terminal SAT high limit of 90°F (adj.) as sensed by VAV Supply air temp (SAT) sensor.
   f. Allow zone set point temperature override of +/- 2°F (adj. by frontend operator), applied to the space zone setpoint, as adjusted at the space sensor:
      i. Maintain the temperature override value until manually changed, or
      ii. Maintain the temperature override value for a period of X hours,
      iii. Maintain the temperature override value until the next unoccupied cycle, or
      iv. Maintain the temperature override value until a time of HH:MM each day.

g. When zone status is overridden to occupied, control as for occupied for the scheduled override time.

4. Unoccupied Temperature Control:
   a. Activation of timed override switch on zone/space thermostats shall only reset zone heating/cooling and CFM setpoint to "occupied" values, but shall not affect otherwise.
   b. Zone/Space occupancy schedule shall be user defined from the frontend graphical interface and shall normally automatically select the Occupied or Unoccupied operating mode of Terminal Unit. All Terminal Units/VAV's shall have temp set points and CFM occupied/unoccupied setback capability for nights/weekends/holiday setback.
   c. During unoccupied mode, the CFM flowing into the space shall be reduced to a preset CFM value (adjustable). Some areas will require no CFM, as long as the temperature is maintained within the dead-band range. Other areas shall provide min CFM for odor control or flushing the space to prevent odor buildup. Other areas shall be setback to no more than 50% of the designed occupied air flow.
   d. Provide a graphical switch to allow frontend user to change between flowing the VAV continuously in unoccupied mode or shut off and activate VAV only when needed to maintain space temperature.
   e. Program unoccupied zone cooling and heating temperature set points shall be set to 66 °F Unoccupied heating and 76 °F Unoccupied Cooling Setpoints.
   f. When a zone's unoccupied heating set point is satisfied, modulate the heating valve closed and reduce the airflow set point to unoccupied minimum to prevent overheating.
   g. When the temperature of any zone rises above its unoccupied cooling set point
      i. Operate the terminal unit as for occupied cooling, until the unoccupied cooling set point is satisfied.
   h. When a zone's unoccupied cooling set point is satisfied, reduce the airflow set point to unoccupied minimum or off to prevent overcooling.

i. Occupancy Override: When the Occupancy Override button on the T-stat is depressed momentarily, the Terminal Unit shall be indexed to the "Occupied" period for 60 min. (Adj.). Each push of the Override button shall add an additional 60 min. to a max of 4 hours(adj.).

J. Optimal Start: The DCP shall monitor environmental conditions and calculate when optimal start occurs. For scheduled startup, use an optimal start algorithm (based on historical time to reach space temperature set point as a function of occupied space setpoints, space temperatures, outside air temperature and outside humidity). Optimal start should learn every time it runs and self-adjust to obtain max efficiency and temperature control of the space to bring zone to normal occupied temperatures at the completion of warm-up or cool-down, just prior to scheduled occupancy.

K. Morning warm-up mode: During optimal start, if the space temperature is below the occupied heating setpoint a morning warm-up mode shall be activated. When morning warm-up is initiated

L. Morning pre-cool mode: During optimal start, if space temperature is above the occupied heating setpoint a morning pre-cool mode shall be activated. When the space temperature reaches the occupied cooling setpoint (adj.) the unit shall transition to occupied mode.

m. Optimal Stop Mode: The controller shall monitor the scheduled unoccupied time, occupied setpoints and space temperature to calculate when the optimal stop occurs.

5. Max Cool Mode

Max Cool mode is used to temporality increase VAV cooling value to 100% and quickly adjust room conditions to within normal occupied setpoints. This is used for conference rooms where the number of people entering the room changes quickly, causing large variation in the space. Allow wall T-stat override button to be used to implement Max Cool and set the Max Cool time for Conference/class rooms during occupied periods.

Max Cool does not activate if space temp is within normal occupied range. Max Cool will cancel when the Max Cool time expires or temperature is in occupied range.

6. Alarms
   a. High Space Temperature: If the space temperature is 5°F above set point.
   b. Low Space Temperature: If the space temperature is 5°F below set point.
   c. Low Zone Airflow: If the zone airflow is 20% below set point.
   d. High Zone Airflow: If the zone airflow is 20% above set point
   e. High SAT: If SAT is 10°F greater than set point (as applicable).
   f. Leaking heating valve: If SAT is 10°F greater than AHU DAT, with heating valve commanded closed for more than 30 minutes (adj). An alarm shall be generated, enunciated audibly and displayed graphically.
7. Frontend Graphics: Frontend graphics shall be modified to show Floor Plan View, VAV Operations, VAV Summary and VAV Occupancy Summary, as shown below:
   a. Floor Plan View: Shall include:
      i. Floor plans with room #'s and room names,
      ii. Space zones, with single-line ductwork and Supply/return grills
      iii. VAV locations,
      iv. T-stat locations,
      v. Each VAV shall graphically represent the space temperature and its reference to the zone setpoint. If the space temperature is 2°F (adj.) over setpoint the zone temperature shall change color tint to red. If the space temperature is 2°F (adj.) below setpoint the zone temperature shall change color tint to blue. If the space temperature is within 0.5°F (adj.) of setpoint the zone temperature shall change color tint to green. A gradient color for any value in between will be used to indicate how far the space temperature is off setpoint. A legend indicating this will be on each floor plan.
      vi. Each VAV Graphic shall include direct links to the next and last VAV, link to the AHU serving the VAV box, Link to the Floor Plan, Link to the home page. The goal is

to minimize the number of clicks it takes to navigate the system. From the home page you should be able to get to a summary page of the equipment within 3 to 4 clicks. For Example Home Page (0), Floor Plan Overview (1), Floor Plan Area Zoom if needed (2), VAV Box (3).

b. VAV Operations: Shall have animated and colored graphics, all setpoints, VAV functions, menu for quick trending setup, alarms and status's.

c. VAV Summary Page shall show:

   i. Name of area of building,
   ii. VAV #,
   iii. Room #,
   iv. Room name,
   v. Occupancy status, and ability to change occupancy mode on this page,
   vi. Space temp, with colors for over/under setpoint conditions,
   vii. Space setpoint, and ability to change temp setpoint on this page
   viii. Actual CFM and Desired CFM,
   ix. Min and Max CFM's,
   x. Damper position,
   xi. Hot water valve position,
   xii. Supply air temp,
   xiii. Related exhaust fan (if available): status, CFM and/or exhaust damper position

d. Occupancy Mode Summary shall include:

   i. Name of area of building,
   ii. VAV number,
   iii. Room name,
   iv. Occupancy status with color,
   v. Current Mode: occupied, unoccupied, Occupied Standby Mode, Occupancy Override, Off and Optimal Start/Stop modes.
   vi. Occupancy Selection dropdown menu,

3.19 Building Pressurization:

A. Building pressurization monitors (BPM) shall be located in Public Corridors, Patient Corridors and Exterior walls as shown on drawings and set for 0.01" WG positive pressure.

1. If BPM is indicating positive pressurization status, the exhaust fan shall be energized or speed increased and vary flow as required to satisfy BPMs.
2. If BPM is indicating negative pressurization status, the outside air intake fan shall be energized or speed increased and vary the flow as required to satisfy BPM's.

3.20 FAN COIL UNITS:

A. **General:** Control shall include scheduled occupancy with optimum preoccupancy, occupancy override, and reheat control as specified below. Schedule shall be the same as the parent AHU.

B. **Space Temperature Control:** Three setpoints shall apply. Normal (72°F adj.)), setback heating (65°F (adj.)), and setback cooling (80°F). These three values shall be the only values changed by the operator to adjust space temperatures. All other deadbands, differentials, etc. shall be calculated in the program logic (unless another means is provided to prohibit overlap of the heating and cooling loops and ensure a dead band such as function block templates that restrict the setpoint input). During the normal periods, separate heating and cooling setpoints shall be calculated.

1. **Normal space cooling setpoint:** shall be the normal space temperature plus 2°F (adj.)
2. **Normal space heating setpoint:** shall be the normal space temperature minus 2°F (adj.)

C. **Fan:** Fan shall be enabled and run continuously during occupied mode. During unoccupied mode, fan shall be de-energized except as required to maintain setback temperature setpoints for both heating and cooling with a cycle differential of 3°f (adj.). BAS shall prove fan operation with a current sensor and use the status indication to accumulate runtime.

D. **Valves:** Heating and cooling control valves shall cycle as required to maintain space temperature setpoint for the associated mode (heating or cooling). Programming shall be implemented to prevent overlap of the heating and cooling valves.

E. **Heating Request:** This unit shall issue a "heating request" to the HW system as follows:

1. Whenever the heating output is at 100%, or
2. Whenever the space temperature falls below the throttling range of the heating loop.

F. **Cooling Request:** This unit shall issue a "cooling request" to the CHW system as follows:

1. Whenever the cooling output is at 100% (full cooling), or
2. Whenever the space temperature rises above the throttling range of the cooling loop.

3.21 ELECTRIC UNIT HEATER:

A. **General:** BAS shall enable the unit heater and provide monitoring and diagnostic information for management purposes.

B. **Fan Control:** BAS shall control the starting and stopping of the unit heater as follows:

1. **Start/Stop:** BAS shall command the operation of the unit heater and it shall run continuously when enabled per occupancy schedule.
2. **Proof:** BAS shall prove fan operation with a current sensor and use the status indication to accumulate runtime. Upon a command status mismatch plus 20 second time delay, the BAS shall generate an alarm, enunciate the alarm, and display it graphically.

C. **Enable Heater:** Unit heater shall be energized whenever space temperature falls below the active heating setpoint.

D. **Disable Heater:** Unit heater shall be de-energized whenever space temperature rises below the active heating setpoint deadband.

E. **Setpoint:** The heating setpoint in unoccupied areas shall be set to 55 °F (adjustable from the graphic screen). The cooling setpoint in occupied areas shall be set to 68 °F (adjustable from the graphic screen).

--End of Section—

SECTION 23 21 13
HYDRONIC PIPING

PART 1 - GENERAL

1.1 DESCRIPTION

A. Water piping to connect HVAC equipment, including the following:
   1. Heating hot water piping.
   2. Extension of domestic water make-up piping.

1.2 RELATED WORK

A. Section 01 00 00, GENERAL REQUIREMENTS.
B. Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES.
C. Section 23 05 11, COMMON WORK RESULTS FOR HVAC and STEAM GENERATION: General mechanical requirements and items, which are common to more than one section of Division 23.
D. Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC: Temperature and pressure sensors and valve operators.

1.3 SUBMITTALS

A. Submit in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES.
B. Manufacturer's Literature and Data:
   1. Pipe and tubing, with specification, class or type, and schedule.
   2. Pipe fittings, including miscellaneous adapters and special fittings.
   3. Flanges, gaskets and bolting.

1.4 APPLICABLE PUBLICATIONS

A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only. American National Standards Institute, Inc.
B. American Society of Mechanical Engineers/American National Standards Institute, Inc. (ASME/ANSI):

B1.20.1-83(R2006).....Pipe Threads, General Purpose (Inch)
B16.4-06.....Gray Iron Threaded FittingsB16.18-01 Cast Copper Alloy Solder joint Pressure fittings
B16.23-02.....Cast Copper Alloy Solder joint Drainage fittings
B40.100-05.....Pressure Gauges and Gauge Attachments

C. American National Standards Institute, Inc./Fluid Controls Institute (ANSI/FCI):

70-2-2006.....Control Valve Seat Leakage

D. American Society of Mechanical Engineers (ASME):

B16.1-98.....Cast Iron Pipe Flanges and Flanged Fittings

B16.3-2006.....Malleable Iron Threaded Fittings: Class 150 and 300

B16.4-2006.....Gray Iron Threaded Fittings: (Class 125 and 250)

B16.5-2003.....Pipe Flanges and Flanged Fittings: NPS ½ through NPS 24 Metric/Inch Standard

B16.9-07.....Factory Made Wrought Butt Welding Fittings

B16.11-05.....Forged Fittings, Socket Welding and Threaded

B16.18-01.....Cast Copper Alloy Solder Joint Pressure Fittings

B16.22-01.....Wrought Copper and Bronze Solder Joint Pressure Fittings.

B16.24-06.....Cast Copper Alloy Pipe Flanges and Flanged Fittings

B16.39-06.....Malleable Iron Threaded Pipe Unions

B16.42-06.....Ductile Iron Pipe Flanges and Flanged Fittings

B31.1-08.....Power Piping

E. American Society for Testing and Materials (ASTM):

A47/A47M-99 (2004).....Ferritic Malleable Iron Castings

A53/A53M-07.....Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

A106/A106M-08.....Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service

A126-04.....Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings

A183-03 ..... Standard Specification for Carbon Steel Track Bolts and Nuts

A216/A216M-08 ..... Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High Temperature Service

A234/A234M-07 ..... Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service

A307-07 ..... Standard Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength

A536-84 (2004) ..... Standard Specification for Ductile Iron Castings

A615/A615M-08 ..... Deformed and Plain Carbon Steel Bars for Concrete Reinforcement

A653/A 653M-08 ..... Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy Coated (Galvannealed) By the Hot-Dip Process

B32-08 ..... Standard Specification for Solder Metal

B62-02 ..... Standard Specification for Composition Bronze or Ounce Metal Castings

B88-03 ..... Standard Specification for Seamless Copper Water Tube

B209-07 ..... Aluminum and Aluminum Alloy Sheet and Plate

C177-04 ..... Standard Test Method for Steady State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded Hot Plate Apparatus

C478-09 ..... Precast Reinforced Concrete Manhole Sections

C533-07 ..... Calcium Silicate Block and Pipe Thermal Insulation

C552-07 ..... Cellular Glass Thermal Insulation

D3350-08 ..... Polyethylene Plastics Pipe and Fittings Materials

C591-08 ..... Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation

D1784-08 ..... Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compound

D1785-06 ..... Poly (Vinyl Chloride0 (PVC) Plastic Pipe, Schedules 40, 80 and 120

D2241-05 ..... Poly (Vinyl Chloride) (PVC) Pressure Rated Pipe (SDR Series)

F439-06 ..... Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80

F441/F441M-02 ..... Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80

F477-08 ..... Elastomeric Seals Gaskets) for Joining Plastic Pipe

F. American Water Works Association (AWWA):

C110-08.....Ductile Iron and Grey Iron Fittings for Water

C203-02.....Coal Tar Protective Coatings and Linings for Steel Water Pipe Lines Enamel and Tape Hot Applied

G. American Welding Society (AWS):

B2.1-02.....Standard Welding Procedure Specification

H. Copper Development Association, Inc. (CDA):

CDA A4015-06.....Copper Tube Handbook

I. Expansion Joint Manufacturer’s Association, Inc. (EJMA):

EMJA-2003.....Expansion Joint Manufacturer’s Association Standards, Ninth Edition

J. Manufacturers Standardization Society (MSS) of the Valve and Fitting Industry, Inc.:

SP-67-02a.....Butterfly Valves

SP-70-06.....Gray Iron Gate Valves, Flanged and Threaded Ends

SP-71-05.....Gray Iron Swing Check Valves, Flanged and Threaded Ends

SP-80-08.....Bronze Gate, Globe, Angle and Check Valves

SP-85-02.....Cast Iron Globe and Angle Valves, Flanged and Threaded Ends

SP-110-96.....Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends

SP-125-00.....Gray Iron and Ductile Iron In-line, Spring Loaded, Center-Guided Check Valves

K. National Sanitation Foundation/American National Standards Institute, Inc. (NSF/ANSI):

14-06.....Plastic Piping System Components and Related Materials

50-2009a.....Equipment for Swimming Pools, Spas, Hot Tubs and other Recreational Water Facilities - Evaluation criteria for materials, components, products, equipment and systems for use at recreational water facilities

61-2008.....Drinking Water System Components - Health Effects

L. Tubular Exchanger Manufacturers Association: TEMA 9th Edition, 2007

PART 2 - PRODUCTS

2.1 PIPE AND TUBING

A. Heating Hot Water:

1. Steel: ASTM A53 Grade B, seamless or ERW, Schedule 40.
2. Copper water tube option: ASTM B88, Type K or L, hard drawn. Soft drawn tubing, 20 mm (3/4 inch) and larger, may be used for runouts routed under slab to floor mounted fan coil units.

2.2 FITTINGS FOR COPPER TUBING

A. Joints:

1. Solder Joints: Joints shall be made up in accordance with recommended practices of the materials applied. Apply 95/5 tin and antimony on all copper piping.
2. Mechanically formed tee connection in water and drain piping: Form mechanically extracted collars in a continuous operation by drilling pilot hole and drawing out tube surface to form collar, having a height of not less than three times the thickness of tube wall. Adjustable collaring device shall insure proper tolerance and complete uniformity of the joint. Notch and dimple joining branch tube in a single process to provide free flow where the branch tube penetrates the fitting.

B. Bronze Flanges and Flanged Fittings: ASME B16.24.

C. Fittings: ANSI/ASME B16.18 cast copper or ANSI/ASME B16.22 solder wrought copper.

PART 3 - EXECUTION

3.1 GENERAL

A. The drawings show the general arrangement of pipe and equipment but do not show all required fittings and offsets that may be necessary to connect pipes to coils, etc., and to coordinate with other trades. Provide all necessary fittings, offsets and pipe runs based on field measurements and at no additional cost to the government. Coordinate with other trades for space available and relative location of HVAC equipment and accessories to be connected on ceiling grid. Pipe location on the drawings shall be altered by contractor where necessary to avoid interferences and clearance difficulties.

B. Store materials to avoid excessive exposure to weather or foreign materials. Keep inside of piping relatively clean during installation and protect open ends when work is not in progress.

C. Install piping generally parallel to walls and column center lines, unless shown otherwise on the drawings. Space piping, including insulation, to provide 25 mm (one inch) minimum clearance between adjacent piping or other surface. Unless shown otherwise, slope drain piping down in the direction of flow not less than 25 mm (one inch) in 12 m (40 feet). Provide eccentric reducers to keep bottom of sloped piping flat.

D. Locate and orient valves to permit proper operation and access for maintenance of packing, seat and disc. Generally locate valve stems in overhead piping in horizontal position. Provide a union adjacent to one end of all threaded end valves. Control valves usually require reducers to connect to pipe sizes shown on the drawing. Install butterfly valves with the valve open as recommended by the manufacturer to prevent binding of the disc in the seat.

E. Offset equipment connections to allow valving off for maintenance and repair with minimal removal of piping. Provide flexibility in equipment connections and branch line take-offs with 3-elbow swing joints where noted on the drawings.

F. Tee water piping runouts or branches into the side of mains or other branches. Avoid bull-head tees, which are two return lines entering opposite ends of a tee and exiting out the common side.

G. Connect piping to equipment as shown on the drawings.

3.2 PIPE JOINTS

A. Screwed: Threads shall conform to ASME B1.20; joint compound shall be applied to male threads only and joints made up so no more than three threads show. Coat exposed threads on steel pipe with joint compound, or red lead paint for corrosion protection.

3.3 LEAK TESTING ABOVEGROUND PIPING

A. Inspect all joints and connections for leaks and workmanship and make corrections as necessary, to the satisfaction of the Resident Engineer. Tests may be either of those below, or a combination, as approved by the Resident Engineer.

B. An operating test at design pressure, and for hot systems, design maximum temperature.

3.4 OPERATING AND PERFORMANCE TEST AND INSTRUCTION

A. Refer to PART 3, Section 23 05 11, COMMON WORK RESULTS FOR HVAC and STEAM GENERATION.

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SECTION 26 05 11
REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

PART 1 - GENERAL

1.1 DESCRIPTION

A. This section applies to all sections of Division 26 and Division 27.

B. Furnish and install electrical systems, materials, equipment, and accessories in accordance with the specifications and drawings. Capacities and ratings of transformers, conductors and cable, and other items and arrangements for the specified items are shown on the drawings.

C. Conductor ampacities specified or shown on the drawings are based on copper conductors, with the conduit and raceways sized per NEC. Aluminum conductors are prohibited.

1.2 MINIMUM REQUIREMENTS

A. The International Building Code (IBC), National Electrical Code (NEC), Underwriters Laboratories, Inc. (UL), and National Fire Protection Association (NFPA) codes and standards are the minimum requirements for materials and installation.

B. The drawings and specifications shall govern in those instances where requirements are greater than those stated in the above codes and standards.

1.3 TEST STANDARDS

A. All materials and equipment shall be listed, labeled, or certified by a Nationally Recognized Testing Laboratory (NRTL) to meet Underwriters Laboratories, Inc. (UL), standards where test standards have been established. Materials and equipment which are not covered by UL standards will be accepted, providing that materials and equipment are listed, labeled, certified or otherwise determined to meet the safety requirements of a NRTL. Materials and equipment which no NRTL accepts, certifies, lists, labels, or determines to be safe, will be considered if inspected or tested in accordance with national industrial standards, such as ANSI, NEMA, and NETA. Evidence of compliance shall include certified test reports and definitive shop drawings.

B. Definitions:

1. Listed: Materials and equipment included in a list published by an organization that is acceptable to the Authority Having Jurisdiction and concerned with evaluation of products or services, that

maintains periodic inspection of production or listed materials and equipment or periodic evaluation of services, and whose listing states that the materials and equipment either meets appropriate designated standards or has been tested and found suitable for a specified purpose.

2. Labeled: Materials and equipment to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the Authority Having Jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled materials and equipment, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.
3. Certified: Materials and equipment which:
   a. Have been tested and found by a NRTL to meet nationally recognized standards or to be safe for use in a specified manner.
   b. Are periodically inspected by a NRTL.
   c. Bear a label, tag, or other record of certification.
4. Nationally Recognized Testing Laboratory: Testing laboratory which is recognized and approved by the Secretary of Labor in accordance with OSHA regulations.

1.4 QUALIFICATIONS (PRODUCTS AND SERVICES)

A. Manufacturer’s Qualifications: The manufacturer shall regularly and currently produce, as one of the manufacturer's principal products, the materials and equipment specified for this project, and shall have manufactured the materials and equipment for at least three years.

B. Product Qualification:
   1. Manufacturer's materials and equipment shall have been in satisfactory operation, on three installations of similar size and type as this project, for at least three years.
   2. The Government reserves the right to require the Contractor to submit a list of installations where the materials and equipment have been in operation before approval.

C. Service Qualifications: There shall be a permanent service organization maintained or trained by the manufacturer which will render satisfactory service to this installation within four hours of receipt of notification that service is needed. Submit name and address of service organizations.

1.5 APPLICABLE PUBLICATIONS

A. Applicable publications listed in all Sections of Division 26 and Division 27 are the latest issue, unless otherwise noted.

B. Products specified in all sections of Division 26 and Division 27 shall comply with the applicable publications listed in each section.

1.6 MANUFACTURED PRODUCTS

A. Materials and equipment furnished shall be of current production by manufacturers regularly engaged in the manufacture of such items, and for which replacement parts shall be available. Materials and equipment furnished shall be new, and shall have superior quality and freshness.

B. When more than one unit of the same class or type of materials and equipment is required, such units shall be the product of a single manufacturer.

C. Equipment Assemblies and Components:

1. Components of an assembled unit need not be products of the same manufacturer.
2. Manufacturers of equipment assemblies, which include components made by others, shall assume complete responsibility for the final assembled unit.
3. Components shall be compatible with each other and with the total assembly for the intended service.
4. Constituent parts which are similar shall be the product of a single manufacturer.

D. Factory wiring and terminals shall be identified on the equipment being furnished and on all wiring diagrams.

1.7 VARIATIONS FROM CONTRACT REQUIREMENTS

A. Where the Government or the Contractor requests variations from the contract requirements, the connecting work and related components shall include, but not be limited to additions or changes to branch circuits, circuit protective devices, conduits, wire, feeders, controls, panels and installation methods.

1.8 MATERIALS AND EQUIPMENT PROTECTION

A. Materials and equipment shall be protected during shipment and storage against physical damage, vermin, dirt, corrosive substances, fumes, moisture, cold and rain.

1. Store materials and equipment indoors in clean dry space with uniform temperature to prevent condensation.
2. During installation, equipment shall be protected against entry of foreign matter, and be vacuum-cleaned both inside and outside before testing and operating. Compressed air shall not be used to clean equipment. Remove loose packing and flammable materials from inside equipment.
3. Damaged equipment shall be repaired or replaced, as determined by the COR.
4. Painted surfaces shall be protected with factory installed removable heavy kraft paper, sheet vinyl or equal.
5. Damaged paint on equipment shall be refinished with the same quality of paint and workmanship as used by the manufacturer so repaired areas are not obvious.

1.9 WORK PERFORMANCE

A. All electrical work shall comply with the requirements of NFPA 70 (NEC), NFPA 70B, NFPA 70E, OSHA Part 1910 subpart J – General Environmental Controls, OSHA Part 1910 subpart K – Medical and First Aid, and OSHA Part 1910 subpart S – Electrical, in addition to other references required by contract.

B. Job site safety and worker safety is the responsibility of the Contractor.

C. Electrical work shall be accomplished with all affected circuits or equipment de-energized. When an electrical outage cannot be accomplished in this manner for the required work, the following requirements are mandatory:

1. Electricians must use full protective equipment (i.e., certified and tested insulating material to cover exposed energized electrical components, certified and tested insulated tools, etc.) while working on energized systems in accordance with NFPA 70E.
2. Before initiating any work, a job specific work plan must be developed by the Contractor with a peer review conducted and documented by the COR and Medical Center staff. The work plan must include procedures to be used on and near the live electrical equipment, barriers to be installed, safety equipment to be used, and exit pathways.

3. Work on energized circuits or equipment cannot begin until prior written approval is obtained from the COR.

D. For work that affects existing electrical systems, arrange, phase and perform work to assure minimal interference with normal functioning of the facility. Refer to Article OPERATIONS AND STORAGE AREAS under Section 01 00 00, GENERAL REQUIREMENTS.

E. New work shall be installed and connected to existing work neatly, safely and professionally. Disturbed or damaged work shall be replaced or repaired to its prior conditions, as required by Section 01 00 00, GENERAL REQUIREMENTS.

F. Coordinate location of equipment and conduit with other trades to minimize interference.

1.10 EQUIPMENT INSTALLATION AND REQUIREMENTS

A. Equipment location shall be as close as practical to locations shown on the drawings.

B. Working clearances shall not be less than specified in the NEC.

C. Inaccessible Equipment:

1. Where the Government determines that the Contractor has installed equipment not readily accessible for operation and maintenance, the equipment shall be removed and reinstalled as directed at no additional cost to the Government.
2. "Readily accessible" is defined as being capable of being reached quickly for operation, maintenance, or inspections without the use of ladders, or without climbing or crawling under or over obstacles such as, but not limited to, motors, pumps, belt guards, transformers, piping, ductwork, conduit and raceways.

1.11 EQUIPMENT IDENTIFICATION

A. In addition to the requirements of the NEC, install an identification sign which clearly indicates information required for use and maintenance of items.

B. Identification signs for Normal Power System equipment shall be laminated black phenolic resin with a white core with engraved lettering. Identification signs for Essential Electrical System (EES) equipment, as defined in the NEC, shall be laminated red phenolic resin with a white core with engraved lettering. Lettering shall be a minimum of 12 mm (1/2 inch) high. Identification signs shall indicate equipment designation, rated bus amperage, voltage, number of phases, number of

wires, and type of EES power branch as applicable. Secure nameplates with screws.

C. Install adhesive arc flash warning labels on all equipment as required by NFPA 70E. Label shall show specific and correct information for specific equipment based on its arc flash calculations. Label shall show the followings:
   1. Nominal system voltage.
   2. Arc flash boundary (inches).
   3. Available arc flash incident energy at the corresponding working distance (calories/cm2).
   4. Required PPE category and description.
   5. Limited approach distance (inches), restricted approach distance (inches).
   6. Equipment/bus name, date prepared, and manufacturer name and address.

1.12 SUBMITTALS

A. Submit to the COR in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.

B. The Government's approval shall be obtained for all materials and equipment before delivery to the job site. Delivery, storage or installation of materials and equipment which has not had prior approval will not be permitted.

C. All submittals shall include six copies of adequate descriptive literature, catalog cuts, shop drawings, test reports, certifications, samples, and other data necessary for the Government to ascertain that the proposed materials and equipment comply with drawing and specification requirements. Catalog cuts submitted for approval shall be legible and clearly identify specific materials and equipment being submitted.

D. Submittals for individual systems and equipment assemblies which consist of more than one item or component shall be made for the system or assembly as a whole. Partial submittals will not be considered for approval.
   1. Mark the submittals, "SUBMITTED UNDER SECTION_____".
   2. Submittals shall be marked to show specification reference including the section and paragraph numbers.
   3. Submit each section separately.

E. The submittals shall include the following:
   1. Information that confirms compliance with contract requirements. Include the manufacturer's name, model or catalog numbers, catalog information, technical data sheets, shop drawings, manuals, pictures, nameplate data, and test reports as required.
   2. Elementary and interconnection wiring diagrams for communication and signal systems, control systems, and equipment assemblies. All terminal points and wiring shall be identified on wiring diagrams.
   3. Parts list which shall include information for replacement parts and ordering instructions, as recommended by the equipment manufacturer.

F. Maintenance and Operation Manuals:
   1. Submit as required for systems and equipment specified in the technical sections. Furnish in hardcover binders or an approved equivalent.
   2. Inscribe the following identification on the cover: the words "MAINTENANCE AND OPERATION MANUAL," the name and location of the system, material, equipment, building, name of Contractor, and contract name and number. Include in the manual the names, addresses, and telephone numbers of each subcontractor installing the system or equipment and the local representatives for the material or equipment.
   3. Provide a table of contents and assemble the manual to conform to the table of contents, with tab sheets placed before instructions covering the subject. The instructions shall be legible and easily read, with large sheets of drawings folded in.
   4. The manuals shall include:
      a. Internal and interconnecting wiring and control diagrams with data to explain detailed operation and control of the equipment.
      b. A control sequence describing start-up, operation, and shutdown.
      c. Description of the function of each principal item of equipment.
      d. Installation instructions.
      e. Safety precautions for operation and maintenance.
      f. Diagrams and illustrations.
      g. Periodic maintenance and testing procedures and frequencies, including replacement parts numbers.
      h. Performance data.

i. Pictorial "exploded" parts list with part numbers. Emphasis shall be placed on the use of special tools and instruments. The list shall indicate sources of supply, recommended spare and replacement parts, and name of servicing organization.

j. List of factory approved or qualified permanent servicing organizations for equipment repair and periodic testing and maintenance, including addresses and factory certification qualifications.

G. Approvals will be based on complete submission of shop drawings, manuals, test reports, certifications, and samples as applicable.

1.13 SINGULAR NUMBER

A. Where any device or part of equipment is referred to in these specifications in the singular number (e.g., "the switch"), this reference shall be deemed to apply to as many such devices as are required to complete the installation as shown on the drawings.

1.14 ACCEPTANCE CHECKS AND TESTS

A. The Contractor shall furnish the instruments, materials, and labor for tests.

B. Where systems are comprised of components specified in more than one section of Division 26 or Division 27, the Contractor shall coordinate the installation, testing, and adjustment of all components between various manufacturer’s representatives and technicians so that a complete, functional, and operational system is delivered to the Government.

C. When test results indicate any defects, the Contractor shall repair or replace the defective materials or equipment, and repeat the tests. Repair, replacement, and retesting shall be accomplished at no additional cost to the Government.

1.15 WARRANTY

A. All work performed and all equipment and material furnished under this Division shall be free from defects and shall remain so for a period of one year from the date of acceptance of the entire installation by the Contracting Officer for the Government.

1.16 INSTRUCTION

A. Instruction to designated Government personnel shall be provided for the particular equipment or system as required in each associated technical specification section.

B. Furnish the services of competent and factory-trained instructors to give full instruction in the adjustment, operation, and maintenance of the specified equipment and system, including pertinent safety requirements. Instructors shall be thoroughly familiar with all aspects of the installation, and shall be factory-trained in operating theory as well as practical operation and maintenance procedures.

C. A training schedule shall be developed and submitted by the Contractor and approved by the COR at least 30 days prior to the planned training.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION (NOT USED)

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SECTION 26 05 19
LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES

PART 1 - GENERAL

1.1 DESCRIPTION

A. This section specifies the furnishing, installation, connection, and testing of the electrical conductors and cables for use in electrical systems rated 600 V and below, indicated as cable(s), conductor(s), wire, or wiring in this section.

1.2 RELATED WORK

A. Section 07 84 00, FIRESTOPPING: Sealing around penetrations to maintain the integrity of fire-resistant rated construction.

B. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: Requirements that apply to all sections of Division 26.

C. Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS: Requirements for personnel safety and to provide a low impedance path for possible ground fault currents.

D. Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS: Conduits for conductors and cables.

1.3 QUALITY ASSURANCE

A. Refer to Paragraph, QUALIFICATIONS (PRODUCTS AND SERVICES), in Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

1.4 FACTORY TESTS

A. Conductors and cables shall be thoroughly tested at the factory per NEMA to ensure that there are no electrical defects. Factory tests shall be certified.

1.5 SUBMITTALS

A. Submit six copies of the following in accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

1. Shop Drawings:
   a. Submit sufficient information to demonstrate compliance with drawings and specifications.
   b. Submit the following data for approval:
      1) Electrical ratings and insulation type for each conductor and cable.
      2) Splicing materials and pulling lubricant.
2. Certifications: Two weeks prior to final inspection, submit the following.

a. Certification by the manufacturer that the conductors and cables conform to the requirements of the drawings and specifications.
b. Certification by the Contractor that the conductors and cables have been properly installed, adjusted, and tested.

1.6 APPLICABLE PUBLICATIONS

A. Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are reference in the text by designation only.

B. American Society of Testing Material (ASTM):

D2301-10.....Standard Specification for Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape

D2304-10.....Test Method for Thermal Endurance of Rigid Electrical Insulating Materials

D3005-10.....Low-Temperature Resistant Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape

C. National Electrical Manufacturers Association (NEMA):

WC 70-09.....Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy

D. National Fire Protection Association (NFPA):

70-11.....National Electrical Code (NEC)

E. Underwriters Laboratories, Inc. (UL):

44-10.....Thermoset-Insulated Wires and Cables

83-08.....Thermoplastic-Insulated Wires and Cables

467-07.....Grounding and Bonding Equipment

486A-486B-03.....Wire Connectors

486C-04.....Splicing Wire Connectors

486D-05.....Sealed Wire Connector Systems

486E-09.....Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors

493-07.....Thermoplastic-Insulated Underground Feeder and Branch Circuit Cables

514B-04.....Conduit, Tubing, and Cable Fittings

PART 2 - PRODUCTS

2.1 CONDUCTORS AND CABLES

A. Conductors and cables shall be in accordance with NEMA, UL, as specified herein, and as shown on the drawings.

B. All conductors shall be copper.

C. Single Conductor and Cable:

1. No. 12 AWG: Minimum size, except where smaller sizes are specified herein or shown on the drawings.
2. No. 10 AWG and smaller: Solid; except shall be stranded for final connection to motors, transformers, and vibrating equipment.
3. Insulation: THHN-THWN.

D. Color Code:

1. No. 10 AWG and smaller: Solid color insulation or solid color coating.
2. For modifications and additions to existing wiring systems, color coding shall conform to the existing wiring system.
3. Conductors shall be color-coded as follows:

208/120 V	Phase	
Black	A	
Red	B	
Blue	C	
White	Neutral	

2.2 SPLICES

A. Splices shall be in accordance with NEC and UL.

B. Above Ground Splices for No. 10 AWG and Smaller:

1. Solderless, screw-on, reusable pressure cable type, with integral insulation, approved for copper and aluminum conductors.
2. The integral insulator shall have a skirt to completely cover the stripped conductors.
3. The number, size, and combination of conductors used with the connector, as listed on the manufacturer's packaging, shall be strictly followed.

C. Plastic electrical insulating tape: Per ASTM D2304, flame-retardant, cold and weather resistant.

2.3 CONNECTORS AND TERMINATIONS

A. Mechanical type of high conductivity and corrosion-resistant material, listed for use with copper and aluminum conductors.

2.4 CONTROL WIRING

A. Unless otherwise specified elsewhere in these specifications, control wiring shall be as specified herein, except that the minimum size shall be not less than No. 14 AWG.

B. Control wiring shall be sized such that the voltage drop under in-rush conditions does not adversely affect operation of the controls.

2.5 WIRE LUBRICATING COMPOUND

A. Lubricating compound shall be suitable for the wire insulation and conduit, and shall not harden or become adhesive.

PART 3 - EXECUTION

3.1 GENERAL

A. Install conductors in accordance with the NEC, as specified, and as shown on the drawings.

B. Install all conductors in raceway systems.

C. Splice conductors only in outlet boxes, junction boxes or pullboxes.

D. Conductors of different systems (e.g., 120 V and 277 V) shall not be installed in the same raceway.

E. Install cable supports for all vertical feeders in accordance with the NEC. Provide split wedge type which firmly clamps each individual cable and tightens due to cable weight.

F. In panelboards, cabinets, wireways, switches, enclosures, and equipment assemblies, neatly form, train, and tie the conductors with non-metallic ties.

G. For connections to motors, transformers, and vibrating equipment, stranded conductors shall be used only from the last fixed point of connection to the motors, transformers, or vibrating equipment.

H. Conductor and Cable Pulling:

1. Provide installation equipment that will prevent the cutting or abrasion of insulation during pulling. Use lubricants approved for the cable.
2. Use nonmetallic pull ropes.
3. Attach pull ropes by means of either woven basket grips or pulling eyes attached directly to the conductors.
4. All conductors in a single conduit shall be pulled simultaneously.

5. Do not exceed manufacturer’s recommended maximum pulling tensions and sidewall pressure values.

I. No more than three branch circuits shall be installed in any one conduit.

J. When stripping stranded conductors, use a tool that does not damage the conductor or remove conductor strands.

3.2 SPLICE AND TERMINATION INSTALLATION

A. Splices and terminations shall be mechanically and electrically secure, and tightened to manufacturer’s published torque values using a torque screwdriver or wrench.

B. Where the Government determines that unsatisfactory splices or terminations have been installed, replace the splices or terminations at no additional cost to the Government.

3.3 EXISTING CONDUCTORS

A. Unless specifically indicated on the plans, existing conductors shall not be reused.

3.4 CONTROL WIRING INSTALLATION

A. Unless otherwise specified in other sections, install control wiring and connect to equipment to perform the required functions as specified or as shown on the drawings.

B. Install a separate power supply circuit for each system, except where otherwise shown on the drawings.

3.5 CONTROL WIRING IDENTIFICATION

A. Install a permanent wire marker on each wire at each termination.

B. Identifying numbers and letters on the wire markers shall correspond to those on the wiring diagrams used for installing the systems.

C. Wire markers shall retain their markings after cleaning.

3.6 ACCEPTANCE CHECKS AND TESTS

A. Perform in accordance with the manufacturer's recommendations. In addition, include the following:

1. Visual Inspection and Tests: Inspect physical condition.
2. Electrical tests:
   a. After installation but before connection to utilization devices, such as fixtures, motors, or appliances, test conductors phase-to-phase and phase-to-ground resistance with an insulation resistance tester. Existing conductors to be reused shall also be tested.

b. Applied voltage shall be 500 V DC for 300 V rated cable, and 1000 V DC for 600 V rated cable. Apply test for one minute or until reading is constant for 15 seconds, whichever is longer. Minimum insulation resistance values shall not be less than 25 megohms for 300 V rated cable and 100 megohms for 600 V rated cable.

---END---

SECTION 26 05 26
GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

A. This section specifies the furnishing, installation, connection, and testing of grounding and bonding equipment, indicated as grounding equipment in this section.

B. The terms "connect" and "bond" are used interchangeably in this section and have the same meaning.

1.2 RELATED WORK

A. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: Requirements that apply to all sections of Division 26.

B. Section 26 05 19, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES: Low-voltage conductors.

C. Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS: Conduit and boxes.

1.3 QUALITY ASSURANCE

A. Refer to Paragraph, QUALIFICATIONS (PRODUCTS AND SERVICES), in Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

1.4 SUBMITTALS

A. Submit six copies of the following in accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

1. Shop Drawings:

a. Submit sufficient information to demonstrate compliance with drawings and specifications.

1.5 APPLICABLE PUBLICATIONS

A. Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by designation only.

B. American Society for Testing and Materials (ASTM):

B1-07.....Standard Specification for Hard-Drawn Copper Wire

B3-07.....Standard Specification for Soft or Annealed Copper Wire

B8-11.....Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

C. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

81-83.....IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part 1: Normal Measurements

D. National Fire Protection Association (NFPA):

70-11.....National Electrical Code (NEC)

70E-12.....National Electrical Safety Code

99-12.....Health Care Facilities

E. Underwriters Laboratories, Inc. (UL):

44-10 .....Thermoset-Insulated Wires and Cables

83-08 .....Thermoplastic-Insulated Wires and Cables

467-07 .....Grounding and Bonding Equipment

PART 2 - PRODUCTS

2.1 GROUNDING AND BONDING CONDUCTORS

A. Equipment grounding conductors shall be insulated stranded copper, except that sizes No. 10 AWG and smaller shall be solid copper. Insulation color shall be continuous green for all equipment grounding conductors, except that wire sizes No. 4 AWG and larger shall be identified per NEC.

B. Bonding conductors shall be bare stranded copper, except that sizes No. 10 AWG and smaller shall be bare solid copper. Bonding conductors shall be stranded for final connection to motors, transformers, and vibrating equipment.

C. Conductor sizes shall not be less than shown on the drawings, or not less than required by the NEC, whichever is greater.

D. Insulation: THHN-THWN.

2.2 GROUND CONNECTIONS

A. Above Grade:

1. Connection to Grounding Bus Bars: Listed for use with aluminum and copper conductors. Use mechanical type lugs, with zinc-plated steel bolts, nuts, and washers. Bolts shall be torqued to the values recommended by the manufacturer.
2. Connection to Equipment Rack and Cabinet Ground Bars: Listed for use with aluminum and copper conductors. Use mechanical type lugs, with

zinc-plated steel bolts, nuts, and washers. Bolts shall be torqued to the values recommended by the manufacturer.

PART 3 - EXECUTION

3.1 GENERAL

A. Install grounding equipment in accordance with the NEC, as shown on the drawings, and as specified herein.

B. Equipment Grounding: Metallic piping, building structural steel, electrical enclosures, raceways, junction boxes, outlet boxes, cabinets, machine frames, and other conductive items in close proximity with electrical circuits, shall be bonded and grounded.

C. For patient care area electrical power system grounding, conform to NFPA 99 and NEC.

3.2 RACEWAY

A. Conduit Systems:

1. Ground all metallic conduit systems. All metallic conduit systems shall contain an equipment grounding conductor.
2. Metallic conduits which terminate without mechanical connection to an electrical equipment housing by means of locknut and bushings or adapters, shall be provided with grounding bushings. Connect bushings with a equipment grounding conductor to the equipment ground bus.

B. Feeders and Branch Circuits: Install equipment grounding conductors with all feeders, and power and lighting branch circuits.

C. Boxes, Cabinets, Enclosures, and Panelboards:

1. Bond the equipment grounding conductor to each pullbox, junction box, outlet box, device box, cabinets, and other enclosures through which the conductor passes (except for special grounding systems for intensive care units and other critical units shown).
2. Provide lugs in each box and enclosure for equipment grounding conductor termination.

D. Fixed electrical appliances and equipment shall be provided with a ground lug for termination of the equipment grounding conductor.

3.3 CORROSION INHIBITORS

A. When making grounding and bonding connections, apply a corrosion inhibitor to all contact surfaces. Use corrosion inhibitor appropriate for protecting a connection between the metals used.

3.4 CONDUCTIVE PIPING

A. Bond all conductive piping systems, interior and exterior, to the grounding electrode system. Bonding connections shall be made as close as practical to the equipment ground bus.

---END---

SECTION 26 05 33
RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

A. This section specifies for Divisions 26 and Division 27 the furnishing, installation, and connection of conduit, fittings, and boxes, to form complete, coordinated, grounded raceway systems. Raceways are required for all wiring unless shown or specified otherwise.

B. Definitions: The term conduit, as used in this specification, shall mean any or all of the raceway types specified.

1.2 RELATED WORK

A. Section 07 84 00, FIRESTOPPING: Sealing around penetrations to maintain the integrity of fire rated construction.

B. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: General electrical requirements and items that are common to more than one section of Division 26.

C. Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS: Requirements for personnel safety and to provide a low impedance path for possible ground fault currents.

D. Section 27 15 00, COMMUNICATIONS STRUCTURAL CABLING.

1.3 QUALITY ASSURANCE

Refer to Paragraph, QUALIFICATIONS, in Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

1.4 SUBMITTALS

A. Submit six copies of the following in accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

1. Shop Drawings:
   a. Layout of required conduit penetrations through structural elements.
   b. Submit the following data for approval:
      1) Raceway types and sizes.
      2) Conduit bodies, connectors and fittings.
      3) Junction and pull boxes, types and sizes.
2. Certifications: Two weeks prior to final inspection, submit the following:
   a. Certification by the manufacturer that raceways, conduits, conduit bodies, connectors, fittings, junction and pull boxes,

and all related equipment conform to the requirements of the drawings and specifications.

b. Certification by the Contractor that raceways, conduits, conduit bodies, connectors, fittings, junction and pull boxes, and all related equipment have been properly installed.

1.5 APPLICABLE PUBLICATIONS

A. Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by designation only.

B. American National Standards Institute (ANSI):

C80.3-05.....Steel Electrical Metal Tubing

C80.6-05.....Electrical Intermediate Metal Conduit

C. National Fire Protection Association (NFPA):

70-11.....National Electrical Code (NEC)

D. Underwriters Laboratories, Inc. (UL):

1-05.....Flexible Metal Conduit

50-95.....Enclosures for Electrical Equipment

360-13.....Liquid-Tight Flexible Steel Conduit

514A-13.....Metallic Outlet Boxes

514B-12.....Conduit, Tubing, and Cable Fittings and Covers

797-07.....Electrical Metallic Tubing

E. National Electrical Manufacturers Association (NEMA):

FB1-12.....Fittings, Cast Metal Boxes and Conduit Bodies for Conduit, Electrical Metallic Tubing and Cable

FB2.10-13.....Selection and Installation Guidelines for Fittings for use with Non-Flexible Conduit or Tubing (Rigid Metal Conduit, Intermediate Metallic Conduit, and Electrical Metallic Tubing)

FB2.20-12.....Selection and Installation Guidelines for Fittings for use with Flexible Electrical Conduit and Cable

PART 2 - PRODUCTS

2.1 MATERIAL

A. Conduit Size: In accordance with the NEC, but not less than 13 mm (0.5-inch) unless otherwise shown.

B. Conduit:

1. Size: In accordance with the NEC, but not less than 13 mm (0.5-inch).
2. Electrical Metallic Tubing (EMT): Shall conform to UL 797 and ANSI C80.3. Maximum size not to exceed 105 mm (4 inches) and shall be permitted only with cable rated 600 V or less.
3. Flexible Metal Conduit: Shall conform to UL 1.
4. Liquid-tight Flexible Metal Conduit: Shall conform to UL 360.

C. Conduit Fittings:

1. Electrical Metallic Tubing Fittings:
   a. Fittings and conduit bodies shall meet the requirements of UL 514B, ANSI C80.3, and NEMA FB1.
   b. Only steel or malleable iron materials are acceptable.
   c. Compression Couplings and Connectors: Concrete-tight and rain-tight, with connectors having insulated throats.
   d. Indent-type connectors or couplings are prohibited.
   e. Die-cast or pressure-cast zinc-alloy fittings or fittings made of "pot metal" are prohibited.
2. Flexible Metal Conduit Fittings:
   a. Conform to UL 514B. Only steel or malleable iron materials are acceptable.
   b. Clamp-type, with insulated throat.
3. Liquid-tight Flexible Metal Conduit Fittings:
   a. Fittings shall meet the requirements of UL 514B and NEMA FB1.
   b. Only steel or malleable iron materials are acceptable.
   c. Fittings must incorporate a threaded grounding cone, a steel or plastic compression ring, and a gland for tightening. Connectors shall have insulated throats.

D. Conduit Supports:

1. Parts and Hardware: Zinc-coat or provide equivalent corrosion protection.

2. Individual Conduit Hangers: Designed for the purpose, having a pre-assembled closure bolt and nut, and provisions for receiving a hanger rod.
3. Multiple Conduit (Trapeze) Hangers: Not less than 38 mm x 38 mm (1.5 x 1.5 inches), 12-gauge steel, cold-formed, lipped channels; with not less than 9 mm (0.375-inch) diameter steel hanger rods.
4. Solid Masonry and Concrete Anchors: Self-drilling expansion shields, or machine bolt expansion.

E. Outlet, Junction, and Pull Boxes:
1. UL-50 and UL-514A.
2. Rustproof cast metal where required by the NEC or shown on drawings.
3. Sheet Metal Boxes: Galvanized steel, except where shown on drawings.

PART 3 - EXECUTION

3.1 PENETRATIONS

A. Cutting or Holes:
1. Cut holes in advance where they should be placed in the structural elements, such as ribs or beams. Obtain the approval of the COR prior to drilling through structural elements.
2. Cut holes through concrete and masonry in existing structures with a diamond core drill or concrete saw. Pneumatic hammers, impact electric, hand, or manual hammer-type drills are not allowed, except when permitted by the COR where working space is limited.

B. Firestop: Where conduits and other electrical raceways pass through fire partitions, fire walls, smoke partitions, or floors, install a fire stop that provides an effective barrier against the spread of fire, smoke and gases as specified in Section 07 84 00, FIRESTOPPING.

C. Waterproofing: At floor and exterior wall conduit penetrations, completely seal the gap around conduit to render it watertight, as specified in Section 07 92 00, JOINT SEALANTS.

3.2 INSTALLATION, GENERAL

A. In accordance with UL, NEC, NEMA, as shown on drawings, and as specified herein.

B. Install conduit as follows:
1. In complete mechanically and electrically continuous runs before pulling in cables or wires.

2. Unless otherwise indicated on the drawings or specified herein, installation of all conduits shall be concealed within finished walls, floors, and ceilings.
3. Flattened, dented, or deformed conduit is not permitted. Remove and replace the damaged conduits with new conduits.
4. Assure conduit installation does not encroach into the ceiling height head room, walkways, or doorways.
5. Cut conduits square, ream, remove burrs, and draw up tight.
6. Independently support conduit at 2.4 M (8 feet) on centers with specified materials and as shown on drawings.
7. Do not use suspended ceilings, suspended ceiling supporting members, lighting fixtures, other conduits, cable tray, boxes, piping, or ducts to support conduits and conduit runs.
8. Support within 300 mm (12 inches) of changes of direction, and within 300 mm (12 inches) of each enclosure to which connected.
9. Close ends of empty conduits with plugs or caps at the rough-in stage until wires are pulled in, to prevent entry of debris.
10. Conduit installations under fume and vent hoods are prohibited.
11. Secure conduits to cabinets, junction boxes, pull-boxes, and outlet boxes with bonding type locknuts. Do not make conduit connections to junction box covers.
12. Conduit bodies shall only be used for changes in direction, and shall not contain splices.

C. Conduit Bends:
1. Make bends with standard conduit bending machines.
2. Conduit hickey may be used for slight offsets and for straightening stubbed out conduits.
3. Bending of conduits with a pipe tee or vise is prohibited.

D. Layout and Homeruns:
1. Install conduit with wiring, including homeruns, as shown on drawings.
2. Deviations: Make only where necessary to avoid interferences and only after drawings showing the proposed deviations have been submitted and approved by the COR.

3.3 CONCEALED WORK INSTALLATION

A. Above Furred or Suspended Ceilings and in Walls:

1. Conduit for Conductors 600 V and Below: EMT. Mixing different types of conduits in the same system is prohibited.
2. Align and run conduit parallel or perpendicular to the building lines.

3.4 EXPOSED WORK INSTALLATION

A. Unless otherwise indicated on drawings, exposed conduit is only permitted in mechanical and electrical rooms.
B. Conduit for Conductors 600 V and Below: EMT. Mixing different types of conduits in the system is prohibited.
C. Align and run conduit parallel or perpendicular to the building lines.
D. Install horizontal runs close to the ceiling or beams and secure with conduit straps.
E. Support horizontal or vertical runs at not over 2.4 M (8 feet) intervals.

3.5 MOTORS AND VIBRATING EQUIPMENT

A. Use flexible metal conduit for connections to motors and other electrical equipment subject to movement, vibration, misalignment, cramped quarters, or noise transmission.
B. Use liquid-tight flexible metal conduit for installation in exterior locations, moisture or humidity laden atmosphere, corrosive atmosphere, water or spray wash-down operations, inside airstream of HVAC units, and locations subject to seepage or dripping of oil, grease, or water.
C. Provide a green equipment grounding conductor with flexible and liquid-tight flexible metal conduit.

3.6 EXPANSION JOINTS

A. Provide conduits smaller than 75 mm (3 inch) with junction boxes on both sides of the expansion joint. Connect flexible metal conduits to junction boxes with sufficient slack to produce a 125 mm (5 inch) vertical drop midway between the ends of the flexible metal conduit. Flexible metal conduit shall have a green insulated copper bonding jumper installed.

3.7 CONDUIT SUPPORTS

A. Safe working load shall not exceed one-quarter of proof test load of fastening devices.

B. Use pipe straps or individual conduit hangers for supporting individual conduits.

C. Support multiple conduit runs with trapeze hangers. Use trapeze hangers that are designed to support a load equal to or greater than the sum of the weights of the conduits, wires, hanger itself, and an additional 90 kg (200 lbs). Attach each conduit with U-bolts or other approved fasteners.

D. Support conduit independently of junction boxes, pull-boxes, fixtures, suspended ceiling T-bars, angle supports, and similar items.

E. Fasteners and Supports in Solid Masonry and Concrete:

1. Existing Construction:

a. Steel expansion anchors not less than 6 mm (0.25-inch) bolt size and not less than 28 mm (1.125 inch) in embedment.

b. Power set fasteners not less than 6 mm (0.25-inch) diameter with depth of penetration not less than 75 mm (3 inch).

c. Use vibration and shock-resistant anchors and fasteners for attaching to concrete ceilings.

F. Hollow Masonry: Toggle bolts.

G. Bolts supported only by plaster or gypsum wallboard are not acceptable.

H. Metal Structures: Use machine screw fasteners or other devices specifically designed and approved for the application.

I. Attachment by wood plugs, rawl plug, plastic, lead or soft metal anchors, or wood blocking and bolts supported only by plaster is prohibited.

J. Chain, wire, or perforated strap shall not be used to support or fasten conduit.

K. Spring steel type supports or fasteners are prohibited for all uses except horizontal and vertical supports/fasteners within walls.

L. Vertical Supports: Vertical conduit runs shall have riser clamps and supports in accordance with the NEC and as shown. Provide supports for cable and wire with fittings that include internal wedges and retaining collars.

3.8 BOX INSTALLATION

A. Boxes for Concealed Conduits:

1. Flush-mounted.

2. Provide raised covers for boxes to suit the wall or ceiling, construction, and finish.

B. Install additional boxes where needed to prevent damage to cables and wires during pulling-in operations or where more than the equivalent of 4-90 degree bends are necessary.

C. Locate pullboxes so that covers are accessible and easily removed. Coordinate locations with piping and ductwork where installed above ceilings.

D. Remove only knockouts as required. Plug unused openings. Use threaded plugs for cast metal boxes and snap-in metal covers for sheet metal boxes.

E. On all branch circuit junction box covers, identify the circuits with black marker.

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SECTION 27 08 00
COMMISSIONING OF COMMUNICATIONS SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

A. This section includes requirements for commissioning facility communications systems, related subsystems and related equipment. This Section supplements general requirements specified in Section 01 91 00, GENERAL COMMISSIONING REQUIREMENTS.

B. Complete list of equipment and systems to be commissioned is specified in Section 01 91 00, GENERAL COMMISSIONING REQUIREMENTS.

C. Commissioned Systems:

1. Commissioning of systems specified in Division 27 is part of project's construction process including documentation and proof of performance testing of these systems, as well as training of VA's Operation and Maintenance personnel in accordance with requirements of Section 01 91 00, GENERAL COMMISSIONING REQUIREMENTS and Division 27, in cooperation with Government and Commissioning Agent.

1.2 RELATED WORK

A. System tests: Section 01 00 00, GENERAL REQUIREMENTS.

B. Commissioning process requires review of selected submittals that pertain to systems to be commissioned: Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA AND SAMPLES.

C. Construction phase commissioning process and procedures including roles and responsibilities of commissioning team members and user training: Section 01 91 00, GENERAL COMMISSIONING REQUIREMENTS.

1.3 COORDINATION

A. Commissioning Agent will provide a list of submittals that must be reviewed by Commissioning Agent simultaneously with engineering review; do not proceed with work of sections identified without engineering and Commissioning Agent's review completed.

B. Commissioning of communications systems require inspection of individual elements of communications system construction throughout construction period. Coordinate with Commissioning Agent in accordance with Section 01 19 00, GENERAL COMMISSIONING REQUIREMENTS and commissioning plan to schedule communications systems inspections as required to support the commissioning process.

1.4 CLOSEOUT SUBMITTALS

A. Refer to Section 01 91 00, GENERAL COMMISSIONING REQUIREMENTS for submittal requirements for pre-functional checklists, equipment startup reports, and other commissioning documents.

B. Pre-Functional Checklists:

1. Complete pre-functional checklists provided by commissioning agent to verify systems, subsystems, and equipment installation is complete and systems are ready for Systems Functional Performance Testing.
2. Submit completed checklists to COR and to Commissioning Agent. Commissioning Agent can spot check a sample of completed checklists. If Commissioning Agent determines that information provided on the checklist is not accurate, Commissioning Agent then returns the marked-up checklist to Contractor for correction and resubmission.
3. If Commissioning Agent determines that a significant number of completed checklists for similar equipment are not accurate, Commissioning Agent can select a broader sample of checklists for review.
4. If Commissioning Agent determines that a significant number of broader sample of checklists is also inaccurate, all checklists for the type of equipment will be returned to Contractor for correction and resubmission.

C. Submit training agendas and trainer resumes in accordance with requirements of Section 01 19 00, GENERAL COMMISSIONING REQUIREMENTS.

PART 2 - PRODUCTS - NOT USED

PART 3 - EXECUTION

3.1 FIELD QUALITY CONTROL

A. Contractor's Tests:

1. Scheduled tests required by other sections of Division 27 must be documented in accordance with Section 01 00 00, GENERAL REQUIREMENTS.
2. Incorporate all testing into project schedule. Provide minimum seven calendar days' notice of testing for Commissioning Agent to witness selected Contractor tests at sole discretion of Commissioning Agent.
3. Complete tests prior to scheduling Systems Functional Performance Testing.

B. Systems Functional Performance Testing:
   1. Commissioning process includes Systems Functional Performance Testing that is intended to test systems functional performance under steady state conditions, to test system reaction to changes in operating conditions, and system performance under emergency conditions.
   2. Commissioning Agent prepares detailed Systems Functional Performance Test procedures for review and acceptance by COR.
   3. Provide required labor, materials, and test equipment identified in test procedure to perform tests.
   4. Commissioning Agent must witness and document the testing.
      a. Provide test reports to Commissioning Agent. Commissioning Agent will sign test reports to verify tests were performed.

3.2 TRAINING

A. Training of Government's operation and maintenance personnel is required in cooperation with COR and Commissioning Agent.
B. Provide competent, factory authorized personnel to provide instruction to operation and maintenance personnel concerning location, operation, and troubleshooting of installed systems.
C. Schedule instruction in coordination with COR after submission and approval of formal training plans.

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SECTION 27 15 00
COMMUNICATIONS STRUCTURED CABLING

PART 1 - GENERAL

1.1 DESCRIPTION

A. This section specifies a complete and operating temperature control digital structured cabling distribution system and associated equipment and hardware to be installed in VA Medical Center, here-in-after referred to as the "facility".

1.2 RELATED WORK

A. General electrical requirements that are common to more than one section in Division 27: Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

B. Requirements for personnel safety and to provide a low impedance path for possible ground fault currents: Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS.

C. Conduits for cables and wiring: Section 26 05 33, RACEWAYS AND BOXES FOR ELECTRICAL SYSTEMS.

1.3 SUBMITTALS

A. In addition to requirements of Section 27 05 11, REQUIREMENTS FOR COMMUNICATIONS INSTALLATIONS provide:

1. Pictorial layout drawing of each distribution cabinet and rack, as each is expected to be installed and configured.
2. List of test equipment.

B. Certifications:

1. Submit written certification from OEM indicating that proposed supervisor of installation and proposed provider of contract maintenance are authorized representatives of OEM. Include individual's legal name and address and OEM warranty credentials in the certification.
2. Pre-acceptance Certification: Submit in accordance with test procedures.
3. Test system cables and certify to COR before proof of performance testing can be conducted. Identify each cable as labeled on as-installed drawings.
4. Provide current and qualified test equipment OEM training certificates and product OEM installation certification for contractor installation, maintenance, and supervisory personnel.

C. Closeout Submittal: Provide document from OEM certifying that each item of equipment installed conforms to OEM published specifications.

1.4 WARRANTY

A. Work subject to terms of Article "Warranty of Construction," FAR clause 52.246-21.

PART 2 - PRODUCTS

2.1 PERFORMANCE AND DESIGN CRITERIA

A. Provide complete system including “punch down” and cross-connector blocks data distribution sub-systems, and associated hardware including telecommunications outlets (TCO); copper and fiber optic distribution cables, connectors, “patch” cables, “break out” devices and equipment cabinets, interface cabinets, and radio relay equipment rack.

B. Industry Standards:

1. Cable distribution systems provided under this section are connected to systems identified as emergency performing patient care HVAC control functions.
2. Conform to National and Local Life Safety Codes (whichever are more stringent), NFPA, NEC, this section, Joint Commission Life Safety Accreditation requirements, and OEM recommendations, instructions, and guidelines.
3. Provide supplies and materials listed by a nationally recognized testing laboratory where such standards are established for supplies, materials or equipment.
4. Refer to industry standards and minimum requirements of Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS and guidelines listed.
5. Active and passive equipment required by system design and approved technical submittal; must conform to each UL standard in effect for equipment, when technical submittal was reviewed and approved by Government or date when COR accepted system equipment to be replaced. Where a UL standard is in existence for equipment to be used in completion of this contract, equipment must bear approved NRTL label.

C. System Performance: Provide complete system to meet or exceed TIA Category 6 requirements.

D. Provide continuous inter- and/or intra-facility data service.

1. Provide data cable distribution system based on a physical “Star" topology.

2. Contact SMCS 005OP2H3 (202-462-5310) for specific technical assistance and approvals.

E. Specific Subsystem Requirements: Provide products necessary for a complete and functional data, communications cabling system, including backbone cabling system, patch panels and cross-connections, horizontal cabling systems, jacks, faceplates, and patch cords.

F. Coordinate size and type of conduit, pathways and firestopping for maximum 40 percent cable fill with subcontractors.

G. Terminate all interconnecting twisted pair, fiber-optic or coaxial cables on patch panels or punch blocks. Terminate unused or spare conductors and fiber strands. Do not leave unused or spare twisted pair wire, fiber-optic cable unterminated, unconnected, loose or unsecured.

H. Color code distribution wiring to conform to ANSI/TIA 606-B and construction documents, whichever is more stringent. Label all equipment, conduit, enclosures, jacks, and cables on record drawings, to facilitate installation and maintenance.

I. In addition to requirements in Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS, provide stainless steel faceplates with plastic covers over labels.

2.2 EQUIPMENT AND MATERIALS

A. Cable Systems - Twisted Pair and Fiber optic:

1. General:

a. Provide cable (i.e. backbone, and horizontal cabling) conforming to accepted industry standards with regards to size, color code, and insulation.

b. Some areas can be considered “plenum”. Comply with all codes pertaining to plenum environments. It is contractor’s responsibility to review the VA’s cable requirements with COR and OI&T Service prior to installation to confirm type of environment present at each location.

c. Provide proper test equipment to confirm that cable pairs meet each OEM’s standard transmission requirements, and ensure cable carries data transmissions at required speeds, frequencies, and fully loaded bandwidth.

2. Telecommunications Rooms (Intermediate Distribution Frame (IDF) Areas):
   a. In IDF areas served with UTP and fiber optic, cables, terminate UTP cable on RJ-45, 8-pin connectors of separate 24-port modular patch panels.
   b. Provide 24 port fiber optic modular patch panels with "LC" couplers dedicated for data applications.
   c. Provide connecting cables required to extend backbone cables (i.e. patch cords, twenty-five pair, etc.), to ensure complete and operational distribution systems.
   d. In IDF areas, which are only served by a UTP backbone cable, terminate cable on separate modular connecting devices, Type 110A punch down blocks (or equivalent), dedicated to data applications.
3. Horizontal Cable: Installed from temperature control panel jack to the IDF area patch panel.
   a. Tested to ANSI/TIA-568-C.2 Category 6 requirements including NEXT, ELFEXT (Pair-to-Pair and Power Sum), Insertion Loss (attenuation), Return Loss, and Delay Skew.
   b. Minimum Transmission Parameters: 250 MHz.
   c. Provide four pair 0.205 mm2 (24 AWG) cable.
   d. Terminate all four pairs on same port at patch panel in IDF area.
   e. Terminate all four pairs on same jack, at temperature control panel:
      1) Jacks: Eight-pin RJ-45 ANSI/TIA-568-C.2 Category 6 Type jacks, unkeyed RJ-45.
4. Fiber Optics Backbone Cable:
   a. Provide 50/125 micron OM4 multi-mode cable, containing at minimum 18 strands of fiber, unless otherwise specified.
   b. Provide tight buffered fiber cable for indoor runs.
   c. Terminate multimode fibers at both ends with LC type female connectors installed in an appropriate patch or breakout panel and secured with a cable management system. Provide minimum 610 mm (2 ft.) cable loop at each end.
   d. Install fiber optic cables in IDF areas, in rack mounted fiber optic patch panels. Provide female LC couplers in appropriate panel for termination of each strand.

e. Test all fiber optic strands' cable transmission performance in accordance with TIA standards. Measure attenuation in accordance with fiber optic test procedures TIA-455-C ('-61', or -53). Provide written results to COR for review and approval.

B. Cross-Connect Systems (CCS):

1. Copper Cables: Provide copper CCS sized to connect cables at IDF areas and allow for a minimum of 50 percent anticipated growth.
2. Maximum DC Resistance per Cable Pair: 28.6 Ohms per 305 m (1,000 feet).
3. Fiber Optic Cables:
   a. Provide fiber CCS sized to connect cables at TR and allow for a minimum of 50 percent anticipated growth.
   b. Install fiber optic cable slack in protective enclosures.

C. IDF Areas:

1. Terminate backbone and horizontal, copper, and fiber optic on appropriate cross-connection systems (CCS) containing patch panels, punch blocks, and breakout devices provided in enclosures and tested, regardless of installation method, mounting, termination, or cross-connecting used. Provide cable management system as a part of each CCS.
2. Coordinate location in IDF area with existing equipment.

D. Main Cross-connection Subsystem (MCCS): MCCS is common point of distribution for inter- and intra-building copper and fiber optic backbone system cables, and connections to data cable systems.

E. Data Cross-Connection Subsystems:

1. Provide patch panels with modular RJ45 female to 110 connectors for cross-connection of copper data cable terminations and system ground with cable management system.
2. Provide patch panels conforming to EIA/ECA 310-E dimensions and suitable for mounting in standard equipment racks, with 24 RJ45 jacks aligned in one horizontal row per panel. Provide RJ45 jacks of modular design and capable of accepting and functioning with other modular (i.e. RJ11) plugs without damaging jack.
   a. Provide system inputs from servers, data LAN, bridge, or interface distribution systems on top row of jacks of appropriate patch panel.
   b. Provide backbone cable connections on bottom row of jacks of same patch panel.

c. Provide patch cords for each system pair of connection jacks with modular RJ45 connectors provided on each end to match panel's modular RJ45 female jack's being provided.

F. Fiber-Optic Cross-Connection Subsystems: Provide rack mounted patch or distribution panels installed inside a lockable cabinet or "breakout enclosure" that accommodate minimum 12 strands multimode fiber - these counts do not include 50 percent spare requirement. Provide cable management system for each panel.

1. Provide panels for minimum 12 female LC connectors, able to accommodate splices and field mountable connectors and have capacity for additional connectors to be added up to OEM's maximum standard panel size for this type of use. Protect patch panel sides, including front and back, by a cabinet or enclosure.
2. Provide panels that conform to EIA/ECA 310-E dimensions suitable for installation in standard racks, cabinets, and enclosures.
3. Provide patch panels with highest OEM approved density of fiber LC termination's (maximum of 72 each), while maintaining a high level of manageability. Provide proper LC couplers installed for each pair of fiber optic cable LC connectors.
   a. Provide system inputs from interface equipment or distribution systems on top row of connectors of appropriate patch panel.
   b. Provide backbone cable connections on bottom row of connectors of same patch panel.
   c. Provide patch cords for each pair of fiber optic strands with connector to match couplers.
4. Provide field installable connectors that are pre-polished.
   a. Terminate every fiber cable with appropriate connector, and test to ensure compliance to specifications and industry standards for fiber optic LC female connector terminated with a fiber optic cable.
   b. Install a terminating cap for each unused LC connector.

G. Horizontal Cabling (HC):

1. Horizontal cable length to farthest system outlet to be maximum of 90 m (295 ft).
2. Splitting of pairs within a cable between different jacks is not permitted.

2.3 DISTRIBUTION EQUIPMENT AND SYSTEMS

A. Telecommunication Outlet:

1. TCO consists of minimum one data RJ45 jack, mounted in a separate steel outlet box 100 mm (4 inches) x 100 mm (4 inches) x 63 mm (2-1/2 inches) minimum with a labeled stainless steel faceplate. Where shown on drawings, provide a second steel outlet box minimum 100 mm (4 inches) x 100 mm (4 inches) x 63 mm (2-1/2 inches), with a labeled faceplate, adjacent to first box to ensure system connections and expandability requirements are met.
2. Provide RJ-45/11 compatible female type voice (telephone) multi-pin connections. Provide RJ-45 female type data multi-pin connections.
3. Provide wall outlet with a stainless steel face plate and sufficient ports to fit data multi- pin jacks, and plastic covers for labels when mounted on outlet box provided (minimum 100mm (4 inches) x 100mm (4 inches) for single and 100mm (4 inches) x 200mm (8 inches) for dual outlet box applications. Install stainless steel face plate, for prefabricated bedside patient unit installations.
4. Interface fiber optic LC jacks to appropriate patch panels in associated TR, but do not cross-connect fiber optic cables fiber optic equipment or install fiber optic equipment.

B. Backbone Distribution Cables:

1. Meet TIA transmission performance requirements of Voice Grade Category 6.
2. Provide cable listed for environments where it is installed.
   a. Unshielded cable with solid conductors.
   b. Able to handle the power and voltage used over the distance required.
   c. Meets TIA transmission performance requirements of Category 6.
   d. Technical Characteristics:
      1) 0.205 mm2 (24 AWG) - 0.326 mm2 (22 AWG) cable
      2) Bend Radius: 10 times cable outside diameter.
      3) Impedance: 100 Ohms + 15%, BAL.
      4) Bandwidth: 250 MHz.
      5) DC Resistance: Maximum 9.38 Ohms/100m (328 ft.) at 20 degrees C.
      6) Maximum Mutual Capacitance: 5.6 nF per 100 m (328 ft.).
      7) Shield Coverage:
         a) Overall Outside (if OEM specified): 100 percent.

b) Individual Pairs (if OEM specified): 100 percent.

8) Maximum attenuation for 100m (328 ft.) at 20° C:

Frequency (MHz)	//Category 6 (dB)//
1	//2.0//
4	//3.8//
8	//5.3//
10	//6.0//
16	//7.6//
20	//8.5//
25	//9.5//
31.25	//10.7//
62.5	//15.4//
100	//19.8//
200	//29.0//
250	//32.8//
300	
400	
500	

3. Fiber Optic:

a. Multimode Fiber:

1) Provide OM4 Type general purpose multimode fiber optic cable installed in conduit for system locations with load-bearing support braid surrounding inner tube for strength during cable installation.

2) Technical Characteristics:

a) Bend Radius: Minimum 152 mm (6 inches); outer jacket as required.

b) Fiber Diameter: 50.

c) Cladding: 125 microns.

d) Attenuation:

1) 850 nanometer: Maximum 4.0 dB per kilometer.

2) 1,300 nanometer: Maximum 2.0 dB per kilometer.

e) Bandwidth:

1) 850 nanometer: Minimum 160 MHz.

2) 1,300 nanometer: Minimum 500 MHz.

f) Connectors: Stainless steel.

C. Outlet Connection Cables:

1. Data:

a. Provide a connection cable for each TCO data jack in system with 10 percent spares to connect a data instrument to TCO data jack. Do not provide data terminals/equipment.

b. Technical Characteristics:

1) Length: Minimum 1.8 m (6 feet).

2) Cable: Data grade Category 5E or on a case-by-case basis Category 6 for specialized powered systems accepted by SMCS 005OP2H3 (202) 461-5310, IT and FMS Services and COR.

3) Connector: RJ-45 male on each end.

4) Color Coding: Required, data industry standard.

5) Size: Minimum 24 AWG.

2. Fiber Optic:

a. Provide a connection cable for each TCO fiber optic connector in system with 10 percent spares. Provide data connection cable to connect a fiber optic instrument to TCO fiber optic jack. Do not provide fiber optic instruments/equipment.

b. Technical Characteristics:

1) Length: Minimum 1.8 m (6 feet).

2) Cable: Flexible single conductor with jacket.

3) Connector: LC male on each end.

4) Size: To fit OM4 multimode cable.

D. System Connectors:

1. Modular RJ-45: Provide high speed data transmission applications type modular plugs compatible with, computer terminals, and other type devices requiring linking through modular telecommunications outlet to the system compatible with UTP cables.

a. Technical Characteristics:

1) Number of Pins:

a) RJ-45: Eight.

2) Dielectric: Surge.

3) Voltage: Minimum 1,000V RMS, 60 Hz at one minute.

4) Current: 2.2A RMS at 30 minutes or 7.0A RMS at 5.0 seconds.
5) Leakage: Maximum 100 µA.
6) Connections:
   a) Initial contact resistance: Maximum 20 milli-Ohms.
   b) Insulation displacement: Maximum 10 milli-Ohms.
   c) Interface: Must interface with modular jacks from a variety of OEMs. RJ-11/45 plugs provide connection when used in RJ-45 jacks.
   d) Durability: Minimum 200 insertions/withdrawals.

E. Fiber Optic Terminators:
1. Pre-polished crimp on type that has proper ferrule to terminate fiber optic cable.
2. Technical Characteristics:
   a. Frequency: Light wave.
   b. Power Blocking: As required.
   c. Return Loss: 25 dB.
   d. Connectors: LC.
   e. Construction: Ceramic.

F. Conduit and Signal Ducts:
1. Conduit:
   a. Provide conduit or sleeves for cables penetrating walls, ceilings, floors, interstitial space, fire barriers, etc.
   b. Minimum Conduit Size: 19 mm (3/4 inch).
   c. Provide separate conduit for each cable type installation.
   d. When metal (plastic covered, flexible cable protective armor, etc.) systems are authorized to be provided for use in system, follow installation guidelines and standard specified in Section 26 05 33, RACEWAYS AND BOXES FOR ELECTRICAL SYSTEMS and NEC.
   e. Maximum 40 percent conduit fill for cable installation.
2. Cable Tray: Use existing cable tray, when identified and accepted by COR.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install for ease of operation, maintenance, and testing.
B. Install system to comply with NFPA 70 National Electrical Code, NFPA 99 Health Care Facilities, NFPA 101 Life Safety Code, Joint Commission Manual for Health Care Facilities, and original equipment manufacturers' (OEM) installation instructions.

C. Cable Systems Installation:

1. Install system cables in innerduct, cable tray, cable runway, conduit or when specifically approved, flexible NEC Article 800 communications raceway. Confirm drawings show sufficient quantity and size of cable pathways. If flexible communications raceway is used, install in same manner as conduit.
2. Install temporary cable to not present a pedestrian safety hazard and be responsible for all work associated with removal. Temporary cable installations are not required to meet Industry Standards; but, must be reviewed and accepted by COR, IT Service, FMS and SMCS 005OP2H3 (202-461-5310) prior to installation.

D. Labeling:

1. Industry Standard: Provide labeling in accordance with ANSI/TIA-606-B.
2. Print lettering of labels with laser printers; handwritten labels are not acceptable.
3. Label both ends of all cables in accordance with industry standard. Provide permanent Labels in contrasting colors and identify according to system “Record Wiring Diagrams”.
4. Termination Hardware: Label workstation outlets and patch panel connections using color coded labels with identifiers in accordance with industry standard and record on“Record Wiring Diagrams”.

3.2 FIELD QUALITY CONTROL

A. Interim Inspection:

1. Verify that equipment provided adheres to installation requirements of this section. Interim inspection must be conducted by a factory-certified representative and witnessed by COR.
2. Check each item of installed equipment to ensure appropriate NRTL label.
3. Verify cabling terminations in telecommunications rooms and at workstations adhere to color code for T568B pin assignments and cabling connections comply with TIA standards.
4. Visually confirm marking of cables, faceplates, patch panel connectors and patch cords.
5. Perform fiber optical field inspection tests via attenuation measurements on factory reels and provide results along with manufacturer certification for factory reel tests. Remove failed cable reels from project site upon attenuation test failure.

6. Notify COR of the estimated date the contractor expects to be ready for interim inspection, at least 20 working days before requested inspection date, so interim inspection does not affect systems' completion date.
7. Provide results of interim inspection to COR. If major or multiple deficiencies are discovered, COR can require a second interim inspection before permitting contractor to continue with system installation.
8. Do not proceed with installation until COR determines if an additional inspection is required. In either case, re-inspection of deficiencies noted during interim inspections must be part of the proof of performance test.

B. Pretesting:
1. Pretest entire system upon completion of system installation.
2. Verify during system pretest, utilizing the accepted equipment, that system is fully operational and meets system performance requirements of this section.
3. Provide COR four copies of recorded system pretest measurements and the written certification that system is ready for formal acceptance test.

C. Acceptance Test:
1. After system has been pretested and the contractor has submitted pretest results and certification to COR, then schedule an acceptance test date and give COR 30 days' written notice prior to date acceptance test is expected to begin.
2. Test only in presence of a COR.
3. Test utilizing approved test equipment to certify proof of performance.
4. Verify that total system meets the requirements of this section.
5. Include expected duration of test time, with notification of the acceptance test.

D. Verification Tests:
1. Test UTP copper cabling for DC loop resistance, shorts, opens, intermittent faults, and polarity between conductors, and between conductors and shield, if cable has an overall shield. Test cables after termination and prior to cross-connection.
2. Multi-mode Fiber Optic Cable: Perform end-to-end attenuation tests in accordance with TIA-568-B.3 and TIA-526-14A using Method A,

Optical Power Meter and Light Source. Perform verification acceptance test.

E. Performance Testing:
   1. Perform Category 6 for specialized powered systems accepted by SMCS 005OP2H3, (202) 461-5310, IT and FMS Services and COR) tests in accordance with TIA-568-B.1 and TIA-568-B.2. Include the following tests - wire map, length, insertion loss, return loss, NEXT, PSNEXT, ELFEXT, PSELFEXT, propagation delay and delay skew.
   2. Fiber Optic Links: Perform end-to-end fiber optic cable link tests in accordance with TIA-568-B.3.

F. Total System Acceptance Test: Perform verification tests for UTP copper cabling systems and multi-mode fiber optic cabling systems after complete telecommunication distribution system and workstation outlet are installed.

3.3 MAINTENANCE

A. Accomplish the following minimum requirements during one year warranty period:
   1. Respond and correct on-site trouble calls, during standard work week:
      a. A routine trouble call within one working day of its report. A routine trouble is considered a trouble which causes a system outlet, station, or patch cord to be inoperable.
      b. Standard work week is considered 8:00 A.M. to 5:00 P.M., Monday through Friday exclusive of Federal holidays.
   2. Respond to an emergency trouble call within six hours of its report. An emergency trouble is considered a trouble which causes a subsystem or distribution point to be inoperable at any time.
   3. Respond on-site to a catastrophic trouble call within four hours of its report. A catastrophic trouble call is considered total system failure.
      a. If a system failure cannot be corrected within four hours (exclusive of standard work time limits), provide alternate equipment, or cables within four hours after four hour trouble shooting time.
      b. Routine or emergency trouble calls in critical emergency health care facilities (i.e., cardiac arrest, intensive care units, etc.) are also be deemed as a catastrophic trouble.

4. Provide COR written report itemizing each deficiency found and the corrective action performed during each official reported trouble call. Provide COR with sample copies of reports for review and approval at beginning of total system acceptance test.

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