ADDENDUM

Addendum No.: **2**
Date: 02/06/2019
Contract No.: 54015
Project: Atherton Civic Center
Location: 80 Fair Oaks Lane
Application No.: TBD
WRNS Project No: 15007.00
WRNS File No: 9.2

This Addendum will become part of the Contract Documents. In case of difference with previous addenda or communications, this addendum takes precedence. It is the responsibility of the Contractor to notify all sub-contractors from whom he accepts bids for all changes in the drawings and specifications covering this project. Receipt shall be acknowledged by inserting the Addendum number and its date in the bid form.

REVISIONS/CLARIFICATIONS TO THE PROJECT MANUAL

1. GENERAL:
   a. Reissued Specification Sections: The following specifications are modified as herein described. Specifications being re-issued with changes incorporated are indicated as (attached).

2. SECTION 00 1119 – REQUEST FOR PROPOSALS
   a. Delete section 01 1119 and replace with attached Section 00 1119. Bid date has been revised.

3. SECTION 00 4336 – PROPOSED SUBCONTRACTORS
   a. Delete section 00 4336 and replace with attached Section 00 4336

4. SECTION 00 5200 – CONSTRUCTION AGREEMENT
   a. Delete pages 1 and 2, and replace with the attached Section 00 5200 pages 1 and 2.

5. SECTION 07 3213 – CLAY ROOF TILES
   a. Delete section and replace with attached Section 07 3213.

6. SECTION 08 1113 – HOLLOW METAL DOORS AND FRAMES
   a. Add sub-paragraph 2.5 C.6 to read as follows:

      6. Finish: Provide wood veneer panels to match adjacent wood doors.

7. SECTION 23 0900 – INSTRUMENTATION AND CONTROL PERFORMANCE SPECIFICATIONS
   a. Add Air Cooled Recovery Heat Pump HP-1, and renumber subsequent paragraphs, per attached Section 23 0900.

REVISIONS/CLARIFICATIONS TO THE DRAWINGS

1. GENERAL
    a. Reissued Drawings: The following drawings are modified as herein described. Drawings are indicated as (attached) or (not attached). Drawings not included at this time will be reissued at full scale in conformance set prior to beginning of construction.

        1. Sheet C-200 Grading Plan
            a. Plan: Revise grading at Fuel Storage area per attached drawing.
        2. Sheet C-301 Utility Plan
            a. Plan: Revise utility connections at Fuel Storage area per attached drawing
        3. Sheet S-101 City Hall – Foundation Structural Framing Plan
            a. Revise Grade Beam Schedule per attached drawing.
        4. Sheet S-102 City Hall – Level 1 Structural Framing Plan
            a. Plan: Add detail per attached drawing.
        5. Sheet S-108 Ancillary Building – Structural Framing Plans
            a. Plan 1: Revise per attached drawing.
        6. Sheet S-113 Library – Finish Floor Structural Framing Plan
            a. Plan 1: Revise note at exterior decks per attached drawing.
        7. Sheet S-116 Library – Enlarged Framing Plans
            a. Plans 3 & 4: Revise note per attached drawing.
        8. Sheet M-002 City Hall – Schedules – Mechanical
            a. Revise schedules per attached drawing.
        9. Sheet M-003 Library – Schedules – Mechanical
            a. Revise Fan Schedule per attached drawing.
        10. Sheet M-201 City Hall – Level 1 Floor Plan – Mechanical
            a. Add transfer duct Storage Room C.25 per attached drawing.
            b. Add sheet notes 24-28, per attached drawing
            c. Relocate C-VAV-1-5A to Dispatch Room C.11 ceiling per attached drawing.
        11. Sheet M-202 City Hall – Level 2 Floor Plan – Mechanical
            a. Add sheet note 17 per attached drawing.
            b. Revise C-AHU-3 length per attached drawing.
        12. Sheet M-210 Library/Town Hall Underfloor - Mechanical
            a. Add/revise sheet notes per attach drawing.
            b. Plan: Revise duct work to meeting rooms per attached drawing.
        13. Sheet M-211 Library/Town Hall – Level 1 Floor Plan – Mechanical
            a. Revise sheet note 13 per attach drawing.
            b. Plan: Revise return duct at Maker Space per attached drawing.
        14. Sheet M-212 Library/Town Hall – Roof Plan – Mechanical
            a. Plan: Revise exhaust fan L-EF-1 per attached drawing.
        15. Sheet M-401 City Hall – Enlarged Plans and Sections – Mechanical
            a. Revise sheet note 4 per attach drawing.
            b. Add Fan Coil Unit to room U.02 per attached drawing.
        16. Sheet M-402 City Hall – Enlarged Plans and Sections – Mechanical
            a. Add sheet note 3 per attached drawing.
            b. Plan 1: Reference sheet note 3, per attached drawing.
        17. Sheet M-403 City Hall – Enlarged Plans and Sections – Mechanical

a. Add sheet note 3 per attached drawing.
b. Plan 1: Reference sheet note 3, per attached drawing

18. Sheet M-502 – Piping Diagrams – Mechanical
    a. Revise diagrams 9 and 10 per attached drawing.
19. Sheet M-505 – Fan Coil – Piping Diagrams – Mechanical
    a. Revise 1 Piping and Instrumentation Diagram, per attached drawing.
20. Sheet M-603 Details – Mechanical
    a. Revise details 4 and 6, per attached drawing.
21. Sheet M-606 Details – Mechanical
    a. Add Heat Pump detail, per attached drawing.
22. Sheet M-702 Control Diagrams Mechanical
    a. Revise Controls Diagram 7, per attached drawing.
    b. Delete Controls Diagram 9.
23. Sheet P-002 Schedule - Plumbing
    a. Revise Plumbing Schedules per attached drawing.
24. Sheet P-401 Enlarged Plans – Plumbing
    a. Revise Plans 4 and 6, per attached drawing.
25. Sheet P-501 Details – Plumbing
    a. Revise detail 1, per attached drawing.
26. Sheet E-104 Site Plan – City Hall - Power
    a. Sheet Notes: Revise sheet notes per attached drawing.
27. Sheet E-201 City Hall – Level 1 Floor Plan – Lighting
    a. Plan: Revise lighting at Reception Desk CA.4 per attached drawing
28. Sheet E-211 Library/Town Hall – Floor Plan – High Ceiling - Lighting
    a. Revise plans per attached drawing.
    b. Revise Sheet Notes per attached drawing.

2. Sheet C-030 Stormwater Management Plan
    a. Delete note “Covered Generator Fuel Storage Area directed to Sanitary Sewer.” at Police Secure Parking Utility Area.

3. Sheet A-411 Library – Enlarged Floor Plans
    a. Elevations 3B, 3C & 3D: Revise CTB-5 to “CTW-5”.
    b. Plan 1: Delete detail call outs noted “2/AF-605”.
    c. Plan 4: Revise PTW-2 to “CTW-6”.

4. Sheet A-701 Door Schedule, Frames & Types
    a. Doors B.08B, B.09A, B.09B and C.20: Change hardware group from 4.0 to 13.0
    b. Doors L12, L.12A-A and L.12B-A: Change Door Material to HM/WV (Hollow Metal with Wood Veneer) change Finish to WD-1

5. Sheet AI-001 Interior Finish and Material Schedule
    a. Base Finish CTB-2: Revise size to “3” high coved base”
    b. Base Finish CTB-3: Delete and replace with the following

Description:	Ceramic Tile Base - Library Restrooms
Contact:	-

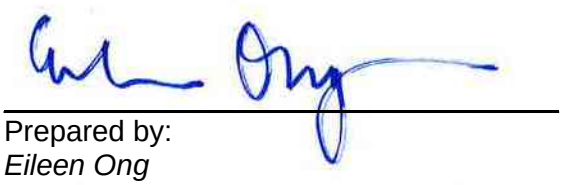
Manufacturer:	Dal Tile
Product:	Natural Hues
Size:	3” high coved base
Grout:	TBD
Color:	QH24 Ivory-Matte (40%); QH83 Lace (60%)

c. Base Finish STB-2: Delete finish.

6. Sheet AI-102 City Hall Level 2 Finish Plan
    a. Plan 1: Revise ST-1 finish at elevator and stair per attached sketch ASK-007.

7. Sheet AI-111 Library/Town Hall Finish and Interior Mock-Up Info
    a. Plan 1: Town Hall Toilet Room delete wall finish PTW-2 and replace with wall finish “CTW-6”

8. Sheet M-703 Control Diagrams – Mechanical
    a. Delete Controls Diagram 4 Heat Exchanger Control Diagram (City Hall)



Prepared by:
Eileen Ong

WRNS STUDIO
February 6, 2019

SPECIFICATIONS

SECTION 00 1119
REQUEST FOR PROPOSALS

ADVERTISEMENT FOR BIDS

TOWN OF ATHERTON
STATE OF CALIFORNIA

Notice: The Town of Atherton (Town) hereby gives notice that it will accept bids for construction of the following public works project:

TOWN CENTER PROJECT
Project No: 54015

1. **Scope of Work:** The work to be completed includes furnish all labor, equipment and materials and perform all work necessary and incidental to construct the Atherton Town Center Project. The Town Center project generally consists of demolishing the existing Administration/Police Department (PD) buildings (fixed and modular), PD garage, renovation of the historic Town Hall building, new City Hall and Library, site improvements and removing, realigning and rebuilding sections of the existing Ashfield Road and Dinkelspiel Station Lane.

2. **Plans & Specifications:** Plans & Specifications may be obtained at the Town of Atherton's website at: http://www.ci.atherton.ca.us/bids.aspx at no cost. Additional information is contained in Town of Atherton Standard Specifications, which are available at: http://www.ci.atherton.ca.us/DocumentCenter/View/285. Contractor shall be responsible for any addendums that may be posted on the Town's website. No Plan holders list will be made available. Drawings and Specifications can be obtained at Contractors Expense from:

   BPXpress Reprographics
   Attn: Will Brown
   4903 Central Avenue
   Richmond, CA 94804
   Office-(510) 559-8299

3. **Project Schedule:** The work shall be completed within ***five hundred and twenty (520)*** working days from the First Day of Construction as defined in the Notice to Proceed.

4. **A pre-bid site conference** will be held for the project scheduled for Wednesday **January 16, 2019, at 10:00 A.M**. at the Atherton City Council Chambers 94 Ashfield Road, Atherton, CA 94027.

5. **Bid Submission:** SEALED BIDS will be received at the office of the City Clerk, 91 Ashfield Road, Atherton, California 94027, ***until 2:00 P.M.*** *Pacific Standard Time on* ***Wednesday, February 27, 2019,*** at which time bids will be publicly opened and read aloud.

6. **Engineer's Estimate** for the project is: ***$48,500,000***.

7. **Bid Requirements:** Bids must be for the entire work, and shall be submitted in sealed envelopes clearly marked: "Bid of (Contractor) for **ATHERTON TOWN CENTER PROJECT, Project No: 54015**", along with date and time of bid opening.

   Bidders shall refer to the **Bid Requirements** section of the project Plans and Specifications for additional information and requirements.

8. **Required Contractor's License:** A **California Class "A" or "B" General Engineering** licenses for performing the work outlined in the Plans and Specifications is required at the time of the Bid to Bid this contract.

9. **Department of Industrial Relations Registration:** A Contractor or Subcontractor shall not be qualified to bid on, be listed in a bid proposal, subject to the requirements of Public Contract Code 4104, or engage in the performance of any contract for public work, as that term is defined in Division 2, Part 7, Chapter 1 of the Labor Code, unless currently registered and qualified to perform public work pursuant to Labor Code Section 1725.5. (http://www.dir.ca.gov/Public-Works/PublicWorks.html)

10. **Reservation of Rights:** The Town reserves the right to reject any or all bids; to make any awards or any rejections in what it alone considers to be in the best interest of the Town, and waive any informalities or irregularities in the bids. ***If the Town elects to award a contract for performance of the project, the contract will be awarded in accordance with California Public Contract Code Section 20162 and other applicable law to the responsible bidder submitting a responsive bid with the lowest total bid price for the base bid without consideration of any alternates.***

11. **Substitution of Securities:** The successful bidder may substitute securities for retention monies withheld to ensure performance of the contract, in accordance with California Public Contract Code, Section 22300.

12. **Prevailing Wage Rates:** Bidders are hereby notified that provisions of California Labor Code regarding prevailing wages and apprentices are applicable to the work to be performed under this contract. Pursuant to Section 1773 et seq. the general prevailing wage rates have been determined by the Director of the California Department of Industrial Relations and appear in the California Prevailing Wage Rates. Copies are on file at the office of the City Engineer and are available to interested parties upon request. The successful bidder shall post a copy of the wage rates at the job site

13. **Bid Preparation Cost**: Bidders are solely responsible for the cost of plan and specification printing and preparing their Bids.

14. **Town Contact:** Questions regarding the project should be directed to Marty Hanneman, Project Manager, by written Requests for Information (RFI) to: Public Works Department, 91 Ashfield Road, Atherton, CA 94027, no later than ten (10) business days before bid opening. RFIs may be emailed to mhanneman@ci.atherton.ca.us.

15. **Understanding:** By submitting a bid in response to this advertisement for bids, the bidder shall be conclusively deemed to have read, understood and agreed with all of the information and materials contained in the bid documents, including but not limited to the standard specifications, the special provisions, the required nature and amount of insurance and the documentation evidencing said insurance.

By: _____
Marty Hanneman, P.E., Project Manager

Date: _____

END OF SECTION

SECTION 00 4336

PROPOSED SUBCONTRACTORS

Pursuant to the provision of Section 4100 to 4113, inclusive, of the Public Contract Code of the State of California, every Bidder shall set forth the name and location of the place of business of each subcontractor who will perform work or labor in or about the construction of the work or improvement in an amount in **excess of one-half (1/2) of one percent (1%) of the Bidder's total bid.** If the Bidder fails to specify a subcontractor for any portion of the work in excess of one-half (1/2) of one percent (1%) of the Bidder's total bid, Bidder agrees to perform that portion himself. The following list gives the name, business address, and portion of work (description of work to be done) for each subcontractor that will be used in the work if the bidder is awarded the Contract (additional supporting data may be attached to this page. Each page shall be sequentially numbered, and headed "Proposed Subcontractors" and shall be signed.)

Columns: "Description of Work" and "Name & Business of Address of Subcontractor" are required to be completed with bid submittal. The remaining columns need to be provided to the Town within two calendar days of bid opening.

Description of Work	Name and Business Address of Subcontractor	License Number	License Type	DIR Registration Number	Cost of Work	% of Bid

Date: _____ Contractor's Signature: _____

****END OF SECTION****

SECTION 00 5200
CONSTRUCTION AGREEMENT

ATHERTON TOWN CENTER PROJECT
Project No. 54015

CONSTRUCTION AGREEMENT

This Agreement made and entered into this ___ day of _____, 2019, by and between _____ Construction Company ("Contractor") and the Town of Atherton ("Town").

RECITALS

A. The Town gave notice inviting bids to be submitted by ***2:00 PM on February 27, 2019*** for the Town Center Project by published notice and/or posting in accordance with California Public Contract Code Section 20174 and other applicable law.

B. ***On February 27, 2019***, Town representatives held a public bid opening for the Town Center Project and read the bids aloud.

C. **On _____, 2019** the City Council awarded the Town Center Project #54015 to the Contractor and directed Town staff to send the Contractor written notice of award of the project. The City Council conditioned award of the project on the Contractor's providing executed copies of all documents specified in the contract checklist included in the bid package within ten (10) working days of receiving written notice of award of the project.

D. The Contractor has provided the Town executed copies of all documents specified in the contract checklist included in the bid package within ten (10) working days of receiving written notice of award.

AGREEMENT TERMS

The Town and Contractor agree as follows:

A. The work: The Contractor will furnish all labor, materials, equipment, tools, transportation, services, and appliances necessary to complete in a good and workmanlike manner the Town Center Project ("Work") as shown in the Specifications and Project Plans in accordance with the Contract Documents and applicable law.

B. Time for Completion: The Contractor must complete the Work in accordance with the Contract Document within five hundred and twenty (520) working days from the date of issuance of the Notice to Proceed (or approved extensions thereof).

C. Remedies for Failure to Timely Complete the Work: It is agreed that Contractor's failure to full perform the Work by the Time for Completion (as modified by approved

extensions) will result in damages being sustained by the Town. Such damages are, and will continue to be, impracticable and extremely difficult to determine. For each calendar day in excess of the Time for Completion (as modified by approved extensions), the Contractor shall pay to the Town, or have monies withheld from monies to it, liquidated damages of $1,000.00 per working day in accordance with California Government Code Section 53069.85 and Section 14.10 of the Standard Specifications.

D. Contract Price and Payment: Town shall pay Contractor _____ million _____ _____thousand _____dollars and 00 cents ($_____.00), for completion of the Work. The Town will have no obligation to pay the Contractor any amount in excess of this Contract Price unless this Agreement is first modified in accordance with its terms. The Town's obligation to pay the Contractor under this agreement is subject to any may be offset by charges that may apply to the Contractor under this Agreement, including but not limited to charges for liquidated damages and/or substitute performance in accordance with the Contract Documents.

E. Prevailing Wages: In accordance with California Labor Code Section 1771, the Contractor will pay and will require all Subcontractors to pay all workers on the work a salary or wage at least equal to the prevailing rate of per diem wages for such work as set forth in the wage determinations and wage standards applicable to this work, a copy of which is on file with the Town Clerk. A copy of the prevailing wage rate of per diem wage shall be posted at the job site. In accordance with California Labor Code Section 1775, the Contractor shall forfeit to the Town, as a penalty, Fifty Dollars ($50.00) for each calendar day or portion thereof for each worker paid (either by the Contractor or Subcontractors) less than the prevailing rate wage rate. The Work covered by this Agreement is a "public work" as that term is defined in California Labor Code, Division 2, Part 7, Chapter 1.

F. The Contract Documents: This agreement consists of the following documents ("Contract Documents"), all of which are incorporated into and made part of this Agreement as if set forth in full. In the event of a conflict between or among the Contract Documents, precedence will be in the following order:

1. This Agreement and change orders and other amendments to this agreement signed by authorized representatives of the Town and the Contractor.
2. The General Provisions and change orders and other amendments to the General Provisions signed by authorized representatives of the Town and the Contractor.
3. The Technical Specifications, addenda to the Technical Specifications signed by authorized representatives of the Town and issued prior to bid opening.
4. The Special Provisions, addenda to the Special Provisions signed by authorized representatives of the Town and issued prior to bid opening, Equal Product Proposals accepted by the Town and signed by authorized Town representatives prior to bid opening, and change orders and other amendments to the Specifications signed by authorized representatives of the Town and the Contractor.
5. Town of Atherton Standard Specifications and Drawings, latest edition ("Standard Specifications").
6. The Project Plans, addenda to the Project Plans signed by authorized representatives of the Town and issued prior to bid opening, Equal Product

SECTION 07 3213

CLAY ROOF TILES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:
1. Clay roof tiles.
2. Metal roof flashing
3. Underlayment.

B. Related Requirements:
1. 06 1053 "Miscellaneous Rough Carpentry" for wood nailers.
2. 07 6200 "Sheet Metal Flashing and Trim" for metal roof-penetration flashings counterflashings and flashings not part of this Section.

1.3 DEFINITIONS

A. Roofing Terminology: See ASTM D 1079, glossaries in TRI/WSRCA's "Concrete and Clay Roof Tile Design Criteria Installation Manual for Moderate Climate Regions," and NRCA's "NRCA Roofing and Waterproofing Manual" for definitions of terms related to roofing work in this Section.

1.4 PREINSTALLATION MEETINGS

A. Preinstallation Conference: Conduct conference at Project site.

1.5 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Sustainable Design Submittals:
1. Product Test Reports: For roof materials, documentation indicating that roof materials comply with Solar Reflectance Index requirements.

C. Samples: For each exposed product and for each color and texture specified.
1. Clay Roof Tiles: Full size, showing full range of values and blends.
2. Accessory Tiles: Full size.
3. Metal Valley Flashing: 12 inches square.
4. Fastenings: Wire-tie system components, 12 inches long.
5. Self-Adhering Underlayment: 12 inches (300 mm) square.

1.6 INFORMATIONAL SUBMITTALS

A. Material Test Reports: For each type of clay roof tile, based on evaluation of comprehensive tests performed by a qualified testing agency.

B. Evaluation Reports: From ICC-ES or other testing and inspecting agency acceptable to authorities having jurisdiction, indicating that product is suitable for intended use under applicable building codes for the following:
   1. Clay roof tiles, fasteners, and attachment systems.
   2. High-temperature self-adhering underlayment.

C. Sample Warranty: For manufacturer's materials warranty.

1.7 CLOSEOUT SUBMITTALS

A. Maintenance Data: For roofing to include in maintenance manuals.

1.8 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials, from the same product run, that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
   1. Clay Roof Tiles: 100 sq. ft. of each type, in unbroken bundles.

1.9 QUALITY ASSURANCE

A. Source Limitations: Obtain clay tiles and clay tile accessories through one source from a single Manufacturer.

B. Mockups: Build mockups to verify selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for materials and execution:
   1. Provide Mock-up Panel as indicated on drawings.
      a. If Architect determines mockups do not comply with requirements, reconstruct mockups and apply air barrier until mockups are approved.
   2. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.
   3. Subject to compliance with requirements, approved mockups may become part of the completed Work if undamaged at time of Substantial Completion.

1.10 DELIVERY, STORAGE, AND HANDLING

A. Store underlayment rolls in a dry, well-ventilated location protected from weather, sunlight, and moisture according to manufacturer's written instructions.
   1. Store on end, on pallets or other raised surfaces. Do not double stack rolls.

B. Protect unused underlayment from weather, sunlight, and moisture when left overnight or when roofing work is not in progress.

C. Handle, store, and place roofing materials in a manner to prevent damage to roof deck or structural supporting members.

1.11 FIELD CONDITIONS

A. Environmental Limitations: Proceed with installation only when existing and forecasted weather conditions permit roofing to be installed according to manufacturer's written instructions and warranty requirements.
   1. Install self-adhering sheet underlayment within the range of ambient and substrate temperatures recommended by manufacturer.

1.12 WARRANTY

A. Materials Warranty: Manufacturer agrees to repair or replace clay roof tiles that fail in materials within specified warranty period.
   1. Clay Tile Warranty Period: Lifetime warranty for the life of the building.
   2. Underlayment Warranty Period: HT Self-Adhering Underlayment 30 Year Manufacturer's Warranty.

B. Roofing Installer's Warranty: On warranty form at end of this Section, signed by Installer, in which Installer agrees to repair or replace components of clay-tile roofing that fail in materials or workmanship within specified warranty period.
   1. Warranty Period: Two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Exterior Fire-Test Exposure: Provide clay roof tiles and related roofing materials identical to those of assemblies tested for Class A fire resistance according to ASTM E 108 or UL 790 by Underwriters Laboratories, Inc. or another testing and inspecting agency acceptable to authorities having jurisdiction. Identify products with appropriate markings of applicable testing agency.

B. Solar Reflectance Index: Not less than 32 when calculated according to ASTM E 1980, based on testing identical products by a qualified testing agency.

C. Building Product Disclosure Requirements: Provide Building Product Disclosure documentation for products used in this section when available.
   1. Environmental product Declarations:
   2. Material Ingredients –Documentation demonstrating the chemical inventory of the product to at least 0.1% (1000ppm).

2.2 CLAY ROOF TILES

A. Clay Roof Tiles: ASTM C 1167, molded- or extruded-clay roof tile units of shape and configuration indicated, kiln fired, and free of surface imperfections. Provide with fastening holes prepunched at factory before firing.
   1. Basis of Design: Subject to compliance with requirements, provide US Tile by Boral Roofing or a comparable product by one of the following:
      a. Ludowici Tile
   2. Durability: Grade 3.
   3. High-Profile Shape: Type I, tapered barrel mission, two piece.
      a. Accessory Tiles: Ridge hip and hip starter and eave closure bird stop units.
   4. California Title 24 (Heat Island) Compliant without upgrades
   5. Size: as indicated.
   6. Finish and Texture: Matte, smooth.
   7. Color: Terra cotta to match existing clay tile roof at Town Hall.

2.3 UNDERLAYMENT MATERIALS

A. Self-Adhering Sheet Underlayment, High Temperature: Minimum of 40-mil-thick; with slip-resisting, polymer-film-reinforced or glass-reinforced top surface laminated to layer of butyl or SBS-modified-asphalt adhesive; with release backing; cold applied; and evaluated and documented to be suitable for use for intended purpose under applicable codes by a testing and inspecting agency acceptable to authorities having jurisdiction.

1. Basis of Design: Boral TileSeal HT Self-Adhering Underlayment.
2. Manufacturers not listed but who do offer products that comply with the requirements of this Section will be considered as substitute manufacturers, subject to the conditions specified in Division 1 Section Product Substitution Procedures.

2.4 ACCESSORIES

A. Asphalt Roofing Cement: ASTM D 4586/D 4586M, Type II, asbestos free.

B. Butyl Sealant: ASTM C 1311, single-component, solvent-release butyl rubber sealant; polyisobutylene plasticized; heavy bodied.

~~B.~~C. Elastomeric Sealant: ASTM C 920, elastomeric silicone-based joint sealant of type, grade, class, and use classifications required to seal joints in clay-tile roofing and remain watertight.

~~C.~~D. Roofing Asphalt: ASTM D 312, Type IV.

E. Mortar materials, plastic cement and sealant meeting ASTM C270, Type M with ASTM C979, pigmented mortar matching the color of clay roof tiles for exposed to view mortar.

~~D. Mortar materials, plastic cement and sealant: Code approved adhesive suitable to bond to clay roof tile.~~
~~1. Sand: ASTM C 144.~~
~~2. Portland cement: ASTM C 150, Type 1.~~
~~3. Plastic cement: ASTM D 2822.~~
~~4. Silicone sealant: ASTM D 1002.~~

~~E.~~F. Cold-Applied Adhesive: Manufacturer's standard asphalt-based, one- or two-part, asbestos-free, cold-applied adhesive specially formulated for compatibility and use with underlayments.

~~F.~~G. Eave Closure: Manufacturer's standard eave closure formed to shape of clay roof tile.

~~G.~~H. Wood Nailers: Comply with requirements for pressure-preservative-treated wood in Section 06 1053 "Miscellaneous Rough Carpentry."

2.5 FASTENERS

A. Roofing Nails: ASTM F 1667, ~~copper,~~ stainless steel, 0.135-inch-diameter shank, sharp-pointed, conventional roofing nails with barbed shanks; minimum 3/8-inch-diameter head; of sufficient length to penetrate 3/4 inch into substrate or through thickness of the sheathing, whichever is less.
1. Where nails are in contact with metal flashing, use nails made from same metal as flashing.

B. Corrosion resistant meeting ASTM A641 Class 1 or approved corrosion resistance, of No. 11 gauge diameter and of sufficient length to properly penetrate 3/4" into or through the thickness of the deck, whichever is less. The head of the nail used for tile fastening shall not be less than 5/16" (.3125") and complying with ASTM F 1667 for dimensional tolerances (+0%, -10%).

C. Twisted Wire-Tie System: Interconnecting eave-to-ridge system, minimum 12 gauge stainless steel wire, preformed to accommodate clay roof tile type and application indicated. Anchor to roof deck 10 feet on center maximum.

D. Single Wire -Tie Wire: Fasten clay roof tile to twisted wire-tie system with 12 gauge stainless steel wire.

~~C. Single Line, Wire Tie System: Interconnecting eave to ridge system, minimum 0.101 inch diameter copper wire, preformed to accommodate clay roof tile type and application indicated.~~

2.6 METAL FLASHING AND TRIM

A. General: Comply with requirements in Section 07 6200 "Sheet Metal Flashing and Trim."
1. Sheet Metal Town Hall: Copper.
~~1.~~2. Sheet Metal City Hall: Stainless Steel

B. Fabricate sheet metal flashing and trim to comply with recommendations in SMACNA's "Architectural Sheet Metal Manual" for design, dimensions, metal, and other characteristics of the item.
1. Apron Flashings: Fabricate with lower flange extending a minimum of 6 inches over and 4 inches beyond each side of downslope tile roofing and 6 inches up the vertical surface.
2. Step Flashings: Fabricate with a head lap of 3 inches and a minimum extension of 5 inches both horizontally and vertically.
3. Rake Pan Flashings: Fabricate with vertical surface extending over fasciae and 6 inches beneath the tile roofing, with a 1-inch-high vertical return to form a runoff channel.
4. Valley Flashings: Fabricate in lengths not exceeding 10 feet with 1-inch-high, inverted-V-profile water diverter at center of valley and equal flange widths of 12 inches, use ribbed flashing product.
5. Drip Edges: Fabricate in lengths not exceeding 10 feet, with 2-inch roof-deck flange and 1-1/2-inch fascia flange with 3/8-inch drip at lower edge.

C. Vent-Pipe Flashings: ASTM B 749, Type L51121, at least 1/16 inch thick. Provide lead sleeve sized to slip over and turn down into pipe, soldered to skirt at slope of roof and extending at least 4 inches from pipe onto roof.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
1. Examine roof sheathing to verify that sheathing joints are supported by framing and blocking or metal clips and that installation is within flatness tolerances.
2. Verify that substrate is sound, dry, smooth, clean, sloped for drainage, and completely anchored and that provision has been made for flashings and penetrations through roofing.

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

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

3.2 UNDERLAYMENT INSTALLATION

A. General: Comply with clay roof tile manufacturer's written instructions and with recommendations in NRCA's "NRCA Roofing Manual: Steep-Slope Roof Systems" unless more stringent requirements are indicated.
1. Cover ridge and hip wood nailers with underlayment strips.

B. Self-Adhering Sheet Underlayment: Install wrinkle free; comply with low-temperature installation restrictions of underlayment manufacturer if applicable. Install lapped in direction that sheds water. Lap sides not less than 3-1/2 inches. Lap ends not less than 6 inches, staggered 24

inches between succeeding courses. Roll laps with roller. Cover underlayment within seven days.

1. Extend self-adhering sheet underlayment over entire roof deck.
2. Chimneys, Skylights, and Other Roof-Penetrating Elements: Extend 18 inches beyond penetrating elements and return vertically against penetrating elements not less than 4 inches.
3. At low slope roofs with slopes below 3:12, two layers are required.
4. Install in accordance with the manufacturer's instructions.

3.3 METAL FLASHING INSTALLATION

A. General: Install metal flashings and other sheet metal to comply with requirements in Section 07 6200 "Sheet Metal Flashing and Trim."
   1. Install metal flashings according to clay roof tile manufacturer's written instructions and recommendations in NRCA's "NRCA Roofing Manual: Steep-Slope Roof Systems."

B. Apron Flashings: Extend lower flange over and beyond each side of downslope tile roofing and up the vertical surface.

C. Step Flashings: Install with a head lap of 3 inches and extend both horizontally and vertically. Install with lower edge of flashing just upslope of, and concealed by, butt of overlying tile. Fasten to roof deck only.

D. Valley Flashings: Install centrally in valleys, lapping ends at least 8 inches in direction that sheds water. Fasten upper end of each length to roof deck beneath overlap.
   1. Secure hemmed flange edges into metal cleats spaced 12 inches apart and fastened to roof deck.

E. Channel Flashings: Install over underlayment and fasten to roof deck.

F. Rake Pan Flashings: Install over underlayment and fasten to roof deck.

G. Rake Drip Edges: Install over underlayment and fasten to roof deck.

H. Eave Drip Edges: Install beneath underlayment and fasten to roof deck.

I. Pipe Flashings: Form flashing around pipe penetrations and tile roofing. Fasten and seal to tile roofing.

3.4 WOOD NAILERS

A. Install wood nailers at ridges and hips and securely fasten to roof deck

3.5 CLAY ROOF TILE INSTALLATION

A. General: Install clay roof tiles according to manufacturer's written instructions and recommendations in TRI/WSRCA's "Concrete and Clay Roof Tile Design Criteria Installation Manual for Moderate Climate Regions" and NRCA's "NRCA Roofing Manual: Steep-Slope Roof Systems" unless more stringent requirements are indicated.
   1. Maintain uniform exposure and coursing of clay roof tiles throughout roof.
   2. Extend tiles 2 inches over eave fasciae.
   3. Nail Fastening: For adequate uplift securement of the clay roof tiles, utilize one (11 gage. 0.135 in. diameter) ASTMF1667 ~~copper~~ stainless steel nails per tile of sufficient length.
      a. Drive nails to clear the clay roof tile so the tile hangs from the nail and is not drawn up.

b. Install wire through nail holes of cut tiles that cannot be nailed directly to roof deck and fasten to nails driven into deck.

4. Wire-Tie Fastening: Install twisted wire-tie systems and fasten clay roof tiles according to manufacturer's written instructions.
5. Mortar Setting: Install clay roof tile according to TRI/FRSA's "Concrete and Clay Roof Tile Installation Manual."
6. Cut and fit clay roof tiles neatly around roof vents, pipes, ventilators, and other projections through roof. Fill voids with mortar.
7. Install clay roof tiles with color blend approved by Architect.

B. High-Profile Clay Roof Tile Installation:
1. Install tile eave closure.
2. Provide minimum 3-inch lap between succeeding courses of clay roof tiles.
3. Install rake tiles indicated. Fasten rake tiles with no less than two nails with a minimum 3/8" head and shall have a dab of roof cement or tile adhesive at overlap.
~~3.~~
4. Install ridge tiles with laps facing away from prevailing wind. Seal laps with ~~asphalt roofing cement~~ butyl sealant.

C. Open Valleys: Cut clay roof tiles at open valleys to form straight lines. Maintain uniform width of 4 inches at exposed open valley from highest to lowest point.
1. Drill or notch cut valley tiles and wire-tie to fastener placed clear of valley metal flashings.
2. Do not nail tiles to metal flashings.

~~2.~~D. All hip and ridge tiles shall be installed with a nail and a galvanized wind lock type nose hook. Also install a continuous bead of tile and adhesive between overlapping area.

3.6 ADJUSTING AND CLEANING

A. Remove and replace damaged or broken clay roof tiles.

B. Remove excess clay roof tiles and debris from Project site.

END OF SECTION

SECTION 23 0900

INSTRUMENTATION AND CONTROL PERFORMANCE SPECIFICATIONS

PART 1 - GENERAL

1.1 SUMMARY

A. Work Included:
1. Communications
2. Operator Interface
3. Controller Software
4. Web Based Access
5. BAS Graphics
6. Building Controllers
7. Application Specific Controllers
8. Advanced Application Controllers
9. Application Specific Controller - Terminal Unit Controllers
10. Input/Output Interface
11. Power Supplies and Line Filtering
12. Control Panels
13. Auxiliary Control Devices
14. Wiring and Raceways
15. Smoke Detection for Projects with a Building Fire Alarm System

B. This is a performance specification and Contractor is responsible for design tasks and engineering.

1.2 RELATED SECTIONS

A. Contents of Division 23, HVAC and Division 01, General Requirements apply to this Section.

1.3 REFERENCES AND STANDARDS

A. References and Standards as required by Section 23 00 00, HVAC Basic Requirements and Division 01, General Requirements.

B. In addition, meet the following:
1. Current edition of ANSI/ASHRAE Standard 135 and addendum, BACnet.
2. Current edition of UL 916 Underwriters Laboratories Standard for Energy Management Equipment, Canada and the US.
3. Current edition of FCC Part 15, Subpart J, Class A.
4. Current edition of BACnet Testing Laboratories (BTL).

1.4 SUBMITTALS

A. Submittals as required by Section 23 00 00, HVAC Basic Requirements and Division 01, General Requirements.

B. In addition, provide:

1. Prepare and submit a detailed schedule of work. Schedule to identify milestones such as equipment submittals, control panel diagrams, color graphic panel displays, Interlock.
2. Wiring diagrams, control program sequence software flow chart diagrams, conduit layout diagrams, device location diagrams, equipment and component deliveries, installation sequencing, controller startup, point to point startup, control programming, sequence testing, commissioning/acceptance testing and training.
3. Submit design drawings, sequences of operation, program listings, software flow charts and details for each typical piece of equipment and system being controlled. No work to be initiated or fabrication of any equipment started prior to the Owner's Authorized Representatives return of REVIEWED submittals.
    a. Sequence of Operation: The sequence of operation included in the design documents is intended only to communicate the Engineers' general control intent and is not to be used as a direct reference for programming of the EMS system. Verbatim duplication of the Engineer's Sequence of Operation on the submittals is discouraged and may result in non-approval of the submittal. Sequence of operation on submittals to accurately detail the system's intended programming, and include details of enhancements, adjustments, or deviations from the Engineer's sequence of operation. Submitted sequence of operation to be written with a logical and organized format and flow. Provide detailed, clear and unambiguous sequence of operation language. Point descriptors and point nomenclature referenced in the submitted sequence of operation to match those (to be) actually programmed. As-built submittal Sequence of Operation to include modifications to the programming made as a result of any addendum, bulletins, RFI's, change orders, and commissioning.
4. Format: Make each submittal in one complete and contiguous package. Partial or unmarked submittals will be rejected without review.
5. Submit Manufacturers Data as Follows:
    a. Complete materials list of items proposed to be furnished and installed. A complete Bill of Materials, listing materials, components, devices, wire and equipment are required for this work. The Bill of Materials to be separate for each controller on its own page(s) and to contain the following information for each item listed:
        1) Manufacturer's Name and Model number with furnished options highlighted.
        2) Quantity of each by controller location.
        3) Description of product (generic).
        4) Specified item.
        5) Operating range or span.
        6) Operating point or setpoint.
    b. Manufacturer's specifications and other data required demonstrating compliance with the specified requirements, including but not limited to: Catalog cuts, technical data and descriptive literature on hardware, software, and system components to be furnished.
    c. The data to be clearly marked and noted to identify specific ranges, model numbers, sizes, and other pertinent data. Submit printed manufacturer's technical product data for each control device furnished, indicating dimensions, capacities, performance characteristics, electrical characteristics, finishes of materials and including printed installation instructions and start-up instructions.
    d. Unless specifically called for otherwise, provide bound copies of catalog cuts for standard products, not requiring specifically prepared Shop Drawings, for the following:
        1) Wire and Cable, Class II
        2) Face Plates for Devices
        3) Disconnect Switches for Power Control
    e. Where more than one item, size, rating or other variations appear on a catalog cut sheet, clearly identify items to be provided. These items to be properly indexed and referenced to identification numbers, designations and/or details on the Drawings.

6. Shop Drawings: Submit shop drawings for each controlled system, depicting the following information:
    a. Schematic flow diagram of system showing fans, pumps, coils, dampers, valves and other control/monitoring devices.
    b. Label each control device with initial setting or adjustable range of control. Label points in schematic diagrams with termination at corresponding controller.
    c. Electrical Wiring: Clearly differentiate between portions of wiring that are factory installed and portions of be field-installed.
    d. Details of control panel faces, including controls, instruments, and labeling.
    e. Interfaces to equipment furnished under other Specification Sections identifying numbers of wires, termination location, voltages and pertinent details. Responsibility for each end of the interfaces to be noted on these drawings whether or not they are a part of this Section.
    f. System architecture diagram showing the global connectivity of new controllers and any existing systems that will be connected to.
7. Equipment locations, wiring and piping schematics, details, panel configurations, sizes, damper motor mounting details, valve schedules, and a points list keyed to specific hardware submittals. Control wiring depicted as fully annotated ladder diagrams with terminations identified, completely configured as to the exact panel, wiring, relay, switch, and component configuration.
8. Tag Number Lists: Develop instruments tag number system and submit list for approval. Coordinate methods and number block with the Owner's Authorized Representative.
9. Format the Shop and Field Drawings to Include:
    a. A Title Sheet containing a drawing list, abbreviations list, symbols list, site and vicinity maps for project location and schedules.
    b. Floor Plans showing proposed device locations and device nomenclatures.
    c. A Riser Diagram illustrating conduit relationships between devices shown on the Floor Plans. Show device nomenclatures.
    d. A Single-Line Diagram for each system showing signal relationships of devices within the system. Show device nomenclatures.
    e. A Wiring Diagram for each assembly, enclosure or free standing device, showing:
        1) The Devices Within
        2) Wiring Connections
        3) Wire Identification
        4) Voltage Levels
        5) Fuse Ratings
    f. Operations and Maintenance Manuals:
        1) Following approval of Shop Drawings of control equipment and prior to acceptance of control work, prepare Operating and Maintenance manuals describing operating, servicing, and maintenance requirements of control systems and equipment installed under this Section, in accordance the General and Special Conditions of these Specifications.
        2) Information contained in the manual for the above equipment to include the following:
            (a) Manufacturer's catalog cuts and printed descriptive bulletins.
            (b) Manufacturer's installation, operating, and maintenance instruction booklets. Complete instructions regarding the operation and maintenance of equipment involved.
            (c) Instrument calibration certificates.
            (d) Parts list and costs.
            (e) Complete nomenclature of replaceable parts, list of recommended spare parts for 12 months operation, their part numbers, current cost and name and address of the nearest vendor of replacement parts.
            (f) Name, address and telephone number for closest source of spare parts.

(g) Wiring and schematic diagrams.
(h) Include final record copies of shop drawings.
(i) Copy of guarantees and warranties issued for the various items of equipment, showing dates of expiration.
(j) Reduced plans, diagrams, and control schematics.
(k) Copies of test results.
(l) Control System Operating Manual including: point of summary and point data base; complete printout of program listings; magnetic tape CD or DVD backup of Field Control Cabinet programs; cabinet layout; hard copy of graphic screens; hard copy of specified reports.

g. A final Bill of Quantities including a separate schedule for portable equipment, if delivered as part of this work.
h. Performance, Test and Adjustment Data: Comprehensive documentation of performance verification according to parameters specified in these specifications.
i. Record Drawings: Comply with Division 01, General Requirements and Section 23 00 00, HVAC Basic Requirements. Provide complete as-built submittals including "as-programmed" sequence of operation as well as final occupancy schedules.

1.5 QUALITY ASSURANCE

A. Quality assurance as required by Section 23 00 00, HVAC Basic Requirements and Division 01, General Requirements.

B. In addition, meet the following:
1. Installer Qualifications: Company specializing in performing work of the type specified in this Section with minimum five years' experience in the local area. Installers required to have successfully completed manufacturer's control system factory training.

1.6 WARRANTY

A. Warranty of materials and workmanship as required by Section 23 00 00, HVAC Basic Requirements and Division 01, General Requirements.

1.7 SYSTEM DESCRIPTION

A. Control system referenced throughout specifications and drawings as Building Automation System (BAS), Building Management System (BMS), or Energy Management System (EMS) interchangeably consists of high-speed, peer-to-peer network of DDC controllers, control system server, and operator workstation.

B. System software based on server/thin-client architecture, designed around open standards of web technology. Control system server accessed using a web browser over control system network, Owner's local area network, and remotely over Internet (through Owner's LAN). Intent of thin-client architecture is to provide operators complete access to control system via web browser. No special software other than web browser required to access graphics, point displays, and trends.

C. Local Area Network (LAN) either 10 or 100 Mpbs Ethernet network.

D. System will consist of open architecture that is capable of:
1. High speed Ethernet communication using TCP/IP protocol.
2. Native BACnet communications according to ANSI / ASHRAE Standard 135, latest edition. Provide necessary BACnet-compliant hardware and software to meet the system's

functional specifications. Controller devices must be BTL tested and listed by an official BACnet Testing Laboratory and have the BTL mark issued.

E. Complete temperature control system to be DDC with electronic sensors and electronic/electric actuation valves and dampers.

F. Prepare individual hardware layouts, interconnection drawings, building riser/architecture diagram and sequence of control from the project design data. Any architecture diagrams on design drawings have been included as schematics only and are not meant to portray quantity of devices or power/data requirements.

G. Design, provide, and install equipment cabinets, panels, data communication network infrastructure (including cables, conduits, outlets, connections, etc.) needed, and associated hardware.

H. Provide complete manufacturer's specifications for items that are supplied. Include vendor name and model number of every item supplied.

I. Provide a comprehensive operator and technician training program as described in these Specifications.

J. Provide as-built documentation, operator's terminal software, diagrams, and other associated project operational documentation (such as technical manuals) on approved media, the sum total of which accurately represents the final system.

K. Provide 120V power, low voltage power, transformers, etc. for control panels, transformer panels, and BAS devices. Install per Division 26, Electrical Specifications. Power for devices within this Specification Section is solely the responsibility of the BAS Contractor.

L. Conduit and raceway systems. Provide per Division 26, Electrical Specifications.

M. Devices, components, controllers, and software to be manufacturer's most current version at the time of installation.

1.8 SYSTEM PERFORMANCE

A. Performance Standards - System conforms to following minimum standards over network connections:
   1. Graphic Display: Graphic with 20 dynamic points display with current data within 10 seconds.
   2. Graphic Refresh: Graphic with 20 dynamic points update with current data within 8 seconds.
   3. Object Command: Devices react to command of binary object within 2 seconds. Devices begin reacting to command of analog object within 2 seconds.
   4. Object Scan: Data used or displayed at controller or workstation have been current within previous 6 seconds.
   5. Alarm Response Time: Object that goes into alarm is annunciated at workstation within 45 seconds.
   6. Program Execution Frequency: Custom and standard applications are capable of running as often as once every 5 seconds. Select execution times consistent with mechanical process under control.
   7. Performance: Programmable controllers are able to completely execute DDC PID control loops at frequency adjustable down to once per second. Select execution times consistent with mechanical process under control.

8. Multiple Alarm Annunciation: Each workstation on network receive alarms within 5 seconds of other workstations.

B. Reporting Accuracy: System reports values with minimum end-to-end accuracy listed in Reporting Accuracy Table below.
   1. Reporting Accuracy Table:

Measure Variable	Reported Accuracy
Space Temperature	Plus or Minus 1 degree F
Ducted Air	Plus or Minus 1 degrees F
Outside Air	Plus or Minus 2 degrees F
Dew Point	Plus or Minus 3 degrees F
Water Temperature	Plus or Minus 1 degree F
Delta-T	Plus or Minus 0.25 degree F
Relative Humidity	Plus or Minus 5 percent RH
Water Flow	Plus or Minus 2 percent of full scale

   2. Note 1: Accuracy applies to 10 percent-100 percent of scale
   3. Note 2: For both absolute and differential pressure
   4. Note 3: Not including utility-supplied meters

C. Control Stability and Accuracy. Control loops maintain measured variable at setpoint within tolerances listed in Control Stability and Accuracy Table below.
   1. Control Stability and Accuracy Table:

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	Plus or minus 0.2 inch wg	0-6 inch wg
Airflow	Plus or minus 10 percent of full scale	
Space Temperature	Plus or minus 2.00 degrees F	
Duct Temperature	Plus or minus 3.0 degrees F	
Humidity	Plus or minus 5 percent RH	
Fluid Pressure	Plus or minus 1.5 PSI	1-150 PSI
	Plus or minus 1.0 inch wg	0-50 inch wg differential

PART 2 - PRODUCTS

2.1 NORTHERN CALIFORNIA MANUFACTURERS/INSTALLERS

A. Alerton/Syserco Inc

B. Automated Logic/Sunbelt Controls, Air Systems Inc

C. Andover (Schneider Electric)/Steven Engineering, Alameda Electrical Distributors Inc, Graybar Electric Company Inc, Powermatic Associates

D. Duct/Spot-Type Smoke Detectors (Project with Fire Alarm System):
   1. See Division 28 for Products.

2.2 COMMUNICATIONS

A. Each controller to have communication port for connection to operator interface.
   1. Internetwork operator interface and value passing to be transparent to internetwork architecture.
   2. Operator interface connected to controller to allow operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, reports, system software, and custom programs to be viewable and editable from each internetwork controller.

B. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers to be readable by each controller on internetwork.

C. Operator Workstation to be capable of simultaneous direct connection and communication with BACnet/IP, OPC and TCP/IP networks without use of interposing devices such as PC or gateway with hard drive.

D. Workstations, Building Control Panels and Controllers with real-time clocks use time synchronization service. System automatically synchronizes system clocks daily from operator-designated device via internetwork. System automatically adjusts for daylight savings and standard time as applicable.

2.3 OPERATOR INTERFACE

A. Operator Interface: PC-based workstations reside on high-speed network with building controllers. Each workstation or each standard browser connected to server is able to access system information.

B. Hardware: Each operator workstation or web server consists of the following:
   1. Computer: Hardware meets or exceeds DDC system manufacturer's recommended specifications and meet response times specified elsewhere in this document. Following hardware requirements also apply:
      a. Hard disk have sufficient memory to store:
         1) Required operator workstation software.
         2) One year of trend data based on points specified to be trended at specified trend intervals.
      b. Minimum hardware configuration includes:
         1) Intel i7 Processor
         2) 22-in LCD Monitor with at least 1024 x 768 Resolution
         3) 8 GB of RAM
         4) 48x CD-RW/DVD Optical Drive
         5) 1 TB Hard Disk Drive Providing Data at 3 GB/sec
         6) Ethernet 10/100 Network Interface Card
         7) High Performance Graphics Card
         8) Keyboard and Mouse
         9) Color Inkjet Printer
         10) UPS (uninterruptible power supply) installed at server, sized with sufficient capacity to allow full operation for 10 minutes or more.
   2. Portable Operator's Terminal: Portable Operator's Terminal capable of accessing system data. This device may be connected to any point on system network or to any controller for programming, setup, and troubleshooting. Portable Operator's Terminal is IBM-compatible notebook-style PC including software and hardware required. PC contains at minimum:
      a. Intel i5 Processor

b. 15-in LCD Monitor with at least 1024 x 768 Resolution
c. 8 GB of RAM
d. 1 TB Hard Drive
e. Touch-Pad or Other Internal Pointing Device
f. High-Performance Graphics Adapter
g. Ethernet 10/100 Network Interface Card
h. Integrated Wireless 802.11 b/g/n
i. Serial Port and CD/RW-ROM
j. Internal Modem, 56Kb Minimum

C. System Software:
1. Operating System: Furnish concurrent multi-tasking operating system. Operating system also supports use of and includes other common software applications such as Microsoft Excel, Word, Microsoft Access and Adobe Acrobat. Acceptable operating systems are Windows 7 and Windows 10.
2. Dynamic Color Graphics:
a. Real-time color graphic displays dynamic and able to update displays.
b. Provide operator ability to change values (setpoints) and states in system controlled equipment directly from graphic display.
c. Custom Graphics. Provide custom graphics generation package.
d. Graphics Library. Furnish library of standard HVAC equipment graphics and include standard symbols for fans, pumps, coils, valves, piping, dampers, and ductwork.
3. Software to be manufacturer's most current version at the time of installation.

D. System Applications: Each workstation provides operator interface and off-line storage of system information. Provide following applications at each workstation:
1. Automatic System Database Save and Restore: Each workstation stores on hard disk copy of current database of each Building Controller. This database automatically updated whenever change is made in any system panel.
2. Manual Database Save and Restore: System operator able to manually save or clear database and initiate download of specified database from/to any panel.
3. System Configuration: Workstation software provides method of configuring system to allow for changes or additions by users and performs following tasks:
a. Create, delete or modify control strategies.
b. Add/delete objects to system.
c. Tune control loops through adjustment of control loop parameters.
d. Enable or disable control strategies.
e. Generate hard copy records of control strategies on printer.
f. Select points to be alarmed and define alarm state.
g. Select points to be trended and initiate automatic recording of values.
h. Start/Stop binary objects and adjust analog objects.
4. Security: Operator required to log on to system with user name and password in order to view, edit, add, or delete data. System security selectable for each operator.
5. System Diagnostics: System automatically monitor operation of workstations, printers, modems, network connections, building management panels, and controllers. Failure of any device to be annunciated.
6. Alarm Indication and Handling:
a. Workstation provides visual means of alarm indication. Alarm indication becomes highest priority regardless of application(s) running.
b. System provides and archive log of alarm messages to hard drive. Alarm messages to include description of event-initiating object, source, location and time/date of alarm.
7. Trend Logs: Operator able to define custom trend log for any data object and include interval, start time, and stop time. Trend data sampled and stored on building controller

panel, is archived on hard disk, and is retrievable for use in spreadsheets and standard database programs.

a. System server to periodically gather historically recorded data stored in the building controllers and archive the information. Archived files to be appended with new sample data, allowing samples to be accumulated.
b. Software to be included that is capable of graphing the trend logged object data. Software capable of creating two-axis (x,y) graphs that display object values relative to time.
c. Operator able to change trend log setup information. This includes the information to be logged as well as the interval at which it is to be logged. Input, output, and value object types in the system may be logged. Provide operations password protected. Setup and viewing may be accessed directly from any graphics on which object is displayed.
d. BAS Contractor to enable trending for any system points (physical or virtual) as directed by the Engineer, Owner or Commissioning Authority (Commissioning Authority). There will be no limit on the number of trended points the BAS Contractor is to set up. BAS Contractor will modify trend setup parameters as directed by the Commissioning Authority during testing. BAS Contractor to be proactive and enable trending for major system points during system startup/programming. BAS Contractor is not to wait for direction to begin trending points. Trend data for each point to be archived on the main server for a minimum of one year. Trend data archiving to be enabled immediately upon trend setup, or as soon as communication between the field panel and sever is established. Trend data uploads from field panel to server set up to be automatically performed with sufficient frequency to ensure no data gaps or loss of trend data.
e. Trend points as identified in the points list. Provide system specific trend data in two-axis (x,y) graphs that display object values relative to time to Engineer, Owner, or Commissioning Authority.

8. Standard Reports: Standard system reports provided for this project. Provide ability for Owner to readily customize these reports for this project:
   a. Objects: System (or subsystem) objects and their current values.
   b. Logs:
      1) Alarm History
      2) System Messages
      3) System Events
      4) Trends
9. Electrical, Gas, and Weather Report:
   a. System server capable of periodically gathering energy log data stored in the field equipment and archive the information. Archive files appended with new data, allowing data to be accumulated.
   b. Operator able to change the energy log setup information as well. This includes the meters to be logged, meter pulse value, and the type of energy units to be logged. Meters monitored by the system may be logged.
   c. System to display archived data in tabular format form for both consumption and peak values. Data shown in hourly, daily, weekly, monthly and yearly formats. In each format the user able to select a specific period of data to view.
   d. Electrical Meter Report: Provide monthly report showing daily electrical consumption and peak electrical demand with time and date stamp for each building meter and for each electrical sub-meter on individual building panels, circuits, equipment (such as chillers), and variable frequency drives. Provide an annual (12-month) report showing monthly electrical consumption and peak electrical demand with time and date stamp for each individual meter.
   e. Weather Data Report: Provide monthly report showing daily minimum, maximum, and average outdoor air temperature (dry bulb, wet bulb) and humidity. Provide annual

(12-month) report showing minimum, maximum, and average outdoor air temperature for month.

E. Interfaces to Third Party Systems: BAS connects to third party systems (VFDs, chillers, emergency generators, rooftop AC units, etc.). Communication protocol specified for third party system, and BAS provides compatible protocol to assure proper two way communication. Points, alarms, and commands displayed on BAS as indicated.

F. Workstation Applications Editors: Each PC workstation supports editing of system applications, which downloaded and executed at one or more controller panels.

2.4 CONTROLLER SOFTWARE

A. Furnish following applications software for building and energy management. Software applications reside and operate in system controllers. Software to be manufacturer's most current version at the time of installation. Software and associated functions (scheduling, optimum start/stop, etc.) noted in this specification are to be configured and enabled for this project. Incorporate into sequence of operation submittals for review prior to installation.

B. System Security:
1. User access secured using individual security passwords and user names.
2. Restrict user passwords to objects, applications, and system functions as assigned by system manager. Provide monitoring only access to Engineer of Record and Commissioning Authority for period of one year for trouble shooting purposes.
3. Record user Log On/Log Off attempts.
4. Provide passwords, user names, and access assignments adjustable at the operator's terminal. Each user to have a set security level, which defines access to displays and individual objects the user may control. System to include 10 separate and distinct security levels for assignment to users.
5. System to include an Auto Logout Feature that will automatically logout user when there has been no keyboard or mouse activity for a set period of time. Time period to be adjustable by system administrator. Auto Logout may be enabled and disabled by system administrator. Operator terminal to display message on screen that user is logged out after Auto Logout occurs.

C. Scheduling: Provide capability to schedule each object or group of objects in system. Coordinate schedule with Owner and program accordingly. Each schedule consists of:
1. Operator's workstation to show information in easy-to-read daily format. Priority for scheduling: Events, holidays and daily with events being the highest.
2. Holiday and special event schedules to display data in calendar format. Operator able to schedule holidays and special events directly from these calendars.
3. Operator able to change information for a given weekly or exception schedule if logged on with the appropriate security access.

D. Optimum Start/Stop: Provide software and program system to start equipment on sliding schedule based upon indoor and outdoor conditions. Determine minimum time of HVAC system operation needed to satisfy space environmental requirements and also determine earliest possible time to stop mechanical systems (i.e. shut down cooling/heating and only provide ventilation one hour prior to scheduled unoccupied period.) Optimum start/stop program operates in conjunction with scheduled start/stop and night setback programs.

E. Alarms:
1. Operator's workstation to provide visual means of alarm indication. The alarm dialog box to always become the top dialog box regardless of the application(s), currently running.

2. System to provide log of alarm messages. Alarm log to be archived to the hard disk of the system operator's terminal. Each entry to include a description of the event-initiating object generating the alarm. Entry to include time and date of alarm occurrence.
3. Alarm messages in user-definable text and entered either at the operator's terminal or via remote communication.
4. Each binary object set to alarm based on operator-specified state.
5. Each analog object have both high and low alarm limits.
6. Alarms must be able to be automatically and manually disabled.
7. Alarms are routed to appropriate workstations based on time and other conditions. An alarm is able to start programs, print, be logged in event log, generate custom messages, and display graphics.
8. System have ability to dial out in event of alarm.
9. Alarm Levels:
    a. Provide 5 levels of alarm as follows, and program alarm levels for every required and specified alarm:
        1) Level 1: Critical/life safety.
        2) Level 2: Significant equipment failure.
        3) Level 3: Non-critical equipment failure/operation.
        4) Level 4: Energy conservation monitor.
        5) Level 5: Maintenance indication, notification.
    b. Prior to training of Owner’s Authorized Representative, submit the complete Points List and suggested Alarm Levels to the Owner.
    c. During training of Owner’s Authorized Representative(s):
        1) Discuss Alarm Levels and the alarms currently included in the BAS.
        2) Provide additional alarms without addition of new hardware points, as required by Owner’s Authorized Representative.
        3) Agree with the Owner’s Authorized Representative on action(s) to be taken for each alarm level and implement same for each alarm. Said action to include visual and/or audible alarm(s) at the Operator workstation including whether Operator acknowledgement is required or not, email messages, and text messages.

F. Demand Limiting:
1. System to include demand limiting program that includes two types of load shedding. One type of load shedding to shed/restore equipment in binary fashion based on energy usage when compared to shed and restore settings. The other type of shedding to adjust operator selected control setpoints in an analog fashion based on energy usage when compared to shed and restore settings. Shedding may be implemented independently on each and every zone or piece of equipment connected to system.
2. Status of each and every load shed program capable of being displayed on every operator terminal connected to system. Status of each load assigned to an individual shed program displayed along with the description of each load.
3. Demand-limiting program monitor building power consumption from signals generated by pulse generator (provided by BAS contractor) mounted at building power meter or from watt transducer or current transformer attached to building feeder lines.
4. Demand-limiting program predicts probable power demand so that when demand exceeds demand limit, action will be taken to reduce loads in predetermined manner. When demand limit will not be exceeded, action will be taken to restore loads in predetermined manner.

G. Maintenance Management: System monitors equipment status and generate maintenance messages based upon user-designated run-time, starts, and/or calendar date limits. Coordinate settings with Owner.

H. Sequencing: Provide application software based upon sequences of operation specified to properly sequence designated systems. Provide points to achieve specified sequences.

I. Staggered Start: This application prevents controlled equipment from simultaneously restarting after a power outage. Order in which equipment (or groups of equipment) is started, along with time delay between starts to be user-selectable.

J. Energy Calculations: Provide software to allow instantaneous power (e.g. kW) or flow rates (e.g. L/s (gpm)) to be accumulated and converted to energy usage data.

K. Anti-Short Cycling: Binary output objects protected from short cycling by allowing minimum on-time and off-time to be selected.

L. On/Off Control with Differential: Provide algorithm that allows binary output to be cycled based on controlled variable and setpoint. Algorithm direct-acting or reverse-acting and incorporate adjustable differential.

M. Run-Time Totalization: Provide software to totalize run-times for binary input objects.

2.5 WEB BASED ACCESS

A. General Description: BAS supplier to provide web-based access to the system as part of standard installation. Provide access to user of displays of real-time data that are part of the BAS via a standard Web browser. Web browser to tie into the network via Ethernet network connection. Provide web-page host that resides on the BAS network. Web-page software not to require a per user licensing fee or annual fees. The web-page host must be able to support at least 50 simultaneous users with the ability to expand the system to accommodate an unlimited number of users. Software to be manufacturer's most current version at time of installation.

B. Browser Technology: Browser to be standard version of Microsoft Internet Explorer (latest edition). No special vendor-supplied software needed on computers running browser. Displays viewable and the Web-page host to directly access real-time data from the BAS network. Data displayed in real time and update automatically without user interaction. User able to change data on displays if logged in with the appropriate user name and password.

C. Display of Data: Web page graphics shown on browser to be replicas of the BAS displays. User to need no additional training to understand information presented on Web pages when compared to what is shown on BAS displays. Web page displays to include animation just as BAS displays. Fans to turn, pilot lights to blink, and coils to change colors, and so on. Real-time data shown on browser Web pages. This data must be directly gathered via the BACnet network and automatically updated on browser Web page displays without any user action. Data on the browser to automatically refresh as changes are detected without re-drawing the complete display. User to be able to change data from browser Web page to if the user is logged on with the appropriate password. Clicking on a button or typing in a new value to change digital data. Using pull-down menus or typing in a new value to change analog data. Data displays navigated using pushbuttons on the displays that are simply clicked on with the mouse to select a new display. Alternatively, the standard back and forward buttons of the browser can be used for display navigation.

D. Web Page Generation: Web pages generated automatically from the BAS displays that reside on the BAS server. User to access Web-page host via the network and initiate a web page generation utility that automatically takes the BAS displays and turns them into Web pages. The Web pages generated are automatically installed on the Web page host for access via any

computer's standard browser. Any system that requires use of an HTML editor for generation of Web pages will not be considered.

E. Password Security and Activity Log: Access via Web browser to utilize the same hierarchical security scheme as BAS system. User asked to log in once the browser makes connection to Web-page host. Once the user logs in, any changes that are made to be tracked by the BAS system. User able to change only those items that the user has authority to change. A user activity report to show any activity of the users that have logged in to the system regardless of whether those changes were made using a browser or via the BAS workstation.

F. Communication: Web-page host to communicate using the specified protocol standard to devices on the BAS network.

2.6 BAS GRAPHICS

A. Develop customized graphics showing the project building(s) and their floor plans, mechanical, and electrical equipment, flow and control diagrams, and other relevant features on Workstation graphic screens. Associated input, output, and virtual objects (e.g., temperature and pressure setpoints) listed in the Sequence of Operation, and shown on the Input/Output Objects List included in the graphic screens and bound to the database. Real-time value of objects updated on the display of each graphic automatically. For projects where existing campus and/or building controls systems exist, replicate graphics used in the existing BAS graphics screens.

B. Graphics to have links to the Print function and to display a Standard Legend in the corner of the graphic. Graphics, except pop-ups, to have the date and time displayed in the upper corner of the graphic. Each graphic titled.

C. Weather: Graphics, except pop-ups, to have the outdoor temperature and humidity in the upper corner of the graphic.

D. Alarms: System and component summary alarms located near the top of each relevant graphic screen. Provide links to the associated system/component as part of these tags to assist trouble shooting. Other alarms placed near the associated system/device as depicted in the graphic. Provide text and color of information tags that describe each object and alarm value consistent with a graphics color legend.

E. The Following Graphics Provided as a Minimum:
   1. A building graphic, typically a photograph of the building, with links to each floor plan and other links as defined below.
   2. A central plant graphic with equipment heat pump, pumps, heat exchangers, storage tanks, etc.), temperature sensors, pressure sensors, and flow sensors. The central plant graphic to have links to each building on the campus.
   3. Central equipment such as air handler, supply fans, and exhaust fans.
   4. Floor plans of each floor, with temperature sensors, pressure sensors, temperature control zones, heating/cooling zones, ventilation zones, and supply air zones identified. Rooms grouped on a graphic only to the extent that detailed and complete sensing information can be comfortably viewed by an operator and the bound points updated in less than 10 seconds. Each zone to have a temperature symbol that changes color over the range from low (blue) through normal (green) to high (red) and indicate an alarm (flashing red). The zone temperature and or pressure symbol(s) to be a link to a zone control pop-up graphic. Individual floor plan graphics to provide links to related mechanical systems. The mechanical room plan graphics to show the relative location of, and provide links to, either the equipment pop-up or flow and control graphic for mechanical equipment monitored or controlled by the BAS.

5. Pop-up graphics provided for each zone control system showing a flow diagram and related monitoring and control points and system parameters. Pop-up graphics provided for each piece of equipment that is not shown on a flow and control graphic.
6. Flow and control diagrams for each system including but not limited to central plant, fan coils, generators, packaged equipment, chilled water systems, heating hot water systems, heat exchangers, pumps, storage tanks, zone terminal units, combination fire and smoke damper status, and ventilation systems. The flow and control graphics to have parameters grouped in the lower portion of the graphics. Standard equipment graphics used. Pumps, fans, dampers and other elements to dynamically indicate their state (i.e. pumps and fans to rotate when on and damper positions to dynamically adjust and be shown in their current position, etc.). System flow and control graphics displayed in a general left to right flow or loop arrangement. Return and exhaust air flow shown on top and return water shown on the bottom of the graphic.
7. Individual equipment/component screens showing sensing and control information available for each device provided.

F. Penetration: The graphic interface to consistently apply a convention whereby a left-click to always penetrate to more detailed information. The text windows to represent the deepest level of penetration. A right-click to always produce a menu of options that are specific to the item selected.

G. Navigation: Graphics organized to provide a "branching structure" that allows an operator to move from a "macro view" to a "micro view" and return. These links to other associated graphics, or allow a return to a previous macro view, provided and arranged horizontally along the bottom of each graphic screen. From left to right, the graphic links as follows: site/building map, building/trailer floor plans, and major mechanical systems at each building. Pop-up right click menus provided as needed on the lower button bar to allow for uncluttered navigation.

H. Clutter Minimization: Each graphic to have separate check boxes in the lower right corner that show/hide setpoints, alarms/safeties, and devices/equipment.

I. Templates: To the maximum extent possible, use standard graphics as templates to provide a consistent look throughout the interface.

J. Color Scheme: The graphics to use dynamic color changes to communicate equipment type, or object status consistent with the graphics color legend.

K. Symbols and Animations: Fans, pumps, dampers, coils, and generation equipment to be dynamic symbols indicating rotation, state, or position, movement, flow, etc.

L. Macros: When macros are used to add functionality to the graphics, detailed documentation provided.

M. Configure Mode: Access to “Configure Mode” for editing of the graphics password protected to prevent unauthorized changes to the graphics. This password supplied to the appropriate personnel.

N. Graphics Version: Graphics provided in the most current format available at time of control system programming.

O. Points and graphics checked for the proper binding and graphic programming, settings to ensure that the correct system, location, point values and dynamics are shown in the proper location and rotate in the proper directions.

P. After graphics have been accepted, provide, on a CD ROM in an agreed upon file structure. If the graphics have active-x controls or other files that must be placed outside the graphics folder structure a set-up program provided on the disk to place the files in the correct locations.

2.7 BUILDING CONTROLLERS

A. General: Provide adequate number of building controllers to achieve performance specified. Panels to meet the following requirements.
   1. Building Automation System (BAS) to be composed of one or more independent, stand-alone, microprocessor-based building controllers to manage global strategies described in Controller Software article.
   2. Provide sufficient memory to support operating system, database, and programming requirements.
   3. Share data between networked building controllers.
   4. Distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
   5. Controllers that perform scheduling have real-time clock.
   6. Continually check status of its processor and memory circuits and if abnormal operation is detected, controller:
      a. Assume predetermined failure mode.
      b. Generate alarm notification.
   7. Building Controller communicates with other devices on internetwork including BACnet communications according to specified protocol.

B. Communication:
   1. Each building controller resides on network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and performs routing to network of custom application and application specific controllers.
   2. Controller provides a service communication port for connection to a portable operator's terminal.

C. Environment:
   1. Controllers used outdoors and/or in wet ambient conditions mounted within NEMA waterproof enclosures and rated for operation at 0 degrees F to 150 degrees F.
   2. Controllers used in conditioned space are mounted in NEMA dust-proof enclosures and rated for operation at 32 degrees F to 120 degrees F.

D. Serviceability: Provide diagnostic LEDs for power, communication, and processor. Wiring connections are made to modular terminal strips or to termination card connected by ribbon cable.

E. Memory: Building controller maintains BIOS and programming information in event of power loss for at least 72 hours.

F. Immunity to power and noise. Controller able to operate at 90 percent to 110 percent of nominal voltage rating and performs an orderly shutdown below 80 percent nominal voltage. Operation protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 3-feet.

G. Controller to have a battery to provide power for orderly shutdown of controller and storage of data in nonvolatile flash memory. Battery backup to maintain real-time clock functions for a minimum of 10 days.

2.8 APPLICATION SPECIFIC CONTROLLERS

A. Application specific controllers (ASCs) are microprocessor-based DDC controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment. Controllers to be fully programmable using graphical programming blocks.
   1. ASC controllers communicate with other devices on internetwork.
   2. Each ASC capable of stand-alone operation without being connected to network.
   3. Each ASC will contain sufficient I/O capacity to control target system.
   4. Application controllers to include universal inputs with minimum 10-bit resolution that accept thermistors, 0-10VDC, 0-5 VDC, 4-20 mA and dry contact signals. Any input on a controller may be either analog or digital with at least 1 input that accepts pulses. Controller to also include support and modifiable programming for interface to intelligent room sensor with digital display. Controller to include binary and analog outputs on board. Provide analog outputs switch selectable as either 0-10VDC or 0-20mA. Software to include scaling features for analog outputs. Application controller to include 24VDC voltage supply for use as power supply to external sensors.
   5. Program sequences stored on board application controller in EEPROM. No batteries needed to retain logic program. Program sequences executed by controller 10 times per second and capable of multiple PI and PID loops for control of multiple devices. Calculations completed using floating-point math and system to support display of information in floating-point nomenclature at operator's terminal. Programming of application controller completely modifiable in the field over installed BAS LANs or remotely via modem interface. Operator to program logic sequences by graphically moving function blocks on screen and tying blocks together on screen.
   6. Application controller to include support for room sensor. Display on room sensor programmable at application controller and include an operating mode and a field service mode. Provide button functions and display data programmable to show specific controller data in each mode based on which button is pressed on the sensor. See sequence of operation for specific display requirements at intelligent room sensor.

B. Communication:
   1. Controller resides on network using MS/TP Data Link/Physical layer protocol.
   2. Each controller connected to building controller.
   3. Each controller capable of connection to laptop computer or portable operator's tool.

C. Environment:
   1. Controllers used outdoors and/or in wet ambient conditions mounted within NEMA waterproof enclosures and rated for operation at 0 degrees F to 150 degrees F.
   2. Controllers used in conditioned space mounted in NEMA dust-proof enclosures and rated for operation at 32 degrees F to 120 degrees F.

D. Serviceability: Provide diagnostic LEDs for power, communication, and processor.

E. Memory: ASC use nonvolatile memory and maintains BIOS and programming information in event of power loss.

2.9 ADVANCED APPLICATION CONTROLLERS

A. General:
   1. Expandable application controller capable of providing control strategies for the system based on information from any connected inputs. Provide program implementing these strategies completely flexible and user definable. Provide program execution of controller a minimum of once per second.

2. Programming: Object-oriented using control program blocks. Controller to support a minimum of 500 Analog Values and 500 Binary Values. Each and every analog and binary value to support standard specified protocol priority arrays.
3. Provide means to graphically view inputs and outputs to each program block in real-time as program is executing. This function may be performed via the operator's terminal or field computer.
4. Controller to have adequate data storage to ensure high performance and data reliability. Battery to retain static RAM memory and real-time clock functions for a minimum of 1.5 years (cumulative). Provide field-replaceable battery (non-rechargeable) lithium type. Unused battery life: 10 years.
5. The onboard, battery-backed real time clock must support schedule operations and trend logs.
6. Global control algorithms and automated control functions should execute via 32-bit processor.
7. Controller to include both on-board Ethernet specified protocol communication over twisted pair cable (UTP) and to include specified protocol IP communication. In addition, controller to include specified protocol PTP connection port.
8. The base unit of the controller to host up to 8 expansion modules with various I/O combinations. These inputs and outputs to include universal 12-bit inputs, binary triac outputs, and 8-bit switch selectable analog outputs (0-10V or 0-20 mA). Inputs to support thermistors, 0-5VDC, 0-10VDC, 4-20mA, dry contacts and pulse inputs directly.
9. Outputs must have onboard Hand-Off-Auto switches and a status indicator light. HOA switch position to be monitored. Each analog output to include a potentiometer for manually adjusting the output when the HOA switch is in the Hand position.
10. The position of each and every HOA switch to be available system wide as a specified protocol object. Expandable Controller to provide up to 176 discreet inputs/outputs per base unit.

B. Schedules: Each controller to support a minimum of 50 Schedule Objects.

C. Logging Capabilities: Each controller to support a minimum of 200 trend logs. Any object in the system (real or calculated) may be logged. Sample time interval adjustable at the operator's workstation.

D. Alarm Generation:
1. Alarms may be generated within the system for any object change of value or state either real or calculated. This includes things such as analog object value changes, binary object state changes, and various controller communication failures.
2. Alarm log provided for alarm viewing. Log may be viewed on-site at the operator's terminal or off-site via remote communications.
3. Controller must be able to handle up to 200 alarm setups stored as event enrollment objects - system destination and actions individually configurable.

2.10 APPLICATION SPECIFIC CONTROLLER - TERMINAL UNIT CONTROLLERS

A. Provide one application controller for each terminal unit that adequately covers objects listed in object list for unit. Controllers to interface to building controller via LAN using specified protocol. Controllers to include on board flow sensor, inputs, outputs and programmable, self-contained logic program as needed for control of units.

B. Application controllers to include universal inputs with 10-bit resolution that can accept thermistors, 0-5 VDC, and dry contact signals. Inputs on controller may be either analog or digital. Controller to also include support and modifiable programming for interface to intelligent room sensor with digital display (digital display to indicate setpoint only). Controller to also

include binary outputs on board. For applications using variable speed parallel fans, provide a single analog output selectable for 0-10 V or 0-20 mA control signals. Application controller to include microprocessor driven flow sensor for use in pressure independent control logic. Terminal units controlled using pressure independent control algorithms and flow readings to be in CFM.

C. Program sequences stored on board application controller in EEPROM. No batteries needed to retain logic program. Program sequences executed by controller 10 times per second and capable of multiple PI loops for control of multiple devices. Provide programming of application controller completely modifiable in the field over installed specified protocol LANs or remotely via modem interface. Operator to program logic sequences by graphically moving function blocks on screen and tying blocks together on screen. Application controller programmed using the same programming tool as Building Controller and as described in Operator Workstation article.

D. Application controller to include support for intelligent room sensor. Display on room sensor programmable at application controller and include an operating mode and a field service mode. Button functions and display data programmable to show specific controller data in each mode based on which button is pressed on the sensor. See sequence for specific display requirements for intelligent room sensor.

E. Provide duct temperature sensor at discharge of each terminal unit that is connected to controller for reporting back to operator workstation. Provide analog inputs for the duct temperatures.

2.11 INPUT/OUTPUT INTERFACE

A. Input/output points protected such that shorting of point to itself, to another point, or to ground will cause no damage to controller. Input and output points protected from voltage up to 24 V.

B. Binary inputs (BI or DI) allow monitoring of On/Off signals from remote devices. Binary inputs sense “dry contact” closure without external power (other than that provided by controller) being applied.

C. Pulse accumulation input objects accept up to 10 pulses per second for pulse accumulation.

D. Analog inputs (AI) allow monitoring of low-voltage (0 to 10 VDC), current (4 to 20 mA), or resistance signals (thermistor, RTD).

E. Binary outputs (BO or DO) provide for On/Off operation or pulsed low-voltage signal for pulse width modulation control. Binary outputs on building and custom application controllers have three-position (On/Off/Auto) override switches and status lights. Outputs selectable for either normally open or normally closed operation.

F. Analog outputs (AO)provide a modulating signal for control of end devices. Outputs provide either a 0 to 10 VDC or a 4 to 20 mA signal as required to provide proper control of the output device. Analog outputs on building controllers have status lights and two-position (AUTO/MANUAL) switch and adjustable potentiometer for manual override. Analog outputs not exhibit drift of greater than 0.4 percent of range per year.

G. Tri-State Outputs. Provide tri-state outputs (two coordinated binary outputs) for control of three-point floating type electronic actuators without feedback. Use of three-point floating devices limited to zone control and terminal unit control applications (VAV terminal units, duct-mounted

heating coils, zone dampers, radiation, etc.). Control algorithms run zone actuator to one end of its stroke once every 24 hours for verification of operator tracking.

2.12 POWER SUPPLIES AND LINE FILTERING

A. Control transformers UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in both primary and secondary circuits. Limit connected loads to 80 percent of rated capacity.

B. DC power supply output match output current and voltage requirements. Unit operates between 32 degrees F and 120 degrees F.

C. Line voltage units UL listed and CSA approved.

D. Power line filtering. Provide transient voltage and surge suppression for workstations and controllers.

2.13 CONTROL PANELS

A. Control Panels:
   1. Enclosures may be NEMA 1 when located in a clean, dry, indoor environment. Indoor enclosures to be NEMA 12 when installed in other than a clean environment. Outdoor enclosures must be NEMA 3R. Provide (hinged door) key-lock latch and removable subpanels. Single key common to field panels and subpanels. In existing campus or building settings, key lock to match existing keys.
   2. Interconnections between internal and face-mounted devices prewired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections UL listed for 600 volt service, individually identified per control/ interlock drawings, with adequate clearance for field wiring. Control terminations for field connection individually identified per control drawings.
   3. Provide ON/OFF power switch with overcurrent protection for control power sources to each local panel.
   4. Provide laminated plastic nameplates for enclosures in any mechanical room or electrical room labeled with TCP number. Laminated plastic to be 1/8-inch thick sized appropriately to make label easy to read.

2.14 AUXILIARY CONTROL DEVICES

A. Temperature Instruments:
   1. Low-voltage or Line-voltage Thermostats: Bimetal-actuated, snap acting SPDT contact, enclosed, UL listed for electrical rating, exposed setpoint adjustment on cover with heat anticipator. Thermostat operates within 55 degrees F to 85 degrees F setpoint range, with 2 degrees F maximum differential.
   2. Room Temperature Sensor: Thermistor or platinum RTD type with accuracy of plus or minus 0.5 degrees F at 70 degrees F; operating range 30-120 degrees F; linear signal; single point sensing element in wall-mounted ventilated enclosure with insulating back plate if mounted on exterior wall; push button for occupancy override; digital setpoint adjustment plus or minus 2 degrees F in both directions; LCD temperature display indicating setpoint only. Setpoint adjustment to revert to building programmed standard temperature upon next building occupancy schedule change (user adjustable). Room temperature sensor may have integral space carbon dioxide sensor with minimum performance characteristics identified within this specification.

3. Averaging Duct Temperature Sensors: Thermistor or platinum RTD element with accuracy of plus or minus 0.5 degrees F at 32 degrees F, consisting of array of single point sensing elements, securely mounted in duct or plenum; operating range 20-120 degrees F; linear signal; 1-foot element per 2 SF of duct cross-sectional area. Use when duct is 9 SF or larger or where air is subject to temperature stratification.
4. Probe Duct Temperature Sensors: Thermistor or platinum RTD element with accuracy of plus or minus 0.5 degrees F at 32 degrees F, consisting of single point sensing elements, securely mounted in duct or plenum; operating range 20-120 degrees F; linear signal; 24-inch rigid probe. Use where duct is less than 9 SF cross-sectional area.
5. Outside Air Temperature Sensor: Thermistor or platinum RTD element with accuracy of plus or minus 0.5 degrees F at 32 degrees F; Range -58 to 120 degrees F, single element, linear, with weather and sun shield for exterior mounting.
6. Low Temperature Limit Thermostat: Minimum 20 foot capillary sensing element, triggering on low temperature as sensed by any 12-inch segment; snap acting, normally open contacts, manual reset, line voltage.
7. Liquid Immersion Temperature Sensor: Thermistor or platinum RTD element, with accuracy of plus or minus 0.5 degrees F at 32 degrees F, stainless steel well and assembly, range 30 to 250 degrees F.

B. Humidity Sensors:
1. Space Humidity Sensors: Operating range 10 to 95 percent relative humidity, accuracy plus or minus percent RH, surface mounted ventilated enclosure for wall mounting.
2. Duct Humidity Transmitter: Capacitive type sensor and transmitter, linear output signal; automatic temperature compensating; air filter; plus or minus 2 percent RH accuracy from 0 to 100 percent RH.
3. Humidity sensor's drift not exceed 1 percent of full scale per year.

C. Dewpoint Transmitter:
1. Uninterrupted, accurate and stable dewpoint measurement in condensing environments. Provide with integral temperature sensor.
2. Calculate:
    a. Relative Humidity
    b. Absolute Humidity
    c. Difference between ambient and dewpoint temperature.
    d. Mixing Ratio of Air
    e. Wet Bulb Temperature of Air
3. Provide hand held field calibration.
4. Provide with local display and connection to BAS (analog output signal from device to BAS 4-20 mA signal).
5. Dust and Chemical Resistant
6. NEMA 4 Housing
7. NIST Traceable with Certificate
8. Specifications:
    a. Dewpoint Measurement Range:-40 degrees F to 212 degrees F
    b. Response Time: 15 seconds
    c. Temperature Measurement Range:40 degrees F to 356 degrees F
    d. Accuracy: 0.18 degrees F
    e. Typical Ranges:
        1) Relative Humidity: 0 to 100 percent
        2) Dewpoint Difference: 0 to 90 degrees F
        3) Mixing Ration: 0 to 3500 gr/lb
        4) Absolute Humidity: 0 to 262 gr/ft^3
        5) Wet Bulb Temperature: 32 degrees F to 212 degrees F
9. Manufacturers:

a. Vaisala HMP243 with HMK41 field calibrator.
b. Or approved Equivalent.

D. Pressure Transmitters and Transducers:
1. Transducer have linear output signal; field adjustable zero and span. Sensing elements withstand continuous operating conditions of positive or negative pressure 50 percent greater than calibrated span without damage.
2. Differential Pressure Switch: Setpoint adjustable with operating range of 0.5 to 12-inch WG for fans, and 5 to 30-feet WC for pumps. Switches UL listed; SPDT snap-acting; pilot duty rated (125 VA minimum); NEMA 1 enclosure; scale range and differential suitable for intended application.
3. Filter Differential Pressure Switch: Setpoint adjustable with operating range of 0.1 to 5-inch WG; auto reset. Contactor to close when pressure differential setting is met or exceeded. Provide mounting bracket, metallic tubing and appropriate fittings for connection to duct or air-handling unit.
4. Duct Static Differential Pressure Transducer: Operating range 0 to 5-inch WC for duct mounted transmitter; ceramic capacitive sensing element with probe securely mounted in duct; digital input terminal and push button to zero output. Accuracy plus or minus 1 percent of full scale; maximum response time 2 seconds.
5. Building Static Pressure Transducer: Operating range of -0.1 to 0.1-inch WC, linear signal. Sensing tubes located inside and outside building use shielding and/or surge tanks to minimize effects of wind. Accuracy plus or minus 1 percent of full scale.
6. Piping Pressure Transmitter: Operating range 0 to 50 PSIG, linear signal; stainless steel diaphragm; digital input terminal and push button to zero output. Accuracy plus or minus 1 percent of full scale.

E. Motorized Control Dampers:
1. Performance: Maximum leakage of 3 CFM/SF at 1-inch WG differential pressure, AMCA Class 1A, maximum pressure rating of 13-inch WG differential pressure, maximum velocity of 6,000 fpm, -72 degrees F to 275 degrees F temperature rating.
2. Multi-blade type, except where either dimension is less than 10-inch single blade may be used. Maximum blade length to be 48-inch.
3. Provide parallel blades for modulating mixing service and opposed blades for throttling service.
4. Blades to be interlocking; minimum 16 gauge galvanized steel; compression type edge seals and side seating stops. In copper, aluminum and stainless steel duct work, damper material matches duct work material.
5. Damper blades are reinforced, have continuous full length axle shafts, axle to axle linkage, and/or operating “jackshafts” as required to provide coordinated tracking of blades.
6. Bearings: Self-lubricating stainless steel sleeve or Celcon bearing.
7. Dampers over 25 SF in area to be in two or more sections, with interconnected blades.
8. Provide remote damper blade position status with binary input.
9. Tested in accordance with AMCA Standard No. 500.

F. Motorized Control Valves:
1. Body pressure rating and connection type construction conforms to pipe, fitting and valve schedules.
2. Fluid valve close-off ratings and spring ranges operate at maximum flows and maximum available pump heads scheduled without leakage.
3. Screwed ends except 2-1/2-inch and larger valves with flanged ends.
4. Steam valve close-off ratings operates at 150 percent of steam pressure without leakage.
5. Motorized Control Valves (Pressure Independent Control Valves):

a. Description: Valve consists of pressure compensating cartridge, actuated ball or Y pattern globe valve, and multiple pressure/temperature test ports in a single valve housing.
b. Construction: Rated for no less than 125 PSI and 250 degrees F. 2-inch and Smaller: brass with threaded connections. 2-1/2-inch and larger: cast iron with flanged connections.
c. Performance: Flow rate controlled linearly to within 5 percent of target flow rate, for any actuator position (0 to 100 percent), over an operating differential pressure range of 6 to 50 PSI across the valve. Provide valve with integral test ports to verify pressure differential.
d. Manufacturers: Belimo, Danfoss, Flow Control Industries, Griswold, Tour and Andersson or approved equivalent.

6. Fluid three-way valves globe valves with linear plug with composition disc for tight shutoff.
7. Pressure drop equal to twice pressure drop through heat exchanger (load), 50 percent of pressure difference between supply and return mains, or 5 PSI, whichever is greater, except two-position valves to be line size.
8. Bubble-tight line size butterfly valves acceptable on 2-1/2-inch lines and above for two-position action only; cast iron body; aluminum bronze disc; EPDM seat, 200 PSI wg
9. Steam Valves: Body and trim materials in accordance with manufacturer's recommendations for design conditions and service with linear ports for modulating service. Sizing Criteria:
   a. Two-Position Service: Pressure drop 10 percent to 20 percent of inlet PSIG.
   b. Modulating Service: 15 PSIG or less; pressure drop 80 percent of inlet PSIG.

G. Electric Damper/Valve Actuators:
1. Provide mechanical or electronic stall protection for each actuator.
2. Where indicated provide internal mechanical, spring-return mechanism or provide uninterruptible power supply (UPS). Non-spring-return actuators have external manual gear release to position damper/valve when actuator is not powered.
3. Proportional actuators accepts 0 to 10 VDC or 0 to 20 mA control signal and provide 2 to 10 VDC or 4 to 20 mA operating range.
4. Actuator sized for torque required plus 25 percent; UL or CSA listed; electronic current overload protection.
5. VAV Actuators: Actuators proportional 24 VAC actuators using a 4 to 20 mA range of control signals; stops automatically at end of travel; include permanently lubricated gear train.

H. Water Flow Meter:
1. Provide a Turbine Flow Meter (reference 23 05 19) complete with installation hardware necessary to enable insertion and removal of the meter without system shutdown. The flow meter hand-insertable up to 400 PSI. The flow meter to have two contra-rotating axial turbines, with electronic impedance-based sensing and an averaging circuit to reduce measurement errors due to swirl and flow profile distortion. Wetted metal components nickel-plated brass. Provide 316L SS construction for hot water applications operating over 250 degrees F, and for any application in non-metallic pipe. The maximum operating temperature 280 degrees F, 300 degrees F peak. Each flow meter individually wet-calibrated against a primary volumetric standard that is accurate to within 0.1 percent and traceable to NIST*. Manufacturer's certificate of calibration provided with each flow meter. Accuracy within plus or minus 0.5 percent of rate at the calibrated velocity, within plus or minus 1 percent of rate over a 10:1 turndown (3.0 to 30 ft/s) and within plus or minus 2 percent of rate over a 50:1 turndown (from 0.4 to 20 ft/s). The flow meter to include integral analog output(s), 4-20 mA, 0-10V, or 0-5V. Bi-directional meters to include an isolated contact closure output for direction. Flow meter covered by the manufacturer's two year warranty.

I. Room Pressure Monitor: Active room pressure monitor and alarm which provides local audio alarm and analog and alarm signals to DDC system. Wall mounted panel with LED differential pressure readout; audible and visual alarm; mute button; range of -0.05 to +0.05-inch WC; accurate to 1 percent of full scale; repeatability plus or minus 1.0 percent of full scale per year, alarm delay ability between 0-30 seconds. Provide door switch to deactivate alarm when space door(s) are open. Input status from BAS to deactivate alarm in unoccupied or shutdown modes. Phoenix Controls APM100.

J. Wall Mounted Space Carbon Dioxide Sensor:
1. Sensor to employ non-dispersive infrared technology. (N.D.I.R.)
2. Sensor Repeatability: Plus or minus 20 ppm. 0-2000.
3. Sensor Accuracy: Less than or equal to 75 ppm over 0-1500 ppm range.
4. Sensor Response Time: Less than 1 minute.
5. Sensor to employ reference channel design for long-term stability.
6. Sensor to have field selectable 0-10VDC, or 4-20mA outputs.
7. Sensor power requirement less than 3W.
8. Sensor Input Voltage: 20 to 30VAC/DC.
9. Sensor Operating Temperature Range: 0 degrees C to 50 degrees C.
10. Sensor to have models for wall mounting or duct mounting.
11. Sensor to provide at least a 1-year factory warranty from date of purchase.
12. Sensor to match cover in color and look to temperature sensor.
13. Sensor to have display.
14. Manufacturers:
    a. Telaire
    b. Vaisala
    c. Veris

K. Paddle Type Flow Switches: Paddle type switches (water service only) UL listed, SPDT snap-acting with pilot duty rating (125 VA minimum) and have adjustable sensitivity with NEMA 1 enclosure.

L. Relays:
1. Control relays UL listed plug-in type with dust cover and LED “energized” indicator. Contact rating, configuration, and coil voltage to be suitable for application.
2. Time delay relays UL listed solid-state plug-in type with adjustable time delay. Delay adjustable plus or minus 200 percent (minimum) from setpoint or as indicated. Contact rating, configuration, and coil voltage to be suitable for application. Provide NEMA 1 enclosure when not installed in local control panel.

M. Override Timers: Override timers spring-wound line voltage, UL Listed, with contact rating and configuration as required by application. Provide 0-to-6-hour calibrated dial unless otherwise specified. Timer suitable for flush mounting on control panel face and located on local control panels or where shown.

N. Current Transmitters:
1. AC current transmitters are self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4 to 20 mA two-wire output. Unit range compatible with actual applied span of current value, with internal zero and span adjustment and plus or minus 1 percent full-scale accuracy at 500 ohm maximum burden.
2. Transmitter meets or exceeds ANSI/ISA S50.1 requirements and UL/CSA recognized.
3. Unit split-core type for clamp-on installation on existing wiring.

O. Current Transformers: AC current transformers UL/CSA recognized and completely encased (except for terminals) in approved plastic material; plus or minus 1 percent accuracy at 5 A full-scale.

P. Voltage Transmitters: AC voltage; self-powered single-loop (two-wire) type; 4 to 20 mA output with zero and span adjustment; UL/CSA recognized at 600 VAC rating and meet or exceed ANSI/ISA S50.1. Ranges include 100 to 130 VAC, 200 to 250 VAC, 250 to 330 VAC, and 400 to 600 VAC full-scale, adjustable, with plus or minus 1 percent full-scale accuracy with 500 ohm maximum burden.

Q. Voltage Transformers: AC voltage transformers UL/CSA recognized, 600 VAC rated; built-in fuse protection; suitable for ambient temperatures of 40 degrees F to 130 degrees F; plus or minus 0.5 percent accuracy at 24 VAC and a 5 VA load.

R. Power Monitors: Selectable rate pulse output for kWh reading; 4-20 mA output for kW reading; N.O. alarm contact; ability to operate with 5.0 amp current inputs or 0-0.33 volt inputs; plus 1.0 percent full-scale true RMS power accuracy; plus 0.5 Hz, voltage input range 120-600 V, and auto range select; NEMA 1 enclosure. Current transformers having a 0.5 percent FS accuracy, 600 VAC isolation voltage with 0-0.33 V output. If 0-5 A current transformers are provided, a three-phase disconnect/shorting switch assembly is required.

S. Overflow Switch: Insertion flow sensor, brass, impeller flow design with analog transmitter unit. Data Industrial Model 220BR.

T. Ultrasonic Level Transmitter: Non-contact measuring device for liquid level; distance ranges from 4-feet to 32-feet; fail-safe intelligence with diagnostic feedback for troubleshooting; automatic temperature compensation; 24VDC; accuracy plus 0.15 percent of span in air. Kele LU Series.

U. End Switches: Turret head Type SPDT. Schneider Electric/Square D Class 9007, Type C54B2, or equal.

V. Condensation Sensor:
   1. Passive condensation sensor which will reliably and instantly indicate that condensation is occurring.
   2. Sensor to be able to indicate condensation prior to the condensation being visually perceptible and to last as long as any trace of condensation remains on the surface.
   3. Manufactured specifically for radiant cooling applications.
   4. Not dependent on dew point, humidity, or temperature determinations.
   5. Specifications (Based on Condenser):
      a. Mounting:
         1) The Model C condenser is mounted via its #8-32 x 3/8-inch non-metallic stud, nut and washer.
         2) A Pipe Adapter (Model PA-3) is available for mounting any condenser to a 1/8-inch to 3-inch OD pipe.
      b. Dimensions: Model C - Nom. 1.1-inch square footprint X 0.8-inch H from the mounting surface.
      c. Connection: Its 3 foot long cable is terminated in a MONO audio phone plug (1/8-inch / 3.5 mm for the Model C). Provide extensions to suit field conditions.
      d. Operating Temperatures: 5 to 70 degrees C.
      e. Humidity: Not a factor.
      f. Contaminants: Inert to materials other than plastic solvents. If it becomes contaminated with dust or other debris, typically, it is easily cleaned by flushing it with alcohol to restore it to service. Require no calibration.

g. Provide circuit module to provide binary input to the EMS/BAS with a "SENSOR FAULT."

6. Manufacturers:
   a. Model CG-ICM, no known equal.
   b. Or approved equivalent.

W. Wind Speed Sensor:
1. Low starting threshold.
2. Solid state light source and electronics.
3. Low profile to minimize “Sensor Turbulence.”
4. Calibrated to NIST secondary standard.
5. Quick-disconnect connector.
6. Internal heater for long bearing life.
7. Built-in electrical field surge protection.
8. Performance Characteristics:
   a. Maximum Operating Range: 0-125 mph (0-60 m/s).
   b. Starting Speed: 0.5 mph (0.22 m/s).
   c. Calibrated Range: 0-99 mph (0-50 m/s).
   d. Accuracy: Plus or minus 1 percent (0.15 mph).
   e. Temperature Range: -50 degrees C to 67 degrees C.
   f. Response: Distant constant less than 5-feet of flow.
9. Electrical Characteristics:
   a. Power Requirements: 12 VDC at 10 mA.
   b. Output Signal: 11 volt pulse.
   c. Output Impedance: 100 ohms maximum.
10. Physical Characteristics:
    a. Weight: 1.5 pounds (.68 kilogram).
    b. Finish: Anodized Aluminum.
    c. Mounting Fixtures: PN 191 Crossarm Assembly.
11. Accessories:
    a. PN 1953 Cable Assembly, vinyl jacketed shielded cable.
    b. Aluminum Cup Assembly, distance constant - 15-feet.
12. Manufacturers:
    a. Met One Instruments, Inc. - 010C
    b. Nova Lynx
    c. Or approved equivalent

X. Wind Direction Sensor:
1. Airfoil shaped polyurethane van assembly.
2. Components: Stainless steel.
3. Electrical Components: Field replaceable without requiring recalibration.
4. Single potentiometer for either 360 degree or 540 degree applications.
5. Low profile to minimize sensor turbulence.
6. High damping ratio.
7. Short relay distance.
8. Orientation lock.
9. Quick disconnect connector.
10. Internal heater for long bearing life.
11. Wind direction translator module.
12. Electrical field surge protection.
13. Performance Characteristics:
    a. Azimuth: Electrical - 0-357 degrees
    b. Azimuth: Mechanical - 0-360 degrees

c. Threshold: 0.5 mph
d. Linearity: Plus or minus 1/2 percent of full scale
e. Damping ratio: 0.25
f. Delay distance: Less than 3-feet.
g. Accuracy: Plus or minus 3 degrees
h. Temperature Range: -50 degrees C to 65 degrees C

14. Electrical Characteristics:
    a. Power Requirements: 12 VDC at 10 mA, 12 VDC at 350 mA for heater
    b. Output Signal: 0-5V volt
    c. Output Impedance: 100 ohms maximum
15. Physical Characteristics:
    a. Weight: 1.5 pounds (.68 kilogram)
    b. Finish: Anodized Aluminum
    c. Mounting Fixtures: PN 191 Crossarm Assembly
16. Accessories: PN 1953 Cable Assembly, vinyl jacketed shielded cable.
17. Manufacturers:
    a. Met One Instruments, Inc. - 010C
    b. Nova Lynx.
    c. Or approved equivalent.

Y. Rain Sensor:
1. Sensor is to be used to detect the onset of rainfall. A gold plated grid sensor activates the circuit when water is deposited onto the grid. The presence of water activates an internal relay that may be used in a Building Automation System.
2. An internal heater constantly dries the grid to prevent relay activation during times of dew, fog, or light moisture that is not actual precipitation. During periods of normal precipitation the heater is unable to dry the grid and the relay is activated. The heater power may be disconnected allowing the detector to be operated as a leaf wetness sensor.
3. The solid state electronics are mounted in a sealed weatherproof enclosure. The precipitation detector may be tilted to allow water to drain off. A mounting bracket is provided with the sensor to allow mounting onto a 1-inch pipe by a U-bolt. The wind screen must be used to prevent premature drying of the grid during precipitation events accompanied by high winds.
4. The unit requires plus 12 Vdc power for operation. A 115 Vac power adapter is provided with each unit. Power adapters for voltages other than 115 Vac are available upon request.
5. Specifications:
    a. Sensor: Gold plated grid 4-inch diameter.
    b. Output: Relay (0.5 amps).
    c. Heater: Resistive element.
    d. Power: 12 Vdc (235 mA max.) 115 Vac 60 Hz adapter supplied.
    e. Size: Overall 4-inch diameter x 2-inch high.
    f. Weight/Shipping: 4 lbs/5 lbs (1.8 Kg/2.3 Kg).
6. Manufacturers:
    a. NovaLynx Model 260-2590 Precipitation Detector
    b. Or approved equivalent.

2.15 WIRING AND RACEWAYS

A. General: Provide copper wiring, plenum cable, and raceways as specified in applicable Sections of Division 26, Electrical.

B. Insulated wire to be copper conductors, UL labeled for 90 degrees C minimum service.

C. Field panels and controllers to be supplied by building emergency power system where systems being monitored or controlled are on emergency power.

D. Run control wiring as follows:
1. Mechanical Rooms: In conduit.
2. Exposed in Building Spaces: In conduit.
3. Concealed in Building Walls and Ceilings: Plenum rated cable.
4. Concealed in Building Ceilings: Plenum rated cable in cable tray.

E. Field and Subfield Panels: Voltage in panels not-to-exceed 120 volts.

F. Motor Control Centers: Responsibility for correct voltage of holding coils and starter wiring in pre-wired motor control centers interfacing with automatic controls is included hereunder.

G. Wiring for BAS systems communications buses two conductor minimum 18 gauge foil-shielded, stranded twisted pair cable rated at 300 VDC or more than 80 degrees C.

2.16 SMOKE DETECTION (FOR PROJECTS WITH A FIRE ALARM SYSTEM)

A. See Division 28 for Products.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Prior to starting work, carefully inspect installed work of other trades and verify that such work is complete to the point where work of this Section may properly commence.

B. Notify the Owner's Authorized Representative in writing of conditions detrimental to the proper and timely completion of the work.

C. Do not begin work until unsatisfactory conditions are resolved.

3.2 CONTROL SYSTEM CHECKOUT AND TESTING

A. Testing completed before Owner's Authorized Representative is notified of system demonstration.

B. Calibrate and prepare for service of instruments, controls, and accessory equipment furnished under this specification.

C. Verify that control wiring is properly connected and free of shorts and ground faults.

D. Enable control systems and verify calibration and operation of input and output devices.

E. Verify that system operation adheres to sequences of operation.

F. Commissioning and Verification: In addition to commissioning requirements specified elsewhere, provide the following commissioning on the HVAC instrumentation and controls system:
1. Control systems completely commissioned to ensure aspects of the system are operating as intended and at optimum tuning.

2. Wiring connections verified and traced from field device to panel to ensure proper connections.
3. Measured values verified by a hand held calibrated device to validate that value indicated by the control system is in fact the actual measured value.
4. Loops properly tuned to obtain the desired control value. Each loop to be "upset" and put back in control to demonstrate its ability to stabilize quickly.
5. Provide a final point-by-point report submitted that indicates the date of each verification, the results, and initialed on each page by the person performing the reading.

3.3 ACCEPTANCE TESTING AND TRAINING

A. Site Testing:
1. Contractor provides personnel, equipment, instrumentation, and supplies necessary to perform testing. Owner or Owner's Authorized Representative will witness and sign off on acceptance testing.
2. Contractor demonstrates compliance of completed control system with Contract Documents. Using approved test plan, physical and functional requirements of project demonstrated.

B. Training:
1. General: Contractor conducts training courses for up to three other designated personnel in operation and maintenance of system. Training manuals provided for each trainee, with two additional copies provided for archival at project site. Manuals include detailed description of subject matter for each lesson. Copies of audiovisuals delivered to Owner. Training day is defined as 8 hours of classroom instruction, including two 15-minute breaks and excluding lunch time, Monday through Friday, during normal first shift in effect at training facility. Notification of any planned training given to Owner's Authorized Representative at least 15 days prior to training.
2. Operator's Training I: First course taught at supplier's facility for period of one training day. Upon completion, each student should be able to perform elementary operations with guidance and describe general hardware architecture and functionality of system.
3. Operator's Training II: Second course taught at project site for a period of one training day after completion of contractor's field testing. Course includes instruction on specific hardware configuration of installed system and specific instructions for operating installed system. Upon completion, each student should be able to start system, operate the system, recover system after failure, and describe specific hardware architecture and operation of system.
4. Operator's Training III: Third course taught at project site for period of one training day no later than six months after completion of the acceptance test. Course will be structured to address specific topics that students need to discuss and to answer questions concerning operation of system. Upon completion, students should be fully proficient in system operation and have no unanswered questions regarding operation of installed system.

3.4 WIRING

A. Provide electrical wiring required to control systems specified in this Section. Control and interlock wiring complies with national, state and local electrical codes and Division 26, Electrical of this specification.

B. Power wiring required for building control panel(s) to be dedicated circuit(s).

C. Verify location of operator work station with Owner prior to installation.

D. NEC Class 1 (line voltage) wiring UL Listed in approved raceway according to NEC and Division 26, Electrical requirements.

E. Low-voltage wiring meets NEC Class 2 requirements. (Low-voltage power circuits subfused when required to meet Class 2 current limit.)

F. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL listed for intended application.

G. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for purpose of interfacing (e.g., relays and transformers).

H. Where Class 2 wiring is run exposed, wiring run parallel along surface or perpendicular to it and tied at 10 foot intervals.

I. Where plenum cables are used without raceway, support from structural members. Do not support cables with ductwork, electrical raceways, piping, or ceiling suspension systems.

J. Make wire-to-device connections at terminal block or terminal strip. Make wire-to-wire connections at terminal block.

K. Maximum allowable voltage for control wiring 24 V. If only higher voltages are available, provide step-down transformers.

L. Wiring installed as continuous lengths, with no splices permitted between termination points.

M. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at penetrations.

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

O. Control and status relays are to be located in designated enclosures. Enclosures include packaged equipment control panels unless they also contain Class 1 starters.

P. Install raceway to maintain a minimum clearance of 6-inches from high-temperature equipment (e.g., steam pipes or flues).

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

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

S. Flexible metal raceways and liquid-tight, flexible metal raceways not-to-exceed 3-feet in length and be supported at each end. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways to be used.

T. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections joined with couplings. Terminations made with fittings at boxes.

U. Input and output terminations to be labeled at the controller to identify if they are AI, DI, AO, DO, and function (i.e. pump start, OM Sensor).

3.5 COMMUNICATION WIRING

A. Follow manufacturer's installation recommendations for communication cabling.

B. Verify integrity of network following cable installation.

C. Communication wiring unspliced length when that length is commercially available; labeled to indicate origination and destination data.

D. Grounding of coaxial cable in accordance with NEC regulations article on “Communications Circuits, Cable, and Protector Grounding.”

3.6 INSTALLATION OF AUXILIARY CONTROL DEVICES

A. General:
1. Install sensors and thermostats in accordance with manufacturer's recommendations.
2. Room sensors and thermostats installed at 48-inches AFF to midline of sensor on concealed junction boxes properly supported by wall framing at the locations shown on the Drawings.
3. Low-limit sensors used in mixing plenums installed in a serpentine manner horizontally across duct.
4. Pipe-mounted temperature sensors installed in wells with heat-conducting fluid in thermal wells.
5. Install outdoor air temperature sensors on north facing wall or screen, complete with sun shield at designated location.

B. Flow Switch: Use correct paddle for pipe diameter. Adjust flow switch in accordance with manufacturer's instructions.

C. Actuators:
1. General:
   a. Mount and link control damper actuators according to manufacturer's instructions.
   b. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
2. Actuator Mounting for Damper and Valve Arrangements to Comply with the Following:
   a. Damper Actuators: Do not install in the air stream.
   b. Use a weather proof enclosure (clear and see through) if actuators are located outside.
   c. Damper or valve actuator ambient temperature not-to-exceed 122 degrees F through any combination of medium temperature or surrounding air. Provide appropriate air gaps, thermal isolation washers or spacers, standoff legs, or insulation as necessary. Mount per manufacturer's recommendations.
   d. Actuator cords or conduit to incorporate a drip leg if condensation is possible. Do not allow water to contact actuator or internal parts. Location of conduits in temperatures dropping below dew point to be avoided to prevent water from condensing in conduit and running into actuator.
   e. Damper mounting arrangements to comply with the following:
      1) Furnish and install damper channel supports and sheet metal collars.
      2) Jack shafting of damper sections not allowed.

3) Multi-section dampers arranged so that each damper section operates individually. Provide one electronic actuator direct shaft mounted per section.

f. Size damper sections based on actuator manufacturers specific recommendations for face velocity, differential pressure and damper type. In general: Damper section not-to-exceed 24 ft-sq. with face velocity 1500 FPM.

g. Multiple section dampers of two or more arranged to allow actuators to be direct shaft mounted on the outside of the duct.

h. Multiple section dampers of three or more sections wide arranged with a 3-sided vertical channel (8-inch wide by 6-inch deep) within the duct or fan housing and between adjacent damper sections. Vertical channel anchored at the top and bottom to the fan housing or building structure for support. Connect sides of each damper frame to the channels. Holes in the channel to allow damper drive blade shafts to pass through channel for direct shaft mounting of actuators. Face open side of channel downstream of the airflow, except for exhaust air dampers.

i. Multiple section dampers to be mounted flush within a wall or housing opening to receive either vertical channel supports as described above or sheet metal standout collars. Sheet metal collars (12-inch minimum) to bring each damper section out of the wall to allow direct shaft mounting of the actuator on the side of the collar.

D. Control Valve:

1. Valves installed in accordance with manufacturer's recommendations.
2. Slip-stem control valves installed so that stem position is not more than 60 degrees from vertical up position. Ball type control valves installed with stem in horizontal position.
3. Control valves accessible and serviceable.
4. Install isolation valves so that control valve may be serviced without draining supply/return side piping system. Install unions at connections to screw-type control valves.
5. Valve Sizing for Water Coil:
   a. On/Off Control Valves: Line size.
   b. Modulating control valve body size may be reduced, at most, two pipe sizes from the line size or not less than 1/2 the pipe size. BAS contractor to size water coil control valves for the application as follows:
      1) Booster-heat valves sized not-to-exceed 4-9 PSI differential pressure. Size valve for 50 percent valve authority. Valve design pressure drop is equal to the sum of coil drop plus the balance valve drop.
      2) Primary valves sized not-to-exceed 5-15 PSI differential pressure. Size valve for 50 percent valve authority. Valve design pressure drop is equal to the sum of coil drop plus the balance valve drop.
      3) Butterfly valves sized for modulating service at 60 to 70 degree rotation. Design velocity 12-feet per second or less when used with standard EPDM seats.
   c. Valve Mounting Arrangements to Comply with the Following:
      1) Provide unions on ports of two-way and three-way valves.
      2) Install three-way equal percentage Characterized Control valves in a mixing configuration with the “A” port piped to the coil.
      3) Install 2-1/2-inch and above, three-way globe valves, as manufactured for mixing or diverting service to the coil.

E. Control Damper:

1. Dampers installed in accordance with manufacturer's instructions. Unless specifically designed for vertical blade application, dampers must be mounted with blade axis horizontal.
2. After installation of low-leakage dampers with seals, caulk between frame and duct or opening to prevent leakage around perimeter of damper.

F. Air Flow Station: Install where indicated in ductwork and/or equipment with manufacturer's recommended straight ductwork upstream and downstream of air flow station or as shown on drawings, whichever is greater. Where equipment manufacturer's standard airflow measuring station cannot read airflows at required design velocities, provide appropriate air flow measuring station to provide accurate reading throughout system design operations range.

3.7 SMOKE DETECTION (FOR PROJECTS WITH A FIRE ALARM SYSTEM)

A. Smoke detector furnished and powered/wired under Division 28, Electronic Safety and Security. Coordinate with fire alarm equipment supplier. Installation of duct smoke detector housing and sampling tube under Division 23, HVAC.

B. Install smoke detectors in supply air systems greater than 2000 CFM.

3.8 SEQUENCES OF OPERATION AND POINTS LISTS

A. Where local energy code dictates certain sequences (such as night setback, night flush, pressure and temperature reset, terminal unit sequences, etc.), the sequences are not necessarily repeated in the documents. It is not the intent of this specification or documentation to reiterate the energy code. Provide energy code mandated sequences and document in sequence of operations submittals at no additional cost to the Owner. Provide required points to achieve the appropriate sequences.

B. See control diagrams and sequences on drawings.

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 to result in the VFD holding its last value. If the VFD is running its own PID loop and the external input to the VFD is a setpoint (e.g. duct static pressure setpoint), the VFD to hold the last setpoint. If the VFD loses its process variable (e.g. duct static pressure), the VFD to go to its minimum speed setting.

D. Except as specified otherwise, throttling ranges, proportional bands, and cycle differentials to be centered on the associated setpoint. Modulating feedback control loops to include the capability of having proportional, integral, and derivative action. Unless the loop is specified “proportional only” or “P+I”, Contractor to apply appropriate elements of integral and derivative gain to each control loop to result in stable operation, minimum settling time and maintain the primary variable within the specified maximum allowable variance.

E. Provide a real time clock and schedule controller with sufficient scheduling capability to schedule required controllers and sequences. Schedule functionality may reside in a controller. If a controller is used, document scheduling functionality including names and types on controller points list submittal. Set up initial schedules in coordination with Owner.

F. Scheduling Terminology: When air handlers are scheduled throughout the day, the following defines the terminology used:
   1. Occupied Period: Period of time when the building is in use and occupied. Confirm schedule with Owner. Exclude all national holidays. Generally systems will be fully operational throughout this period and ventilation air to be continuously introduced. Space temperature setpoints will generally be in the “normal” range of 68 degrees to 78 degrees F.
   2. Unoccupied period: Period of time when the building or zone is not in use and unoccupied. Ventilation air not to be introduced.
   3. Preoccupancy Period: 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 unless outside air conditions permit free-cooling or to support a pre-occupancy purge sequence. Time period to 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.

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

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

I. When a power failure is detected in any phase, the BAS start commands to be retracted immediately from electrically powered units served by the failed power source. If the associated controller is powered by normal or emergency power, it may monitor its own power source as an indication of power status. If the controller is powered by uninterruptible power supply (UPS), or if it is not capable of monitoring its own power for use in sequences, provide at least one voltage monitor (three phase when applicable) per building. When the BAS detects that normal or emergency power has been restored, all equipment for which the BAS start command had been retracted to be automatically restarted in an orderly manner on staggered 5 second intervals to minimize inrush current.

J. Where reset action is specified in a sequence of operation, but a reset schedule is not indicated on the drawings, employ one of the following methods:

1. Determine a fixed reset schedule to result in stable operation and maintain the primary variable within the specified maximum allowable variance.
2. Use a floating reset algorithm which increments the secondary variable setpoint (setpoint of control loop being reset) on a periodic basis to maintain primary variable setpoint. The recalculation time and reset increment to be chosen to maintain the primary variable within the specified maximum allowable variance.
3. Primary variable to control the devices directly using a PID feedback control loop without resetting the secondary variable. However, the control devices to still modulate as necessary to maintain upper and lower limits on the secondary variable. Proportional band, integral gain, and derivative term to be selected to maintain the primary variable within the specified maximum allowable tolerance while minimizing overshoot and settling time. Gain prior approval for implementing this method of reset.

K. Where a supply air temperature or duct pressure setpoint is specified to be reset by the space temperature of the zones calling for the most cooling/heating, employ the following method:

1. Use a floating reset algorithm which increments the secondary variable (e.g., supply air temperature or duct pressure) setpoint on a periodic basis to maintain primary variable (e.g., space temperature) setpoint. The reset increment to be determined by the quantity of “need heat” or “need cool” requests from individual SCU's. A SCU's “need heat” virtual point to activate whenever the zone's space temperature falls below the currently applicable (occupied or unoccupied) heating setpoint throttling range. A SCU's “need cool” virtual point to activate whenever the zone's space temperature rises above the currently applicable (occupied, unoccupied, or economy) cooling setpoint throttling range. The recalculation time and reset increment to be chosen to maintain the primary variable within the specified maximum allowable variance while minimizing overshoot and settling time. Reset range maximum and minimum values to limit the setpoint range.

L. Where a supply air temperature, duct pressure, or differential water pressure setpoint is specified to be reset by valve or damper position of the zone or zones calling for the most cooling/heating, the following method to be employed:
   1. A floating reset algorithm to be used which increments the secondary variable (e.g., supply air temperature, pipe or duct pressure) setpoint on a periodic basis to maintain primary variable (e.g., cooling valve, heating valve, damper position) setpoint of 85 percent open. The reset increment to be calculated based on the average position of the quantity of the worst (most open valve/damper) zone(s) as specified. The recalculation time, reset increment and control device position influence to be chosen to maintain the primal variable within the specified maximum allowable variance while overshoot and settling time. The BAS analog output value to be acceptable as indicating the position of the control device.
   2. Alternatively to continuously calculating the average of the quantity of worst valve/damper positions, a method similar to the one described above may be employed whereby the “need heat” or “need cool” virtual point to increment by one unit each time a zone's valve/damper position rises to greater than 95 percent. The quantity of “need heat” or “need cool” points to then be the basis for reset.

M. Where “prove operation” of a device (generally controlled by a digital output) is indicated in the sequence, it shall require that the BAS, 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, an alarm to be enunciated audibly. Upon failure, run command to be removed and the device to be locked out until the alarm is manually acknowledged unless specified otherwise.

N. BAS to provide for adjustable maximum rates of change for increasing and decreasing output from the following analog output points:
   1. Speed control of variable speed drives
   2. Control Reset Loop
   3. Valve Travel Limit

O. Wherever a value is indicated to be dependent on another value (i.e., setpoint plus 5 degrees F) BAS to 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 to be provided. One to store the parameter (5 degrees F), one to store the setpoint, and one to store the value which is the result of the equation.

P. Trend points as identified in the points list. Trends to be grouped system specific and setup in two-axis (x,y) graphical format that display object values relative to time. Setup trends to record data in 5 minute increments.

Q. Sequence of Operations for Air Handling Units
   1. Occupied Mode:
      a. General:
         1) Initiate occupied mode from BAS schedule.
         2) Open fire and smoke dampers in distribution ductwork. After 60 second delay start fans to allow fire and smoke dampers to open without causing duct damage.
         3) Fans run continuously.
         4) Open outdoor air damper or minimum outdoor air damper position and reset minimum outdoor air quantity to minimum Demand Control Ventilation (DCV) air quantity position where a DCV value is shown on Schedules.
   2. Economizer operation with Return Fan:

a. Implement the following, in sequence, to maintain unit's supply air temperature setpoint.
    1) Fully open outdoor air damper.
    2) Modulate return air damper.
    3) Modulate relief air damper in reverse of return air damper.

3. Economizer operation with Gravity Relief Damper
    a. Implement the following, in sequence, to maintain unit's supply air temperature setpoint.
        1) Open relief air damper, if motorized.
        2) Return air damper to be fully open.
        3) Modulate outdoor air damper until fully open.
        4) Modulate return air damper until fully closed.
4. Supply Air Temperature Control with Chilled Water Coil
    a. When outdoor air temperature is higher than return air temperature, disable economizer operation and modulate chilled water control valve to maintain supply air temperature setpoint.
    b. When outdoor air temperature is less than return air temperature, initiate economizer operation as first stage of cooling.
    c. As second stage of cooling modulate chilled water control valve.
    d. When outdoor air temperature is less than supply air temperature setpoint modulate heating hot water control valve to maintain supply air temperature set point.
    e. Supply air temperature setpoint to have 4 F deadband.
5. Supply Air Temperature Control for with Chilled Water Coil for 100 Percent Outdoor Air Units
    a. When supply air temperature is above setpoint, modulate chilled water control valve to maintain supply air temperature set point.
    b. When supply air temperature is below setpoint modulate heating hot water control valve to maintain supply air temperature set point.
    c. Supply air temperature setpoint to have 4 F deadband.
6. Supply Air Temperature Setpoint Reset
    a. When unit is enabled in occupied mode initially SAT setpoint set at 70 degrees F
    b. If any zone has a cooling demand above 10 percent set the SAT setpoint at 68 degrees F (adj).
    c. If the total number of zones with 100 percent cooling demand is greater than one reset the SAT setpoint down 1 degree F every five minutes (adj) to a minimum of 55 degrees F (adj).
    d. If the total number zones with 100 percent cooling demand is zero, then reset SAT setpoint up 1 degrees F every five minutes (adj) to a maximum of 68 degrees F.
    e. If the total number zones with a cooling demand greater than 10 percent is zero set the SAT setpoint at 70 degrees F (adj).
7. Fan Speed Control for Air Handling Units with VFDs
    a. Vary fan speed by the following methods, as applicable:
        1) Determine minimum fan speed in cooperation with the test and balance agent, with an initial speed of 20 percent of unit's peak design speed. Limit fan speed change 10 percent per minute (adj).
        2) For fans/ fan systems with one VFD, vary VFD frequency to maintain setpoint, with minimum speed as determined above.
        3) For fans/ fan systems with multiple VFDs including a standby VFD, vary frequency of non-standby VFDs in unison to maintain setpoint, with minimum speed as determined above. Shut down lag VFD when the speed of VFDs is at minimum, and turn on the lag VFD(s) when the speed of operating VFD(s) is at 85 percent of peak speed. On failure of lead VFD, shut down lead VFD and turn on lag VFD in sequence with standby VFD, via BMS and through hardwire connection between VFDs.

4) For units with multiple VFDs, without a standby VFD, vary the speed of VFDs in unison. Shut down lag VFD when the speed of VFDs is at minimum, and turn on the lag VFD(s) when the speed of operating VFD(s) is at 85 percent of peak speed or at failure of lead fan(s) or lead VFD. On failure of lead fan(s) or lead VFD shut down lead VFD and start lag VFD through hardwire connection between VFDs.
5) For units with multiple fans with ECM motors, vary the speed of motors in unison to maintain setpoint, and maintain minimum speed as determined above. Shut down fan(s) in sequence when fan(s') speed is less than 20 percent above fan(s') minimum speed. Start fan(s) in sequence when the speed of operating fan(s) is at or above 85 percent of peak speed. On failure of individual fans as determined by each fan's dry contact, start a lag fan and standby fan, in sequence, as applicable.
6) Display total air quantity delivered by fans with ECM motors, at the unit's graphic display screen, and provide additional screens/tables to display air quantity of all fans in an air handling unit with multiple fans with ECM motors.

8. Medium Pressure Supply Air Duct Static Pressure Setpoint Reset
   a. Reset supply air duct static pressure setpoint between 0.15-inch (adj) and scheduled maximum unit ESP (adj), using Trim and Respond logic in conjunction with terminal units' pressure requests, with the high static pressure setpoint determined in cooperation with test and balance agent.
   b. Provide a means to automatically identify rogue zones and eliminate them from the logic by assigning an Importance Factor of zero. Rogue Zones are zones with Cumulative-Request-Hours of greater than 70 percent, with Cumulative-Request-Hours, expressed as a percentage, defined as:
      1) Zone Request Hours divided by the zone run-hours.
      2) Zone run-hours is defined as hours in any Mode other than Unoccupied Mode since the last reset.
   c. Provide trending of individual zone's damper position, pressure request, and Cumulative-Percent-Request-Hours.
   d. When unit is enabled in any mode, set initial supply air static pressure setpoint at 0.5-inch (adj).
9. Medium Pressure Supply Air Duct Static Pressure Control
   a. Modulate supply fan speed to maintain duct pressure setpoint at remote duct static pressure sensor located downstream of supply fan at approximately 2/3 length of medium pressure ductwork.
   b. If duct static pressure is 1-inch below the SMACNA duct rating class for which the ductwork was designed for, generate an alarm and do not increase supply fan speed until duct static pressure is below this value.
   c. If duct static pressure is 0.5-inch below the SMACNA duct rating class, generate an alarm and shut down fans through a hardwire connection.
10. Raised Floor Static Pressure Control
    a. Modulate zone supply dampers to maintain raised floor static pressure setpoint of 0.06-inch (adj) at each zone.
11. Building Static Pressure Control with Return Fan
    a. Modulate fan speed to maintain building static pressure of 0.05-inch positive (adj) relative to outdoors.
    b. Open relief air damper to fully open position when fan operates. Provide 15-second delay in fan start/stop to allow damper to open/close without causing duct damage.
    c. If return fan is at minimum speed, modulate relief damper to maintain building static pressure setpoint.
12. Minimum Outdoor Air Quantity Setpoint

a. Minimum outdoor air quantity setpoint is the lesser of MIN OSA or DCV MIN (where indicated), as indicated on Schedules and as reset by Demand Control Ventilation algorithm, as applicable.

13. Demand Control Ventilation
    a. If the unit is supplying only one zone, and that zone has CO2 monitoring sensor(s), and CO2 level is above 900 ppm (adj), gradually increase minimum outdoor air quantity setpoint from DCV MIN to MIN OSA value to maintain a maximum CO2 concentration of 1,000 ppm. Generate an alarm if the zone's CO2 concentration is greater than 1,200 ppm (adj).
    b. If there are any rooms/zones with a CO2 sensor, execute Demand Control Ventilation (DCV) control strategy at the zone level. If the zone's DCV control strategy has been executed and any zone's CO2 level is above 900 ppm (adj), gradually increase minimum outdoor air quantity setpoint from DCV MIN to MIN OSA value to maintain a maximum CO2 concentration of 1,000 ppm.
    c. Provide adequate time delay, to be determined in cooperation with the test and balance agent, to avoid false alarms and adequate time for system to balance during sudden loading of space.
14. Minimum Outdoor Air Control with Airflow Measuring Station
    a. Enable minimum outdoor airflow control when unit is not in economizer mode.
    b. Modulate outdoor air damper and return air damper, in sequence, to maintain minimum outdoor airflow setpoint.
15. Shutdown Mode
    a. Shut down unit according to BAS schedule or if required due to safeties, and:
        1) Disable fans.
        2) Close outdoor and relief air dampers.
        3) Open return air damper.
        4) Close chilled water control valve.
        5) Close heating water control valve.
        6) 60 seconds (adj) after fan shutdown close fire and smoke dampers in distribution ductwork.
16. Unoccupied Mode
    a. General
        1) Shut down unit unless enabled in Night Setback, Night Setup, Night Purge or Unoccupied Override mode.
17. Night Setback
    a. Night Setback does not apply to 100 percent outdoor air units without a return air connection.
    b. When any space temperature drops 2 F (adj) below heating setpoint temperature:
        1) Run fans.
        2) Outdoor and relief air dampers remain closed and return air dampers remains open.
        3) Modulate heating hot water control valve, to maintain discharge air temperature setpoint of 90 F (adj).
        4) Shutdown unit when lowest space temperature is 2 F (adj) above heating setpoint.
18. Night Set-up
    a. Night Set-up does not apply to 100 percent outdoor air units without a return air connection.
    b. When any space temperature rises 2 F (adj) above cooling setpoint temperature:
        1) Run unit and interlocked fans.
        2) Relief fan or exhaust fan interlocked with the unit remain off.
        3) Outdoor and relief air dampers remain closed and return air damper remains open, unless in economizer mode.

4) If outdoor air temperature is higher than return air temperature disable economizer mode and modulate chilled water control valve, where applicable, to maintain design supply air temperature (adj).
5) If outdoor air temperature is less than return air temperature enable economizer operation as first stage of cooling followed by modulate chilled water control valve to maintain design cooling supply air temperature.
6) Shutdown unit when highest space temperature is 2 F (adj) below cooling temperature setpoint.

19. Night Purge
    a. Begin Night purge modes when all the following conditions are met:
        1) Peak outdoor air temperature in previous 24 hours has exceeded 80 F (adj).
        2) Unit is less than 5 hours (adj) from occupancy.
        3) Space temperature is above 68 F (adj) in more than 2 zones.
        4) Outdoor air temperature is above 45 F (adj) and below 65 F (adj).
    b. For Night Purge operation:
        1) Disable morning warmup prior to occupancy.
        2) Run unit and fans, as applicable.
        3) Enable economizer mode and maintain supply air temperature setpoint of 50 F (adj).
        4) Disable mechanical cooling and heating systems.
        5) Reset room cooling temperature setpoint to 65 F (adj) until scheduled occupancy.
    c. Terminate night purge when one of the following occurs:
        1) Zone is less than 20 minutes (adj) from occupancy.
        2) Return air temperature is less than 65 F (adj).
20. Unoccupied Override
    a. Divide the areas served by the unit into Override Zones with each zone containing one or more terminal control units. Grouping of terminal units into Override Zones to be determined by the Owner and easily changeable by the Owner. Provide a graphical representation of Override Zones with the ability of assigning/re-assigning zones/terminal units to Override Zones without leaving the current screen.
    b. When an override signal from a space temperature sensor has been received, enable all terminal units within the Override Zone which the space temperature sensor is a part of, and disable all other terminal units, except enable adequate number of additional Override Zones to satisfy the minimum air quantity requirements of the unit.
    c. Initiate Occupied Mode upon receiving an override signal from designated space temperature sensors.
    d. Initiate Unoccupied Mode when one of the following occurs.
        1) Timed override period of 2 hours (adj) has expired.
        2) Timed override is cancelled.
21. Morning Warm-up
    a. Initiate Morning Warm-up mode using an optimal start algorithm that uses an adaptive learning feature that automatically adjusts the morning warm-up start time so that the average zone temperature in the exterior zones is 68 F (adj) at the start of scheduled occupied period.
    b. During morning warm-up operation:
        1) Unit and applicable fans operate.
        2) Outdoor and relief dampers are closed.
        3) Return air damper is open.
        4) Mechanical cooling is de-energized.
        5) Modulate heating control valve, as applicable, to maintain supply air temperature setpoint of 90 F (adj).
22. Morning Warm-up with Pre-Occupancy Purge

a. Initiate Morning Warm-up mode using an optimal start algorithm that uses an adaptive learning feature that automatically adjusts the morning warm-up start time so that the average zone temperature in the exterior zones is 68 F (adj) at the start of scheduled occupied period.
b. During morning warm-up operation:
    1) Unit and applicable fans operate.
    2) Outdoor and relief dampers are closed.
    3) Return air damper is open.
    4) Mechanical cooling is de-energized.
c. Modulate heating control valve, as applicable, to maintain supply air temperature setpoint of 90 F (adj).
d. Initiate Pre-occupancy Purge Mode one hour prior to start of occupancy.
e. During Pre-occupancy Purge operation:
    1) Enable unit to Occupied mode and set the Minimum Outdoor Air quantity setpoint to the lesser of MIN OSA cfm or 3 air changes per hour for all areas served by the unit.
f. Reset space heating and cooling temperature setpoints to 68 F and 78 F, respectively.

23. Pre-occupancy Purge
    a. Initiate Pre-occupancy Purge Mode one hour prior to start of occupancy.
    b. During Pre-occupancy Purge operation:
        1) Enable unit to Occupied mode and set the Minimum Outdoor Air quantity setpoint to the lesser of MIN OSA cfm or 3 air changes per hour for all areas served by the unit.
        2) Reset space heating and cooling temperature setpoints to 68 F and 78 F, respectively.
24. Morning Cool-Down:
    a. Morning cool-down does not apply to 100 percent outdoor air units without a return air connection.
    b. Initiate Morning Cool-down mode using an ‘optimal’ start algorithm that uses an adaptive learning feature that automatically adjusts the Morning Cool-down start time so that the average zone temperature in the exterior zones is 78 F (adj) at the scheduled occupied start time.
    c. During Morning Cool-down operation:
        1) Unit and applicable fans operate.
        2) Outdoor and relief dampers are closed, except when in economizer mode.
        3) Return air damper is open.
        4) Heating system is disabled.
        5) If outdoor air temperature is higher than return air temperature disable Economizer mode and modulate chilled water control valve, where applicable, to maintain scheduled supply air temperature.
        6) If outdoor air temperature is less than return air temperature, enable Economizer mode as first stage of cooling followed by: modulate chilled water control valve, where applicable.
25. Fire Mode for Low Rise Buildings:
    a. Generate an alarm on activation of Fire signal from Fire Alarm Control Panel.
    b. Maintain operational mode of the unit, unless shut down due to safeties.
26. Freeze Protection:
    a. Enable Freeze Protection during all modes of operation.
    b. If supply air temperature is at or below 40 F for longer than 5 minutes generate an alarm.
    c. Open the hot water valve and ensure the heating hot water system is active.
27. Alarms / Safeties:
    a. Generate an alarm if any of the following conditions occur:

1) Smoke is detected in the supply air duct(s) as shown on control drawings and/or Points Lists. Shutdown unit through a hardwire connection.
2) Static pressure at the discharge of the unit exceeds alarm setpoint
3) Shut down unit and generate an alarm when the high limit pressure switch at the discharge of the unit is activated.
4) Low limit detection thermostat located upstream of cooling coil senses air temperature below 36 degrees F and shuts down unit through hardwire connection.
5) Differential pressure sensors located across each filter bank is activated when static pressure drop exceeds the following values:
   (a) For a pre-filter only, up to 4-inches depth: 0.50-inches (adj).
   (b) For a minimum 12-inches deep final filter only: 1.25-inches (adj).
   (c) For a pre-filter and final filter: 1.50-inches (adj).
6) Static pressure at the inlet to the return fan exceeds the lesser of negative 2.0-inches (adj).
7) Static pressure at the inlet to the return fan exceeds the lesser of negative 2.5-inches. Shutdown air handling unit.
8) Any fan's VFD or ECM motor signals an alarm.

R. Global Sequence of Operations:
1. Include the following sequences in the BAS catalog of routines and execute when called upon by specific equipment. Mode of operation of units is initiated from BAS schedule.

S. Air Handling Unit - Variable Air Volume with Hydronic Coils:
1. Refer to "Global Sequence of Operations for Air Handling Units" article for definition of various modes of operation indicated herein. Mode of operation of units is initiated from BAS schedule.
2. Unit to operate under following modes:
3. Occupied Mode - OM-AHU-1:
4. Economizer operation - EM-AHU-1
5. Supply Air Temperature Control - SAT-C-AHU-1
6. Supply Air Temperature Control for 100 percent Outdoor Air Units - SAT-C-AHU-OA-1
7. Supply Air Temperature Setpoint Reset - SAT-Reset-1
8. Fan Speed Control for Air Handling Units - FSC-AHU-1
9. Medium Pressure Supply Air Duct Static Pressure Control - MP-DSP-AHU-1
10. Medium Pressure Supply Air Duct Static Pressure Setpoint Reset - MPDSP-reset-1
11. Raised Floor Static Pressure Control - RFSP-C-AHU-1
12. Return Fan, or Exhaust Fan Building Static Pressure Control - RF-BSP-AHU-1
13. Minimum Outdoor Air Quantity Setpoint - MOA-SP-1
14. Demand Control Ventilation - DCV-AHU-1
15. Minimum Outdoor Air Control with Mixed Air Plenum Pressure Control- MOA-MAPP-AHU-1
16. Minimum Outdoor Air Control with Airflow Measuring Station - MOA-AFMS-AHU-1
17. Minimum Outdoor Air Control with Minimum Outdoor Air Damper and Airflow Measuring Station - MOA-MOAD-AHU-1
18. Shutdown Mode - SM-AHU-1
19. Unoccupied Mode - UOCC-1
20. Night Setback - NSB-AHU-1
21. Night Setup - NSU-AHU-1
22. Night Purge - NP-AHU-1
23. Unoccupied Override - UO-1
24. Morning Warm-up - MWU-AHU-1
25. Pre-occupancy Purge - POCCP-1
26. Morning Cool-down - MCD-AHU-1

27. Fire Mode for Low Rise Buildings - FM-LR-1
28. Freeze Protection - FP-AHU-1
29. Alarms / Safeties - AL-1
30. Alarms / Safeties - AL-AHU-1

T. Air Cooled Heat Recovery Heat Pump HP-1

1. Heating or Cooling Mode

a. Enable HP-1 mode when all the following is true:

1) A definable number of chilled water or hot water coils need heating or cooling.

2) Cooling mode has been disabled for minimum of 15 minutes (adj) only if HP-1 does not have internal control to limit restarts.

b. Disable HP-1 when all chilled water and hot water control valves are closed.

2. Chilled water & HHW systems' system differential pressure control - Primary Variable Flow Systems

a. In sequence, modulate lead primary pump's speed, stage on/off lag primary pump(s) and run in unison with the lead pump to maintain differential pressure (DP) setpoint at the most remote control valve (adj), with DP setpoint determined in cooperation with the test and balance agent.

b. For each CHwW and HHW system, if the respective pump's VFD speed is greater than 90-percent (adj) for 3 minutes, stage on lag pump, and open HP-1 evaporator and condenser isolation valve if HP-1's differential pressure exceeds a value corresponding to a flowrate of 10-percent above HP-1 design water flow rate.

c. If pumps' VFD speed are below 45-percent (adj) for 3 minutes stage off respective lag pump.

d. When the lag pump for CHW and/or HHW systems are started, ramp up the respective lag pump VFD speed to match the lead VFD speed and then run in unison to maintain differential pressure setpoint.

e. Set the VFD minimum speed at a speed determined in cooperation with the test and balance agent and the pump and motor manufacturer.

3. Chilled Water & Heating Hot Water Differential Pressure Reset

a. Reset differential pressure setpoint between 1 psi (adj) and DP setpoint using Trim and Respond logic in conjunction with cooling coil control valves' pressure requests.

b. Provide means to automatically identify rogue zones and eliminate them from the logic by assigning an Importance Factor of zero. Rogue Zones are zones with Cumulative-Request-Hours of greater than 70-percent, with Cumulative-Request-Hours, expressed as a percentage, defined as:

1) Zone Request Hours divided by the zone run-hours.

2) Zone run-hours is defined as hours in any Mode other than Unoccupied Mode since the last reset.

c. Provide trending of individual zone's valve position, pressure request, and Cumulative--percent-Request-Hours.

d. When unit is enabled in any mode, set initial differential pressure setpoint at 3 psi (adj).

4. Chilled water & HHW system's minimum flow control

a. Modulate minimum flow/differential pressure bypass control valve of each system to maintain differential pressure (DP) setpoint, minimum flow required to protect pumps, and minimum flow required by HP-1 as measured by differential pressure sensors across the evaporator and condenser.

5. Heat Pump capacity control

a. -1 is controlled by its stand-alone controller to maintain chilled water and heating hot water supply water temperature setpoint.

b. Transmit CHW & HHW supply temperature setpoint to HP-1's controller.

6. CHW & HHW Supply Temperature - Setpoint Reset:

a. Reset the Chilled Water Supply (CHWS) temperature setpoint using a trim and respond logic between design CHWS temperature and 5 F (adj) above design CHWS temperature in conjunction with cooling coil control valves' pressure requests.

b. As the outside air temperature varies from 60 deg F (adj) to the ASHRAE 1-percent winter design temperature, reset the heating hot water supply temperature setpoint from 20 F less (adj) than the design heating hot water supply temperature to the heating hot water supply temperature.

c. Provide means to automatically identify rogue zones and eliminate them from the logic by assigning an Importance Factor of zero. Rogue Zones are zones with Cumulative-Request-Hours of greater than 70-percent, with Cumulative-Request-Hours, expressed as a percentage, defined as:

1) Zone Request Hours divided by the zone run-hours.

2) Zone run-hours is defined as hours in any Mode other than Unoccupied Mode since the last reset.

d. Provide trending of individual zone's valve position, pressure request, and Cumulative--percent-Request-Hours.

e. On startup of HP-1, reset the CHWS temperature setpoint and HHWS temperature setpoint to the HP-1's maximum value (adj) and minimum value (adj), respectively, and gradually ramp down/up the setpoint from its maximum/minimum value to the previous CHWS/HHWS temperature setpoint. Minimum chilled water temperature is the design CHWS temperature (adj) unless reset as noted above. Maximum hot water temperature is the design HWS temperature (adj) unless reset as noted above.

7. Alarms/Safeties:

a. Generate an alarm if any pump VFD speed feedback is less than 80-percent of command for 3 minutes, VFD status is lost for minimum 1 minute, VFD fault, drive failure, is off, or in hand.

b. Unit Status Display: Connect with HP-1's control panel, obtain all pertinent information and display the following minimum information at the Operator Workstation.

1) System mode of the chiller plant

2) Enable/disable status

3) System CHW & HHW supply water temperature setpoint

4) System CHW & HHW supply and return water temperature

5) System CHW & HHW water pump status

6) System CHW & HHW flow

7) Current plant control operation

8) System failure information

9) HP-1's failure information

10) Remove a pump from a sequence temporarily for service purposes.

11) High CHW & HHW Differential Pressure: If the CHW or HHW differential pressure is 25-percent (adj.) greater than setpoint.

12) Low CHW & HHW Differential Pressure: If the CHW or HHW differential pressure is 25-percent (adj.) less than setpoint.

c. Event Processing - Record HP-1's control and status events at the operator's selection, in the BAS event log to facilitate troubleshooting.

d. System Security - Provide program security designation for each operator with a choice of the following functions.

1) View HP-1's status

2) Change HP-1's plant status

3) View HP-1's plant setup

4) Change HP-1's plant setup

e. Alarm Indications - Display HP-1's plant and alarm messages at HP-1 plant control status screens.

U. Terminal Units with Hot Water Reheat (TU):

1. Occupied Mode:
   a. Maintain space heating and cooling temperature setpoints by implementing the following routine, in sequence:
      1) If space temperature is higher than cooling temperature setpoint, disable terminal unit's heating system and maintain cooling temperature setpoint by modulating damper from Minimum Heating airflow to Maximum Cooling airflow.
      2) If space temperature is less than heating temperature setpoint, initiate first stage of heating at Minimum Heating airflow and modulate heating coil's control valve(s), as applicable, to gradually increase unit's supply air temperature setpoint from 80 to 95 F.
      3) If space temperature is still less than heating temperature setpoint, confirm that the boiler plant is enabled and supply air temperature is above room setpoint and initiate second stage of heating by modulating damper from Minimum Heating airflow to Maximum Heating airflow while maintaining supply air temperature setpoint of 95 F.
      4) If space temperature is still less than occupied heating setpoint temperature, initiate third stage of heating by modulating heating coil's control valve.
   b. For zones with CO2 sensors, if space CO2 concentration is greater than 800 ppm (adj) modulate damper between Minimum Heating and Maximum Heating airflow setpoints to maintain maximum CO2 concentration of 900 ppm. Generate an alarm if the zone CO2 concentration is greater than 1,200 ppm (adj). Provide adequate delay (time determined during commissioning) to avoid false alarming and adequate time for system to balance during sudden loading of spaces.
2. Window Switch
   a. For zones that have operable windows (at wall or roof) with indicator switches, when the window switch(es) indicates the window(s) is(are) open, initiate Unoccupied mode, ignore Unoccupied Override signals, and reset the zone heating temperature setpoint and the zone cooling temperature setpoints to 40 F and 120 F, respectively.
   b. Generate an alarm if the zone temperature is 50 F or less.
   c. Revert to normal setpoints when the window switch(es) indicate that window(s) is(are) closed.
3. Unoccupied Mode:
   a. Close terminal unit damper and disable heating system. Ignore any signals from space occupancy or carbon dioxide sensors.
   b. If space temperature is greater than unoccupied cooling temperature setpoint, and if central air handling unit is operating, modulate damper between no airflow and Maximum Cooling airflow setpoints to maintain space temperature at unoccupied cooling temperature setpoint.
   c. If space temperature is less than unoccupied heating temperature setpoint, modulate damper between no airflow and Maximum Heating airflow setpoints, in sequence with modulating heating coil's control valve subject to a maximum discharge air temperature of 95 degrees F (adj.), as appropriate, to maintain space temperature at unoccupied heating setpoint.
   d. During Unoccupied Mode, if any single zone falls below 40 F, generate an alarm and initiate Setback Mode until all zones are above 50 F.
4. Morning Warm-up Mode
   a. Modulate damper between no airflow and Maximum Heating airflow setpoints, in sequence with modulating heating coil's control valve subject to a maximum

discharge air temperature of 90 degrees F (adj.) to maintain space temperature setpoint corresponding to the appropriate mode.

5. Night Setback Mode
   a. Modulate damper between no airflow and Maximum Heating airflow setpoints, in sequence with modulating heating coil's control valve subject to a maximum discharge air temperature of 90 degrees F (adj.) to maintain space temperature setpoint corresponding to the appropriate mode.
6. Morning Cool-down Mode:
   a. Modulate damper between no airflow and Maximum Cooling airflow setpoints to maintain space temperature at unoccupied cooling temperature setpoint.
7. Night Set-up Mode:
   a. Modulate damper between no airflow and Maximum Cooling airflow setpoints to maintain space temperature at unoccupied cooling temperature setpoint.
8. Night Purge Mode:
   a. Modulate damper between no airflow and Maximum Cooling airflow setpoints to maintain space temperature at unoccupied cooling temperature setpoint.
9. Pre-occupancy Purge Mode:
   a. One hour prior to occupancy operate the terminal unit at a minimum flowrate of 3 air changes per hour for all areas served by the unit and modulate terminal unit damper and HHW heating control valve, in sequence, to maintain corresponding cooling and heating temperature setpoints.
10. Unoccupied Override:
    a. When an override signal from a space temperature sensor has been activated, change the mode of the terminal unit to Occupied for 2 hours (adj).
    b. Terminate Unoccupied Override mode when one of the following occurs:
       1) Timed override period of 2 hours (adj) has expired.
          (a) Timed override is cancelled.

V. Terminal Units - Cooling Only (TU)

1. Occupied Mode:
   a. Maintain space heating and cooling temperature setpoints by implementing the following routine, in sequence:
      1) If space temperature is higher than cooling temperature setpoint, maintain cooling temperature setpoint by modulating damper from Minimum airflow to Maximum airflow.
   b. For zones with CO2 sensors, if space CO2 concentration is greater than 800 ppm (adj) modulate damper between Minimum and Maximum airflow setpoints to maintain maximum CO2 concentration of 900 ppm. Generate an alarm if the zone CO2 concentration is greater than 1,200 ppm (adj). Provide adequate time delay, to be determined in cooperation with the test and balance agent, to avoid false alarms and adequate time for system to balance during sudden loading of space.
2. Window Switch:
   a. For zones that have operable windows with indicator switches (at wall or roof), when the window switch(es) indicates the window(s) is(are) open, initiate Unoccupied mode, ignore Unoccupied Override signals, and reset the zone heating temperature setpoint and the zone cooling temperature setpoints to 40 F and 120 F, respectively.
   b. Generate an alarm if the zone temperature is 50 F or less.
   c. Revert to normal setpoints when the window switch(es) indicate that window(s) is(are) closed.
3. Unoccupied Mode:
   a. Close terminal unit damper. Ignore signals from space occupancy or carbon dioxide sensors.
   b. If space temperature is greater than unoccupied cooling temperature setpoint, and if central air handling unit is running, modulate damper between no airflow and

Maximum Cooling airflow to maintain space temperature at unoccupied cooling temperature setpoint.

c. If space temperature is less than unoccupied heating temperature setpoint, close damper.

d. During Unoccupied Mode, if any single zone falls below 40 F, generate an alarm and initiate Setback Mode until all zones are above 50 F.

4. Morning Warm-up or Night Setback Mode
   a. Modulate damper between no airflow and Maximum Heating airflow setpoints, in sequence with modulating heating coil's control valve subject to a maximum discharge air temperature of 95 degrees F (adj.), as appropriate, to maintain space temperature setpoint corresponding to the appropriate mode.
5. Morning Cool-down Mode:
   a. Modulate damper between no airflow and Maximum Cooling airflow setpoints to maintain space temperature at unoccupied cooling temperature setpoint.
6. Night Set-up Mode:
   a. Modulate damper between no airflow and Maximum Cooling airflow setpoints to maintain space temperature at unoccupied cooling temperature setpoint.
7. Night Purge Mode:
   a. Modulate damper between no airflow and Maximum Cooling airflow setpoints to maintain space temperature at unoccupied cooling temperature setpoint.
8. Pre-occupancy Purge Mode:
   a. One hour prior to occupancy operate the terminal unit at a constant airflow rate of 3 air changes per hour for all areas served by the unit and modulate terminal unit damper to maintain corresponding cooling temperature setpoint.
9. Unoccupied Override
   a. When an override signal from a space temperature sensor has been activated, change the mode of the terminal unit to Occupied for 2 hours (adj).
   b. Terminate Unoccupied Override mode when one of the following occurs:
      1) Timed override period of 2 hours (adj) has expired.
      2) Timed override is cancelled.

W. Radiant Floor Heating & Cooling System

1. General:
   a. Maintain slab temperature at corresponding setpoint temperatures at all times, except if the upcoming unoccupied period is longer than 167 hours (adj), at which time lock out chilled water flow and reset slab temperature to 60 F if outdoor air temperature is less than 50 F for 8 continuous hours, or turn off the radiant system if outdoor air temperature exceeds 70 F for 8 continuous hours.
   b. Except as noted for Morning Cooldown mode, at all operating modes, slab temperature shall be not less than 62 degrees F (adj), not more than 80 degrees F (adj), 2 degrees F (adj) warmer than indoor dew point temp, and during unoccupied hours only, 2 degrees F (adj) warmer than outdoor dew point temperature. Generate an alarm if slab temperature is beyond setpoints indicated.
   c. Use PID control loops to reset slab setpoint temperature based on current space temperature setpoint and rate of change of space temperature, and upcoming space temperature setpoint (ie change in setpoints corresponding with change of occupancy mode from unoccupied to occupied).
   d. Commissioning Agent, TAB Technician shall be present during the commissioning period and provide input for correct setting of PID loop parameters.
2. UNOCCUPIED MODE :
   a. Reset slab temperature setpoint to 70 degrees F (adj) with a deadband of 2 degrees F. Reset space temperature setpoint to set-back temperature. Ignore space CO2 signals, close Terminal Unit damper, and open 6-way valve to heating hot water or chilled water flow, as required to maintain slab temperature setpoint.

3. Morning Warm-Up:
    a. Initiate Morning Warm-up mode using an optimal start algorithm that uses an adaptive learning feature that automatically adjusts the morning warm-up start time so that the average zone temperature in the exterior zones is 68 F (adj) at the start of scheduled occupied period. Reset slab temperature setpoint as determined by PID control loop and open 6-way valve to heating hot water flow, as required to maintain slab space temperature setpoint. Close Terminal Unit damper.
4. Morning Cool Down:
    a. Initiate Morning Cool-down mode using an optimal start algorithm that uses an adaptive learning feature that automatically adjusts the morning cool-down start time so that the average zone temperature in the exterior zones is 72 F (adj) at the start of scheduled occupied period. Reset slab temperature setpoint to 60 F (adj). Open 6-way valve to chilled water flow, as required to maintain slab temperature. Close Terminal Unit damper. At a time period determined by PID loop, lock out chilled water flow so that slab temperature reaches 65 F (adj) 30 minutes (adj) after start of occupancy, at which point chilled water flow lockout is removed.
5. Occupied Mode:
    a. Reset slab temperature setpoint as determined by PID control loop and open 6-way valve to heating hot water or chilled water flow, as required to maintain slab space temperature setpoint.
    b. For spaces with CO2 sensors:
        1) Operate Terminal Unit and set supply air quantity at Minimum Heating CFM and if space CO2 concentration is greater than 800 ppm (adj) modulate damper between Minimum Heating and Maximum Heating airflow setpoints to maintain maximum CO2 concentration of 900 ppm. Generate an alarm if the zone CO2 concentration is greater than 1,000 ppm (adj). Provide adequate delay (time determined during commissioning) to avoid false alarming and adequate time for system to balance during sudden loading of spaces. Modulate Terminal Unit heating hot water control valve to maintain space temperature.
    c. For spaces without CO2 sensors:
        1) Operate Terminal Unit and set supply air quantity at Minimum Heating CFM and modulate Terminal Unit heating hot water control valve to maintain space temperature.
6. Pre-occupancy Purge Mode:
    a. One hour prior to occupancy operate radiant floor system at Morning Warmup or Morning Cool mode, as appropriate. Operate the terminal unit at a minimum flowrate of 3 air changes per hour for all areas served by the unit and modulate terminal unit HHW control valve to maintain heating temperature setpoints.
7. Unoccupied Override:
    a. When an override signal from a space temperature sensor has been activated, change the mode of the radiant zone and the corresponding Terminal Unit(s) to Occupied for 2 hours (adj).
        1) Terminate Unoccupied Override mode when one of the following occurs:
            (a) Timed override period of 2 hours (adj) has expired.
            (b) Timed override is cancelled.
8. Standby Mode:
    a. During occupied hours, for spaces without an occupancy sensor, enter Standby mode at the end of the Unoccupancy Override period if Unoccupancy Override switch has been activated, or when the Unoccupancy Override switch has been not activated by the occupant.
    b. Initiate Standby mode if all normally occupied spaces served by the unit are provided with occupancy sensors. Enter “Standby Mode” if the occupancy sensors in all rooms served by the terminal unit do not detect occupancy for 15 minutes (adj).
    c. During Standby mode:

1) Reset cooling temperature setpoint to 3 F (adj) above normal occupied setpoint and heating temperature setpoint to 3 F (adj) below normal occupied heating setpoint.
2) After 30 minutes in Standby mode (adj), for a period of 15 minutes (adj) reset Minimum Heating CFM of the terminal unit to zero. At the end of 15 minute (adj) period, increase the Minimum outdoor air quantity setpoint of the air handling system by the Minimum Heating CFM of the zone.
3) If the zone's occupancy sensors in all rooms served by the terminal unit do not detect occupancy, or Unoccupancy Override switch has not been activated, for an additional 45 minutes (adj), for the next 15 minutes (adj) reset Minimum Heating CFM of the terminal unit to zero. Continue this routine until occupancy is detected, Unoccupancy Override switch has not been activated, or there is a change in the mode of the system.

9. Alarms:
   a. Generate an alarm if dampers or valves are commanded open/closed or to modulate but do not send feedback of proper position. Generate an alarm upon sensing of condensation and lock out cooling water flow at the 6-way valve.

X. Exhaust Fan (Constant Volume)

1. General:
   a. Operate unit under the following modes, as initiated from BMS schedule:
      1) Occupied
         (a) For isolation damper(s) shown on drawings as being connected to the exhaust fan, open isolation damper(s), and run fan continuously.
         (b) Generate an alarm if fan fails to operate.
         (c) Operate supply fan(s) or other units that are indicated as being interlocked with the exhaust fan.
      2) Unoccupied
         (a) Close isolation damper(s), as applicable, and shut down exhaust fan and supply fans or other units indicated as being interlocked with the exhaust fan.
         (b) Operate fan, if called upon by other systems interlocked with the exhaust fan.

Y. Split Type Fan Coil Units

1. Connect with the split unit's controller, and:
   a. Operate unit as initiated from BAS schedule.
   b. Monitor unit status.
   c. Generate an alarm on receipt of an alarm signal from unit controller.
2. Monitor room temperature and generate an alarm if room temperature is more than 4 F from setpoint (adj).

Z. Variable Refrigerant Flow System

1. Connect to the unit's controller and operate unit as initiated from BAS schedule.
2. Each unit's controller will monitor and control its full range of operations.
3. General:
   a. Unit to operate under the following modes, as initiated from BAS schedule:
      1) Occupied
      2) Unoccupied
4. Occupied Mode:
   a. Fan runs continuously.
   b. Operate fan coil units at occupied mode setpoint temperatures.
5. Create a graphical screen for each Variable Refrigerant Flow system, including all connected fan coils and condensing units, and:

a. Provide ability of individual or global changes to:
   1) Temperature setpoints.
   2) Fan speed.
   3) Forced shut down of heating and cooling (ie the fan continues operation)
   4) Operation mode setting: cool/heat/fan/dry/auto.
   5) Forced system stop.
b. Monitor the following additional points in the system's graphical screen:
   1) Unit alarm.
   2) Malfunction code.
   3) Filter alarm.
   4) Thermo-on status (whether the unit is actively heating or cooling).
   5) Compressor status.
   6) Fan status.
   7) Auxiliary heat status.
   8) Communication status.
   9) Remote controller prohibit status.

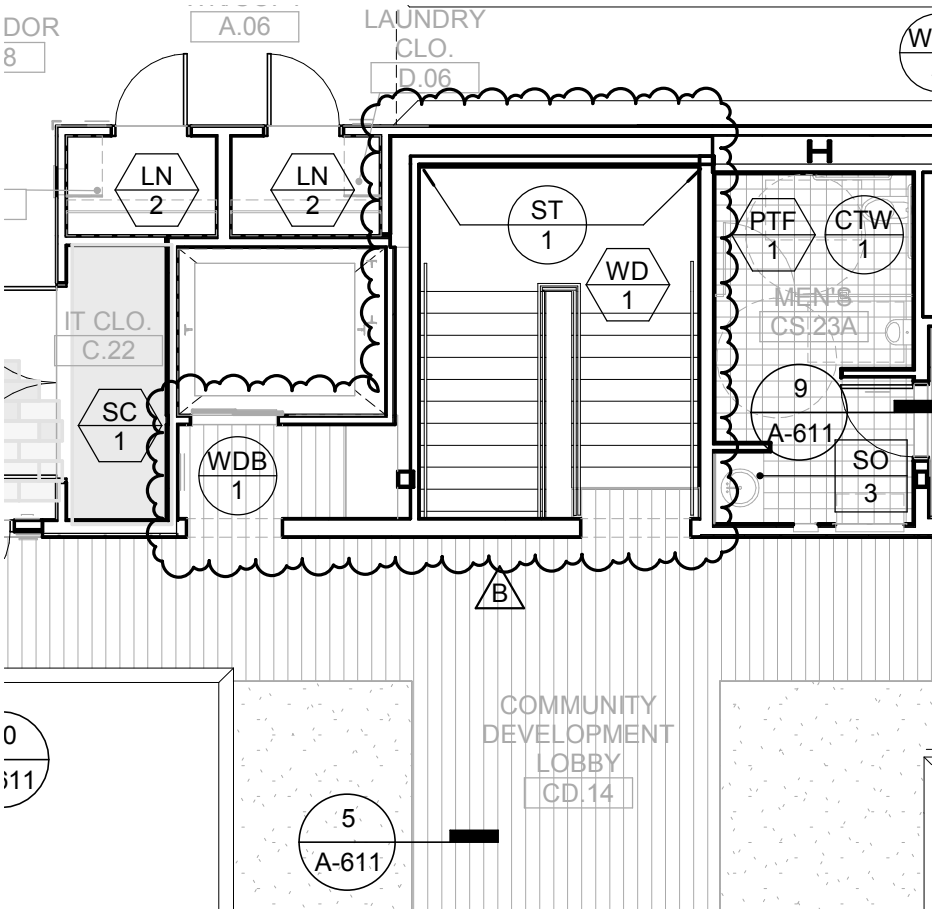
AA. Meters
1. Meters:
   a. Connect to water and electricity meters, as supplied and installed by other Divisions or Sections, at incoming water and electricity services and monitor and trend all values.
   b. Refer to drawings for quantity and location of meters.
   c. Display summed meter data for the last year, month, week, and day, and allow the operator to download all saved data in CVS or equivalent ASC-II format.
   d. For electricity meter(s) trend, store and display data for power demand, cumulative KWH consumption, KVAR, Amps, and volts. Display monthly, weekly daily, and instantaneous usage and PV system's KWH production, where applicable.
   e. For electricity meter(s) trend, store and display instantaneous consumption in 1 minute interval as well as monthly, weekly and daily usage.

AB. Variable Frequency Drives (VFD):
1. Monitor variable speed drives from points indicated on Control Diagrams and through LAN communications port on each drive. As minimum, monitor and/or report the following points:
   a. Frequency output - Hz
   b. Speed - Hz
   c. Current - Amps
   d. Power - KW
   e. Energy - KWH
   f. Runtime - Hours
   g. System Fault
   h. Input speed setpoint - Hz (reporting in " percent" speed is not acceptable)
2. Generate an alarm if VFD status is lost for more than 1 minute, VFD fault, drive failure, is off, or in hand.

AC. Combination Fire Smoke Dampers (FSD):
1. Close dampers 60 seconds (adj) after their corresponding fan system is no longer operating.
2. Open dampers when fan systems are operating.

END OF SECTION

SKETCHES



REFERENCE SHEET: AI-102

WRNS STUDIO
501 SECOND STREET
4TH FLOOR, STE. 402
SAN FRANCISCO
CALIFORNIA, 94107
415.489.2224 TEL
415.358.9100 FAX
WWW.WRNSSTUDIO.COM

PROJECT: ATHERTON CIVIC CENTER
PROJECT NO: TofA 54015 WRNS 15007.00
TITLE: CITY HALL LEVEL 2
FINISH PLAN

SCALE: 1/8" = 1'-0"
BY: EFO
ISSUES/REV.: ADDENDUM 2

ASK-007