SECTION 23 09 00
INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 STIPULATIONS

A. The specifications sections "General Conditions to the Construction Contract", "Special Conditions" and "Division 01 - General Requirements" form a part of this Section by this reference thereto, and shall have the same force and effect as if printed herewith in full.

1.2 ADDITIONAL RELATED DOCUMENTS

A. Division 23 Section, 230993 - "Sequence of Operation for HVAC Controls" for sequences of operation and additional control system requirements.

B. Other Division 23 Sections for factory mounted controls and communication interface gateways and DDC System Sub-Contractor led commissioning for equipment with factory controls packages.

1.3 SYSTEM DESCRIPTION AND SUMMARY

A. The Direct Digital Control (DDC) System shall be entirely electronic utilizing microprocessor based direct digital temperature controllers and electric valve and damper actuators. System shall be complete in all respects including microprocessor, graphical user interface software, sensors, actuators, and other software in order to provide the functions described.

B. The system shall be an extension of the existing DDC system located on the Loysville YDC campus.

C. Access to the control system, either locally in the building, or remotely, shall be accomplished through the following:

1. The existing centralized campus workstation.
2. DDC system webserver, using standard web browsers, via the internet and/or local area network.

D. The proposed system shall be backwards compatible so as to eliminate system obsolescence and provide seamless integration of future systems and software installed on future projects.

E. Throughout this specification, any reference to "DDC Contractor or Subcontractor", "ATC Contractor or Subcontractor", "BMS Contractor", "BAS Contractor", "Control Contractor", "installer", "supplier", "Manufacturer" or "local field office" shall be interpreted as referring to the automatic temperature control system supplier/installer performing the work of this Section, and Section, 230993 - "Sequence of Operation for HVAC Controls".

F. All labor, material, equipment and software not specifically referred to herein or on the Drawings, that are required to meet the functional intent of this specification, shall be provided without additional cost to the Client Agency.

G. The DDC Contractor shall be responsible for integrating factory-supplied HVAC unit controls (supplied by the unit manufacturers) into a unified system in order to provide flexibility for expansion, maintenance, and service of the system.

1. It is the responsibility of the DDC Contractor to coordinate, during the bid period, with the Division 23 Contractors regarding factory supplied controls.
2. All equipment furnished with controls that are furnished and installed by the manufacturer shall have BACnet MS/TP or BACnet IP communication capability from the equipment manufacturer unless coordinated otherwise between the DDC Contractor and the equipment supplier, with the approval of the Architect / Engineer.
3. Coordinate and resolve incompatibility issues that arise between control products provided under this Section and those provided under other Sections or Divisions of the Contract Document Specifications.
4. The DDC Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.
5. Map all available points available from factory supplied control system interfaces.

H. The Client Agency shall be the named license holder of all software associated with any and all incremental work on the project(s).

I. The system shall be provided completely by the DDC Contractor with the exception of any factory-supplied HVAC unit controls and any factory supplied dampers that are integral to equipment. Furthermore, items such as automatic control valves, separable wells, and field-applied automatic dampers, shall be furnished by the DDC Contractor to the Division 23 Contractor for installation. DDC Contractor shall select the proper location for each control valve, separable well, or damper to be installed by the Division 23 contractor, and shall supervise installation of same.

J. After completion of the installation, the DDC Contractor shall completely adjust all control equipment provided under this contract, place the system in operation, subject to the engineer's approval, and instruct the operating personnel in the operation of the control system.

K. The temperature control system supplier shall satisfactorily complete the entire control system so that it is functional and operating to the satisfaction of the Architect. Systems and their controls and their sequencing shall be demonstrated and operated to the satisfaction of the Architect. It is the intent of this specification that this entire system, with its complement of equipment and controls, operate properly in accordance with the design concept and functional intent.

L. All product names and manufacturer names listed as acceptable products or manufacturers in this Section shall be taken to only be acceptable subject to meeting the project requirements (as defined by the Project Specifications, Sequences of Operation, and Drawings), and approval of a product submittal by the Architect / Engineer.

1.4 SYSTEM PERFORMANCE

A. Comply with the following performance requirements, while all DDC-controlled HVAC systems are operating, and trend data (equivalent to up to 20% of the total system point count, with each trended point collected every 60 seconds) is being reported to the building automation database server:

1. Graphic Display: Display graphic with minimum 20 dynamic points with current data within 10 seconds.

2. Graphic Refresh: Update graphic with minimum 20 dynamic points with current data within 8 seconds, and shall automatically refresh every 15 seconds.
3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
4. Object Command: Reaction time of less than two (2) seconds between operator command of a binary or analog object and device reaction.
5. Object Scan: Transmit change of state and change of analog values to control units or workstation within six (6) seconds.
6. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations shall receive alarms within five (5) seconds of each other.
7. Program Execution Frequency: Run capability of both custom and standard applications may be as often as five (5) seconds. Select execution times consistent with mechanical process under control.
8. Performance: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at an adjustable frequency down to once per second. Select execution times consistent with mechanical process under control.
9. Minimum Reporting Accuracy: Report values within the minimum tolerances as follows, unless a more demanding value is specified elsewhere:

    a. Water Temperature: Plus or minus 0.5 deg F.
    b. Water Flow: Plus or minus 3% of full scale.
    c. Water Pressure, Absolute and Differential: Plus or minus 2% of full scale.
    d. Space Temperature: Plus or minus 0.5 deg F.
    e. Ducted Air Temperature: Plus or minus 0.5 deg F.
    f. Outside Air Temperature: Plus or minus 1 deg F.
    g. Dew Point Temperature: Plus or minus 3 deg F.
    h. Temperature Differential: Plus or minus 0.25 deg F.
    i. Relative Humidity: Plus or minus 2% of full scale.
    j. Airflow (Pressurized Spaces): Plus or minus 3% of full scale.
    k. Airflow (Measuring Stations): Plus or minus 5% of reading.
    l. Airflow (Terminal): Plus or minus 10% of full scale.
    m. Air Pressure (Space): Plus or minus 0.01-inch wg.
    n. Air Pressure (Ducts): Plus or minus 0.1-inch wg.
    o. Carbon Monoxide: Plus or minus 5% of reading.
    p. Carbon Dioxide: Plus or minus 50 ppm.
    q. Electrical: Plus or minus 2% of reading.

10. Minimum Control Accuracy: Maintain measured variables within the minimum tolerances as follows, unless a more demanding value is specified elsewhere:

    a. Water Temperature: Plus or minus 1 deg F.
    b. Water Flow: Plus or minus 5% of full scale.
    c. Water Pressure, Absolute and Differential: Plus or minus 3% of full scale.
    d. Space Temperature: Plus or minus 1.5 deg F.
    e. Ducted Air Temperature: Plus or minus 2 deg F.
    f. Relative Humidity: Plus or minus 4% of full scale.
    g. Airflow (Pressurized Spaces): Plus or minus 5% of full scale.
    h. Airflow (Measuring Stations): Plus or minus 7% of reading.
    i. Airflow (Terminal): Plus or minus 15% of full scale.
    j. Air Pressure (Space): Plus or minus 0.02-inch wg.
    k. Air Pressure (Ducts): Plus or minus 0.2-inch wg.
    l. Carbon Dioxide: Plus or minus 50 ppm.

1.5 ACTION SUBMITTALS

A. Primary Submittal:

1. Shop drawings and product data of the entire DDC System shall be submitted and shall consist of no less than the following:

   a. Product Data: A complete list of equipment and materials, including manufacturers catalog data sheets and installation instructions for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics and power requirements, finishes for materials, and installation and startup instructions for each type of product indicated. Include software descriptions, calculations, and any other details required to demonstrate that the system has been coordinated and will properly function as a system.

      1) DDC System Hardware: Bill of materials of equipment indicating quantity, manufacturer, and model number. Include technical data for operator workstation equipment, interface equipment, control units, transducers/transmitters, sensors, actuators, valves, relays/switches, control panels, and operator interface equipment.

   b. Complete wiring and schematic diagrams showing each control point and field device. Schematic control diagrams shall also indicate points obtained from equipment factory packaged control devices. The depictions of these points shall appear alongside field-applied devices and points on the same diagram / schematic.
   c. Terminal identification for all control wiring. Include all pertinent data, including firmware/software versions, switch settings, and calibration data.
   d. A complete point list of all points to be connected DDC System.
   e. List of points obtained through the connection to equipment factory packaged controllers. This list shall appear alongside a points list of field-applied devices/points related to the equipment.
   f. A complete written Sequence of Operation. The sequence shall also incorporate and reflect the control sequence of factory packaged controls.
   g. Schedule of dampers including size, leakage, and flow characteristics.
   h. Schedule of valves including flow and leakage characteristics and shutoff ability.
   i. Schedule of damper and valve actuators.
   j. Schedule of airflow measuring stations. The airflow measuring station manufacturer's representative shall prepare this portion of the submittal by reviewing equipment and ductwork shop drawings to ensure that the proposed installations of the airflow measuring stations meet the requirements and recommendations of the station manufacturers for accuracy, including straight duct upstream and downstream of the station. Install airflow straighteners if required by the manufacturer to meet the specified accuracy given the installation constraints.

2. Division 23 and 26 Contractors supplying products and systems as part of their packages shall provide catalog data sheets, wiring diagrams and point lists to the BAS Contractor for proper coordination of work. Such information shall be included in this primary ATC submittal.
3. System Architecture Diagrams: Trunk cable schematic diagram depicting Tier 1 (head end) controllers, Tier 2 (field level) controllers, control panel locations and a description of the communication type, media and protocol. Though the Division 23 and 26 contractors shall provide these diagrams for their portions of work, the BAS Contractor shall be responsible for integrating those diagrams into the overall trunk cable schematic diagrams for the entire Wide Area Network (WAN).

4. Floor Plans: Indicate controller locations and communication trunk cable routing. Indicate sensor locations, except for those installed on or within a piece of equipment, which shall be shown on an equipment control diagram. Indicate control power sources and routing of control power wiring.

B. Graphics Submittal:

1. This submittal shall occur after the primary submittal described above, but not less than 4 weeks prior to the planned date for installing graphics into the system in the field.
2. Include a copy of each of the graphics developed for the Graphic User Interface including a flowchart (site map) indicating how the graphics are to be linked to one another for system navigation. The graphics are intended to be 90% complete at this stage with the only remaining changes to be based on review comments from the A/E design team and/or Client Agency.

    a. The graphics submitted shall be the actual graphics intended to be utilized on this project, and shall be completely job specific.
    b. Generic or typical graphics are not acceptable, however a single typical graphic may be submitted for types of equipment where this project has multiple, identically controlled pieces of equipment (e.g. VAV boxes, fan coils, etc.).

1.6 INFORMATIONAL SUBMITTALS

A. Field quality-control / commissioning test reports.

1. Phase I - General Performance Testing reports.
2. Phase II - Operational Sequence Testing reports.

1.7 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For HVAC instrumentation and control system to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:

1. Maintenance instructions and lists of spare parts for each type of control device.
2. Interconnection wiring diagrams with identified and numbered system components and devices.
3. Keyboard illustrations and step-by-step procedures indexed for each operator function.
4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
5. Calibration records and list of set points.
6. The point naming and tagging conventions used.
7. A schedule of all manufacturer's extended warranties on component parts of the DDC system which come with such a warranty. The schedule shall list the start and end dates, the manufacturer's name, and the component or device name. Included with the schedule shall be copies of the manufacturer's warranty certificates.

B. Complete 'As-Built' Documents: Provide electronically and in paper manual form. Electronic drawings shall be provided as AutoCAD™ compatible files (.dwg or .dxf) or as Visio files, as per the preference of the Client Agency, as well as PDF format. Three paper hard copies of the 'as-built' documents shall be provided in addition to the documents on flash drive, DVD, or CD. Division 23 and 26 contractors shall provide 'as-builts' for their portions of the control work. This contractor shall be responsible for 'as-builts' pertaining to overall DDC System architecture and

network diagrams. All as built documents shall also be installed into the DDC System database server in a dedicated directory. Any changes made to graphics or sequences of operation during the Commissioning process shall be included in the as-built documents.

1.8 WARRANTY

A. General Warranty: This warranty shall cover all costs for parts, labor, software, associated travel, and expenses for a period of one (1) year from the date of final acceptance by the Architect / Engineer and the Client Agency, and shall keep the control system adjusted throughout the first year.

1. This warranty shall apply equally to both hardware and software, and all related end devices.
2. Upon receipt of DDC system commissioning reports (both Phase I and Phase II testing), and when the system performance is deemed satisfactory by the Architect / Engineer and the Client Agency, the system parts will be accepted for beneficial use and the warranty period shall begin.

1.9 WARRANTY MAINTENANCE

A. At no cost to the Client Agency, during the warranty period, the Contractor shall provide maintenance services for software and hardware components as specified below:

1. Maintenance services shall be provided for all devices and hardware specified in this Section. Service all equipment per the manufacturer's recommendations. All devices shall be calibrated within the last month of the warranty period.
2. Emergency Service: Any malfunction, failure, or defect in any hardware component or failure of any control programming that would result in property damage or loss of comfort control shall be corrected and repaired following telephonic notification by the Client Agency to the Contractor.

    a. Response to any request for service shall be provided within two (2) hours of the Client Agency's initial telephone request for service.
    b. In the event that the malfunction, failure, or defect is not corrected through the telephonic communication, at least one (1) hardware and software technician, trained in the system to be serviced, shall be dispatched to the Client Agency's site within eight (8) hours of the Client Agency's initial telephone request for such services, as specified.

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

    a. Response to any request for service shall be provided within eight (8) working hours (contractor specified 40 hr. per week normal working period) of the Client Agency's initial telephone request for service.
    b. In the event that the malfunction, failure, or defect is not corrected through the telephonic communication, at least one (1) hardware and software technician, trained in the system to be serviced, shall be dispatched to the Client Agency's site within three (3) working days of the Client Agency's initial telephone request for such services, as specified.

4. Technical Support: Contractor shall provide remote technical support throughout the warrantee period.
5. Preventive maintenance shall be provided throughout the warrantee period in accordance with the hardware component manufacturer's requirements.
6. The Client Agency shall grant to the DDC System Contractor, reasonable access to the DDC System during the warranty period. The Client Agency shall allow the contractor to access the DDC System from a remote location for the purpose of diagnostics and troubleshooting, via the Internet, during the warranty period.

1.10 DEFINITIONS

A. Some of the acronyms used in this specification are as follows:

DDC	Direct Digital Control System
NAC	Network Area Controller
IBC	Interoperable BACnet Controller
GUI	Graphical User Interface
WBI	Web Browser Interface
POT	Portable Operator's Terminal
PMI	Power Measurement Interface
LAN	Local Area Network
AHJ	Authority Having Jurisdiction
WAN	Wide Area Network
PICS	Product Interoperability Compliance Statement
I/O	Input / Output
MS/TP	Master Slave/Token Passing
PC	Personal Computer
PID	Proportional (plus) Integral (plus) Derivative
RTD	Resistance Temperature Detector
OWS	Operator's WorkStation
AAC	Advanced Application Controller
ASC	Application Specific Controller
HMI	Human-Machine Interface
Workstation	Generically refers to the HMI and associated software and graphics
HOA	Hand-Off-Auto (switch)
SPST	Single Pole, Single Throw
SPDT	Single Pole, Double Throw
DPDT	Double Pole, Double Throw
DPST	Double Pole, Single Throw
BC	Building Controller
BO	Binary Output (w/ respect to the DDC system)
BI	Binary Input
AO	Analog Output
AI	Analog Input
DO	Digital Output
DI	Digital Input

IP	Internet Protocol
NIST	National Institute of Standards and Technology

B. Miscellaneous Definitions:

1. Tier 1: Automation level network (aka. 'head end' or 'host level') generally consisting of the user interface(s), workstation hardware (if present), web server (if present), building / network level controllers, database server, network media converters, routers, and switches.
2. Tier 2: Field level network generally consisting of advanced application controllers, application specific controllers, and controllers that are factory furnished as part of packaged equipment.
3. Throughout this specification, any reference to "DDC Contractor", "ATC Contractor or Subcontractor", "BMS Contractor", "BAS Contractor", "Control Contractor", "installer", "supplier", "Manufacturer" or "local field office" shall be interpreted as referring to the automatic temperature control system supplier/installer performing the work of this Section.
4. Where the term 'workstation' is used, it shall mean all means of human-machine interface with the DDC system.

1.11 SCOPE

A. The scope of work for the temperature controls system includes, but is not limited to, the following:

1. Provide a complete Direct Digital Control System for all Division 23 systems and equipment, unless otherwise indicated.
2. Provide raceways and conduits as required by the installation. Provide wiring, cable, conduit, hangers, fittings, and couplings. Make final connections to control devices.
3. Provide water control valves and automatic control air dampers, complete with electric actuators**.**
4. Provide integration of factory mounted DDC controls furnished under other Sections as described herein.
5. Provide controls in pre-wired apparatus control panels. Internal components shall be fully pre-wired so that only external connections need to be made to these panels. Control panels shall be provided complete with controllers, relays, transformers, terminal strips, wire-way, convenience outlet, and fuses.
6. Furnish complete sets of submittals and installation drawings as described herein.
7. Provide complete start-up, commissioning and testing, and training services.
8. Provide floor plans and mechanical system graphics on the building automation database server.
9. Provide a complete set of DDC operating manuals, programming manuals, and maintenance manuals.
10. Provide Client Agency's Manual, complete operating instructions and spare parts lists.
11. Coordinate DDC work with the work of the other Contractors involved in this project and the Commissioning Agent.
12. Review the approved and finalized HVAC equipment submittals for control requirements of that equipment. Look for requirements related to minimum run times, temperature limits, minimum flow rates, and similar parameters. Modify control programming to implement the equipment manufacturer's recommendations and requirements. Direct questions regarding conflicts between manufacturer's requirements and the sequences of operation to the Architect / Engineer.

13. Review the Division 23 Contractor's preliminary ductwork and piping shop drawings and identify the required locations of all duct and piping system mounted input and output control devices. Identify conflicts for resolution prior to submission of the shop drawings.

B. Automatic Temperature Control System Coordination:

1. Factory Controls: The Division 23 Contractor (HVAC system installer) providing HVAC equipment shall coordinate with all of their equipment suppliers providing factory controllers to furnish the following to the DDC Contractor:

   a. A BACnet Conformance statement applicable to the controller or gateway BACnet device profile classification (i.e. B-ASC - Application Specific Controller; B-AAC - Advanced Application Controller; B-BC - BACnet Building Controller, etc.).
   b. Documentation identifying all addressable points available from the controller or gateway including device ID, detailed point descriptions and addresses.

2. Control Signal and Control Power Wiring: Power wiring ATC system panels and electric motor operated dampers will be provided under Division 26 only where such work is shown on the Electrical Drawings. Where such required work is not indicated on the Electrical Drawings, power wiring for control systems shall be provided under Division 23 by the ATC sub-contractor.

   a. Control signal and interlock wiring (regardless of voltage) for HVAC control systems and equipment shall be provided under Division 23 by the ATC sub-contractor.
   b. The ATC sub-contractor shall be responsible for furnishing and installing the thermostats, aquastats, etc. and similar line voltage devices for final wiring connections under Division 26, as applicable. Coordinate all work with the work of Division 26.
   c. The Division 26 Contractor will be providing 120V, 20A circuits terminated in junction boxes throughout the building for the ATC system provider / sub-contractor's use in providing power to controllers and control devices requiring power, including VAV boxes and similar terminal control equipment. Power sources to some specific ATC equipment may also be indicated on the Electrical drawings. Control power wiring work from these Division 26-provided power sources to the control system controllers and other devices, including any required control transformers, are the responsibility of the ATC system sub-contractor.
   d. Provide disconnect (toggle) switches at all 120V power supply connections to control devices / equipment / controllers. This includes, but is not limited to, electric actuators, transmitters, and control panels.
   e. All electrical work provided under Division 23 shall conform to the National Electric Code and applicable Division 26 specifications.

3. Smoke Detectors: Duct type smoke detectors for HVAC equipment will be furnished under Division 26 or 28 and shall be installed under Division 23 by the HVAC system installer to conform to the requirements of the building code. Wiring from contacts on the smoke detectors or associated zone area modules to the motor controls of HVAC equipment shall be provided by the ATC Subcontractor to shut down the associated air handling equipment upon the detection of smoke in accordance with the requirements of the building code. Power wiring and interface wiring from the duct type smoke detectors to the building fire alarm panel will be provided under Division 26 or 28.
4. Thermowells and Flow Meters: Separable thermowells for pipe mounted temperature sensors required for ATC operation, and flow meters, shall be furnished by the ATC Subcontractor and installed in pipelines by the HVAC system installer at locations required by the ATC Subcontractor.

5. Pipeline pressure monitoring piping taps shall be provided by the HVAC system installer at locations required by the ATC Subcontractor.
6. Control Valves: Automatic temperature control valves for HVAC equipment shall be furnished by the ATC Subcontractor and installed by the HVAC system installer.
7. Airflow Measuring Stations: Stations, whether duct, plenum, or equipment mounted, shall be furnished by the ATC Subcontractor and installed by the HVAC system installer unless clearly specified to be part of the equipment package. For ATC sub-contractor supplied stations, the ATC subcontractor shall be present at the time the stations are mounted to verify proper installation for accuracy and shall approve the installation.
8. Motor Operated Dampers: Field-applied motor operated dampers shall be furnished by the ATC Subcontractor as per this Section, and installed in ductwork and at intake and discharge air louvers and ventilators under Division 23 by the HVAC systems installer.

    a. Air handling units and similar equipment may be factory furnished with dampers where indicated in the various other Division 23 equipment specification Sections.
    b. Unless specified otherwise in the various Division 23 equipment specification Sections, damper operators shall be furnished and installed by the ATC Subcontractor.
    c. The ATC Subcontractor shall supervise the installation of dampers furnished by them to the Division 23 HVAC systems installer for installation. The ATC Subcontractor shall direct the Division 23 HVAC systems installer to provide blank off plates when the demands of the control application requires dampers smaller than duct size in order to provide for sufficiently linearization for control stability.

9. The Division 23 Contractor / HVAC System installer shall perform work specified elsewhere in this Section, and the following:

    a. Provide pressure sensing taps required in piping complete with isolating petcocks.
    b. Provide various HVAC equipment items complete with self-contained controls as described in other portions of the Specification.
    c. Provide "approved" HVAC equipment submittals, including wiring diagrams, to the DDC Contractor for HVAC equipment provided under other Division 23 Sections.
    d. Verify that the dampers are correctly installed so that they operate freely and close tightly. Provide blank off plates when directly by the ATC Subcontractor to reduce the functional size of control dampers to that which is smaller than the duct size.
    e. All cutting and patching necessary for the installation/relocation/demolition of any existing automatic temperature controls system shall be performed by the HVAC systems installer.
    f. Depict the locations, as coordinated with the ATC Subcontractor, of all ductwork and piping system mounted control devices, on the respective ductwork and piping shop drawings, and coordination drawings.

1.12 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. The DDC system and components shall be listed by Underwriters Laboratories (UL 916) as an Energy Management System.

C. BACnet: The system shall comply with the native BACnet architecture and web browser access described in this specification. All Tier 1 and 2 controllers shall be approved by BACnet Testing Laboratories (BTL Listed).

D. Code Compliance: All HVAC controls shall be programmed in order to meet all requirements articulated in ASHRAE 90.1-2016 and the 2018 International Energy Conservation Code.

E. ASHRAE Guideline 36: Sequences of operation and alarm management methods shall comply with the latest version of the guideline and all current addendums to the greatest extent possible. Identify any discrepancies between the sequences of operation included with these contract documents and the Guideline. Resolve discrepancies by requesting clarification from the Architect / Engineer.

F. Point Naming Conventions: All point text naming conventions shall be consistent in their use and application with existing points on the DDC system.

1.13 FACTORY MOUNTED EQUIPMENT CONTROLS

A. DDC System Provider / Sub-Contractors Scope and Responsibilities:

1. Provide integration of the factory supplied controls into the Building DDC system. Factory supplied control points shall be programmed into the operator's interface, system applications and graphics software and operate seamlessly with the Building DDC system.
2. Coordinate and resolve incompatibility issues that arise between control products provided under this Section and those provided under other Sections or Divisions of the contract document specifications.
3. Communication Gateway Connections: Extend the appropriate / required portion of the DDC system network and connect to all packaged equipment controls, air and water flow meters, and other devices provided with communications gateways.

    a. DDC system graphics shall initially incorporate all 'communication' points available through integration gateways provided with packaged equipment controls, air and water flow meters, and other devices provided with such communications gateways.
    b. Within the warranty period, remove any points obtained through the gateway from the workstation graphics that the Client Agency desires to be removed.

B. Division 23 Contractor's Scope and Responsibilities:

1. The Division 23 Contractor shall ensure that the equipment manufacturer's representative is on-site during the DDC system commissioning process to ensure full integration of factory controls with the DDC System.
2. The Division 23 Contractor shall ensure that the manufacturer's representatives have made all project-specific adjustments and settings during equipment start-up to the factory controllers prior to the joint field-commissioning efforts.
3. All equipment furnished with controls that are furnished and installed by the manufacturer shall have BACnet MS/TP or BACnet IP communication capability from the equipment manufacturer.

    a. Modbus TCP/IP is also acceptable, but only if BACnet MS/TP or BACnet IP is not offered by the equipment manufacturer, and the use of Modbus TCP/IP is fully coordinated between the ATC system supplier and the equipment supplier, and is approved by the Architect / Engineer and the DDC system sub-contractor.
    b. The Division 23 Contractor's equipment supplier shall provide to the DDC system sub-contractor all documentation required for the mapping in of points obtained through communication gateway into the DDC system.

C. Representatives from each manufacturer providing factory mounted controls and the DDC subcontractor shall cooperate in the integration of the individual systems operation prior to bid and during field installation and commissioning / functional testing.

1.14 SOFTWARE LICENSE AGREEMENT AND SERVICE TOOLS

A. The Client Agency shall take ownership of all proprietary material generated or used in the execution of this project as a requirement of this Contract.

1. The Client Agency shall be the named perpetual license holder of all software associated with any and all incremental work on the project(s), including all configuration and service software tools required for setup and modification of the system, hardware, firmware, and documentation that was used in the development, programming, or commissioning of the system for this project.
2. Licenses shall not rely on a physical license key, dongle, or similar device.

1.15 SYSTEM SOFTWARE - GENERAL REQUIREMENTS

A. Functionality and Completeness: The Contractor shall furnish and install all software and programming necessary to provide a complete and functioning system as specified. The Contractor shall include all software and programming not specifically itemized in these Specifications that is necessary to implement, maintain, operate, and diagnose the system in compliance with these Specifications.

B. Configuration: The software shall support the system as a distributed processing network configuration.

C. Offsite Software Retainage: Contractor shall be required to retain backup copies of custom software drivers and documentation of same for no less than ten (10) years with free access to the Client Agency for the same period. If the backup is not available within the specified time frame, Contractor shall recreate the custom software at no charge to the Client Agency.

D. Site Specific Application Programming: Provide all database creation and site-specific, custom application control programming as required by these specifications, national and local standards, and for a fully functioning system. The BAS Contractor shall provide all initial site-specific application programming and thoroughly document programming. The programming shall meet the functional intent of the sequences of operation included in the contract documents. It is not acceptable for the BAS Contractor to merely provide typical or 'canned' software programs without thorough comparison to the contract document sequences of operation, and resulting modification as required. While the BAS Contractor is encouraged to utilize control programming that has been thoroughly tested and successfully implemented on past projects, where the control applications are very similar to this project, the BAS Contractor is still obligated to make project specific modifications as required, and to identify discrepancies between the Contractor's proposed sequence and those in the contract documents. Similarly, the BAS Contractor shall evaluate the suitability of the contract document sequences of operation for implementation on this project. It is the BAS Contractor's responsibility to request clarification on sequence issues and questions that require such clarification, and to request approval for deviations from the contract document sequences of operation. All site specific programming shall be fully documented and submitted for review and approval, both prior to downloading into the panel, at the completion of functional performance testing, and at the end of the warranty period.

1.16 DDC SYSTEM PROVIDER AND BIDDING

A. The DDC system shall be provided by Conexus Inc. of Middletown PA. No exceptions.

1. Contact: Mike Furlow: 717-769-0644; mfurlow@conexus.biz

B. The above DDC system provider has been approved by the Department as a proprietary source/provider. No other provider will be accepted. Sections 9.6 and 9.7 of the General Conditions to the Construction Contract do not apply to the above listed provider.

1.17 GENERAL SYSTEM REQUIREMENTS

A. Refer to the Article titled "General Sequence of Operation Requirements" in Division 23 Section "Sequence of Operation for HVAC Controls" for additional, general system requirements.

B. Control Loops:

1. Unless otherwise indicated, control loops shall be enabled and disabled based on the status of the system being controlled to prevent windup.
2. When a control loop is enabled or re-enabled, it and all its constituents (such as the proportional and integral terms) shall be set initially to a neutral value. The control loop in neutral shall correspond to a condition that applies the minimum control effect, i.e., valves/dampers closed, VFDs at minimum speed, etc.
3. The term “control loop” or “loop” is used generically for all control loops. These shall typically be PID loops, but proportional plus integral plus derivative gains are not required on all loops. Unless specifically indicated otherwise, the following guidelines shall be followed:

    a. Use proportional only (P-only) loops for limiting loops (such as zone CO2 control loops, etc.).
    b. Do not use the derivative (D) term on any loops unless field tuning is not possible without it.

4. To avoid abrupt changes in equipment operation, the output of every control loop shall be capable of being limited by a user adjustable maximum rate of change, with a default of 25% per minute.
5. Safety modes of operation and programmed response to the activation of a safety device shall override all other control loops governing typical system operation as well as any manual overrides performed at the DDC system Workstation. Examples of such safety devices include, but are not limited to, duct smoke detectors and other fire alarm devices, gas detectors, duct pressure sensors / switches, vibration cut out switches, freezestats, and water overflow and leak sensors / switches. Comply with the following hierarchy, in order of highest priority to lowest priority:

    1) Control modes dictated by life safety functions, the fire alarm system, or smoke control modes.
    2) Control modes triggered by safety devices, such as gas detectors, duct pressure sensors / switches, vibration cut out switches, freezestats, and water overflow and leak sensors / switches.
    3) Manual overrides at the DDC system Workstation.
    4) Normal operating modes.

C. Motor Controls:

1. Wire DDC system contacts for start/stop control over 3-phase motors to the magnetic motor starters provided by Division 26. Refer to the Electrical Drawings for locations of magnetic motor starters.
2. The DDC system supplier shall provide line voltage control relays for automatic on-off control of single-phase motors. Locate relays near to the associated motor, and coordinate power wiring with the Division 26 Contractor. The DDC system supplier shall make power and control wiring terminations at the relay in accordance with applicable Division 26 provisions.
3. Electrically Commutated (EC) Motors: EC motors serving fans and pumps indicated in the sequence of operation to have on-off and/or speed control shall receive an external binary and/or analog signal for this purpose. Note that for many EC motors, a zero (0) -VDC or -mA analog speed control signal is used to automatically de-energize the motor. Coordinate signal type requirements with the equipment supplier.

D. Communication Gateway Connections: Extend the appropriate / required portion of the DDC system network and connect to all packaged equipment controls, air and water flow meters, and other devices provided with communications gateways.

E. Factory Control Packages: Where equipment is specified in Division 23 with a factory control package, the DDC system sub-contractor shall be responsible for powering the unit controls (if not powered from the equipment's power connection), mapping points into the DDC system workstation when specified with a communication gateway, making control setting adjustments for proper operation with the assistance of the equipment factory's representative, commissioning and functionally testing the factory controls, and installing and wiring any field mounted control devices shipped loose and/or not factory wired.

F. Manual Overrides: The DDC system operator shall have the ability to override the speed, position, or operational status of all fans, dampers, pumps, and control valves via override command at the operator's workstation, including at the graphics, the I/O points list, and control logic pages. Any points manually commanded by an operator shall be clearly labeled and shall be reflected at all locations where manual commands can be executed. Values on the graphics shall also reflect any operator manual commands. Exceptions are as follows:

1. Systems, equipment, and control devices that perform a life safety function shall not be capable of being manually overridden off or into a mode or position that would reduce the safety of the building. This includes, but is not limited to, lab exhaust fans, grease hood exhaust fans, refrigerant exhaust fans, smoke exhaust fans, stairway or elevator shaft pressurization, fans, and fans dedicated to ventilating fire pump rooms and fire command rooms.
2. Systems, equipment, and control devices when they are automatically responding via programming to the activation of safety device to prevent damage to equipment, building materials or building contents, or prevent the introduction of a hazard to the building, shall not be able to be manually overridden. Examples of such safety devices include, but ae not limited to, duct smoke detectors and other fire alarm devices, gas detectors, duct pressure sensors / switches, vibration cut out switches, freezestats, and water overflow and leak sensors / switches. Any manual overrides put in place prior to the activation of a safety device shall be automatically and immediately canceled when the safety device is activated.

G. Trends: All inputs, outputs, and calculated points of the DDC system shall be capable of being trended. The DDC system provider shall establish trends for any points the Client Agency deems necessary. Trends shall be initially set for a sampling rate of once every 5 minutes for each point or as required by the Client Agency. Trends shall be maintained for a minimum of seven days for all terminal equipment unless required otherwise by the Client Agency. Viewing

of trend graphs shall be available at the DDC workstations or via the web browser. DDC controllers, panels and workstations shall be selected with adequate memory and storage capacity. The workstation shall issue an alarm and provide the user opportunity to save trend data to files prior to erasure of that data. Auto-save features shall be incorporated into the system to retain user-selected trend data without requiring continual user input.

H. Unless explicitly specified otherwise elsewhere, all modulating dampers and valves shall be proportioning. The use of tristate outputs (two coordinated digital outputs) for floating control of is not permitted.

I. Stand-By Control Power: HVAC systems and equipment served by a stand by generator shall have associated DDC system products that control such systems and equipment also served from that same stand by generator power source. This shall include building controllers, routers, workstation, and the webserver so that internet access to the system is maintained. All such items shall be powered through a control panel mounted UPS to prevent even an momentary interruption in control and monitoring.

J. Automatic Restart after Power Failure: Upon restoration of power, the equipment controller shall automatically and without human intervention: update all monitored functions; resume operation based on current, synchronized time and status, and implement special start-up strategies as required.

1.18 OPEN SYSTEM REQUIREMENTS

A. It is the Client Agency's expressed goal to implement an open Building Automation System that will allow products from different manufacturers and/or suppliers to be integrated into a single unified system in order to provide flexibility for expansion, maintenance, and service of the system. The BAS manufacturer / contractor must provide proof of open system design as outlined below.

B. The controls system shall utilize the Niagara4 software framework.

C. Submit the Niagara Compatibility Statement (NiCS) via a letter from the manufacturer. The NiCS shall have no connectivity restrictions and all aspects of the Niagara Framework will be provided to maintain an Open System Design. The System as provided shall confirm with the following NiCS properties (Station Compatibility In, Station Compatibility Out, Tool Compatibility In, AND Tool Compatibility Out shall each have a value of “All”).

D. The controls system shall conform to the following guidelines for communication protocols.

1. BACnet shall be used for all BAS provided controllers.

    a. The manufacturer of the hardware and software components as well as its subsidiaries must be a member in good standing of the BACnet International and all controllers used shall be BACnet Listed with documentation on the BACnet website (https://www.bacnetinternational.net/btl/search.php)
    b. The use of BACnet Communications protocol alone shall NOT warrant an “Open System Design.”

2. Modbus shall only be acceptable for third party devices.
3. LonTalk shall only be acceptable for sites with existing LonTalk controls architecture where the Client Agency has explicitly stated that the LonTalk architecture must remain in place.
4. Proprietary communications protocols shall NOT be acceptable.

E. A software programming toolS shall be provided for this project and adhere to the following guidelines:

1. All software tools needed for full functional use, including programming of controllers, Niagara4 Framework network management and expansion, and graphical user interface use and development, of the BAS described within these specifications shall be provided to the Client Agency or his designated agent.
2. The software programming tool shall be free of charge and openly available for download from the internet.
3. For any manufacturer that does not have a free programming tool the manufacturer must provide the tool with this project for a minimum of 5 years with proof of availability via letter from the manufacturer.
4. Any licensing required by the manufacturer now and to the completion of the warranty period, including changes to the licensee of the software tools and the addition of hardware corresponding to the licenses, to allow for a complete and operational system for both normal day to day operation and servicing shall be provided.

PART 2 - PRODUCTS

2.1 COMPUTER HARDWARE

A. Provide the following computer hardware for this project:

1. Onsite Server.
2. Uninterruptable Power Supplies

B. Server Hardware Requirements:

1. The Server shall adhere to the following minimum requirements: the latest generation Intel Core i5 processor, 16 GB RAM, and a 1TB solid state hard drive. It shall include the latest Windows 64-bit operating system (Windows 10 pro or newer), VM support, and an Ethernet adapter (10/100MB with RJ45 connector).Connection to the BAS LAN network shall be via an Ethernet network interface card, 100 Mbps.
2. The server shall support all network/building controllers, OWSs, and 3rd party mechanical / electrical systems connected to the Facility Management Control / Building Automation System Local Area Network.
3. {SERVER}Acceptable Manufacturers are:

    a. {SERVER}Dell
    b. Lenovo
    c. HP (Hewlett Packard)

C. Uninterruptable Power Supplies: Provide the OWS, Server, and each network/building controller with individual UPS to provide clean, reliable, noise-filtered power at all times and to protect and maintain systems operation throughout short term power interruptions of up to 15 minutes duration. Acceptable Manufacturer is APC.

2.2 REMOTE ACCESS AND CYBER SECURITY BEST PRACTICES

A. Remote Access:

1. The BAS contractor shall comply with Client Agency IT infrastructure security policies for remote access. The Client Agency IT team shall provide VPN, firewalls, etc. as needed for secure remote access.
2. A VPN and firewall must be used for secure remote access.

B. Cyber Security Best Practices:

1. Unless predetermined by the Client Agency IT team the BAS network shall be separate from the Client Agencys IT infrastructure besides a single point connection for remote access (Client Agency provided internet access). All Ethernet switches and communication backbone required for a fully operational BAS shall be provided by the BAS contractor.
2. Refer to “Communication Backbone” section of this specification for further details on segmenting the network (VLANs, subnets) and when edge or managed switches are required based on building size / type.
3. Do not use factory provided usernames and passwords. Update passwords and usernames regularly for strong system security.
4. Update software and firmware regularly.
5. Adhere to controls manufacturer hardening guidelines where applicable.

2.3 OPERATOR SOFTWARE

A. Real-Time Displays:

1. Provide a visual graphical representation of buildings, floor layouts, each piece of mechanical equipment and/or mechanical system that duplicates the represented system, presented as a web page via any industry standard web browser, where applicable.
2. Graphics shall include at a minimum the value of each input, each output, each setpoint, alarms and graphical representation of trend logs.

B. On-Line Help: Provide a context sensitive, on-line help system to assist the operator in operation and editing of the system.

C. Security:

1. Each operator shall be required to log on to that system with a user name and password in order to view, edit, add, or delete data.
2. System security shall be selectable for each operator.
3. The system administrator shall have the ability to set passwords and security levels for all other operators.
4. Each operator password shall be able to restrict the operators’ access for viewing and/or changing each system application, full screen editor, and object.
5. Each operator shall automatically be logged off of the system if no keyboard or mouse activity is detected.
6. This auto log-off time shall be set per operator password.
7. All system security data shall be stored in an encrypted format.

D. System Diagnostics:

1. The system shall automatically monitor the operation of all workstations, printers, modems, network connections, building management panels, and controllers.
2. The failure of any device shall be annunciate to the operator.

E. Third-Party Windows-Based Programs:

1. The system shall be capable of utilizing third-party Windows-based programs for such things as spreadsheet analysis, graphing, charting, custom report generation, and graphics design packages.
2. Graphics generation shall be done using standard Windows packages.
3. No proprietary graphics generation software shall be needed.

F. Overrides:

1. It shall be possible for the operator to override automatic analog and digital output commands.
2. Where the BAS software normally originates these outputs, the provision shall exist for the operator to terminate automatic BAS control of any particular output and to originate a manual analog or digital output command.
3. The provision shall exist for the operator to return analog or digital output command functions to automatic BAS software control.

G. Password Protection: Provide security system that prevents unauthorized use unless operator is logged on.

H. Trend Data:

1. System shall periodically gather historically recorded selected samples of object data stored in the field equipment (global controllers, field controllers) and archive the information on the operator’s workstation (server) hard disk.

    a. Archived files shall be appended with new sample data, allowing samples to be accumulated over 3 years.
    b. Systems that write over archived data shall not be allowed, unless limited file size is specified.
    c. Samples may be viewed at the operator’s terminal in a trend log.
    d. Logged data shall be stored in spreadsheet format.
    e. Operator shall be able to scroll through all trend log data.

2. Software shall be included that is capable of graphing the trend logged object data. Software shall be capable of creating two-axis (x,y) graphs that display up to six object types at the same time in different colors and these Graphs shall show object type value relative to time.
3. Operator shall be able to change trend log setup information such as time intervals and objects logged

I. Graphics:

1. The operator’s workstation shall display all data associated with the project.

    a. Operator’s workstation shall display all data using 3-D graphic representations of all mechanical equipment.

2. System shall be capable of displaying graphic file, text, and dynamic object data together on each display.

    a. Information shall be labelled with descriptors and shall be shown with the appropriate engineering units.
    b. All information on any display shall be dynamically updated without any action by the user.
    c. Terminal shall allow user to change all field-resident BAS functions associated with the project, such as setpoints, weekly schedules, exception schedules, etc. from any screen no matter if that screen shows all text or a complete graphic display.

3. Animated graphic objects shall be displayed as a sequence of multiple bitmaps to simulate motion.
4. Analog objects may also be assigned to an area of a system graphic, where the color of the defined area would change based on the analog objects value.

    a. For example, an area of a floor-plan graphic served by a single control zone would change colour with respect to the temperature of the zone or its deviation from setpoint.

5. Separate Displays shall be supplied, specific to the project, to form the following overall presentation style.
6. All Displays will be linked in a logical fashion using hyperlink style (single left mouse click on text/display object/dynamic to load linked display if programmed)
7. Entire system shall operate without dependency on the operator's terminal. Provide graphic generation software at each workstation.

J. Alarms:

1. Operator’s terminal shall provide audible, visual, electronic and printed means of alarm indication.
2. Any alarm may be handled based on its individual or assigned class actions.

    a. Displayed on the Alarm console.

        1) The system shall be provided with a dedicated alarm window or console.
        2) This window will notify the operator of an alarm condition, and allow the operator to view details of the alarm and acknowledge the alarm.

    b. Alarm reports shall be viewable via the BAS system and available for delivery by electronic mail (e-mail) or printing.

3. System shall provide log of alarm messages. Alarm log shall be archived to the hard disk of the system operator’s terminal.

    a. Each entry shall include a description of the event-initiating object generating the alarm, time and date of alarm occurrence, time and date of object state return to normal, and time and date of alarm acknowledgement.

K. Scheduling:

1. Operator’s terminal display of weekly schedules shall show all information in easy-to-read 7-day (weekly) format for each schedule.
2. Exception schedules (non-normal schedules, such as holidays or special events) shall display all dates that are an exception to the weekly schedules.

3. At the operator's terminal, the system user shall be able to change all information for a given weekly or exception schedule if logged on with the appropriate security access.

L. Archiving:

1. Store back-up copies of all controller databases in at least one OWS and the server.
2. Provide continuous supervision of integrity of all controller databases.
3. Data base back up and downloading to occur over LAN without operator intervention.
4. Operator to be able to manually download entire controller database or parts thereof.

M. Reports:

1. Provide a report facility to generate and format for display, printing, or permanent storage, as selected by the operator, the reports as specified in this section.
2. Provide the software to automatically generate any report specified; the user will be able to specify the type of report, start time and date, interval between reports (hourly, daily, weekly, monthly) and output device.
3. As a minimum, the following reports shall be configured on the system:

   a. Dynamic Reports: To allow operator to request a display of the dynamic value for the user specified points which shall indicate the status at the time the request was entered and updated at an operator modifiable scan frequency.
   b. Summary Report: To permit the display or printing of the dynamic values for the user specified points.
   c. Trend Reports: To permit the trending of points selected by the operator, including as a minimum digital input and output, analog input and output, set points, and calculated values.
   d. Historical Data Collection: Provision shall be made to ensure historical data is not lost.
   e. Alarm Summary: Provide a summary of all points in alarm and include as a minimum; point acronym, point description, current value, alarm type, limit exceeded, and time and date of occurrence.
   f. Disable Point Summary: Provide a summary of all points in the disabled state and include as a minimum point acronym and point description.
   g. Run Time Summary: Provide a summary of the accumulated running time of selected pieces of equipment with point acronym and description, run time to date, alarm limit setting. The run time shall continue to accumulate until reset individually by means of suitable operator selection.
   h. Schedule Summary: Provide a summary of all schedules and indicate as a minimum, which days are holidays and, for each section, the day of the week, the schedule times and associated values; for digital schedules value will be on or off; for analog schedules value will be an analog value.
   i. User Record Summary: Provide a summary of all user records to include as a minimum; user name, password, initials, command access level and point groups assigned.

2.4 BAS CONTROLLERS

A. All controllers on the job shall have the following minimum requirements:

1. IP Communication (BACnet/IP):

   a. BACnet/IP communication protocol shall be used for all BAS manufacturer provided controllers (including terminal devices such as VAVs, FCUs, etc.)

b. Support for IPv4 addressing
c. DHCP support and Auto DNS
d. Baud rate of not less than 100 Mbps
e. 2 - RJ45 ports each capable of supporting 10/100 Base-T.

1) Supporting controller daisy chaining on the Ethernet network via integral switch functionality.
2) Integrated fail-safe should allow for communication when the controller is powered down.

f. All controllers shall be able to communicate peer-to-peer without the need for a Network Control Unit (such as JACE, NAE, etc.) and shall be capable of assuming all responsibilities typically assumed by a Network Control Unit.

1) Any controller on the Ethernet Data Link/Physical layer shall be able to act as a Master to allow for the exchange and sharing of data variables and messages with any other controller connected on the same communication cabling. Slave controllers are not acceptable.
2) The resulting network will be a 'Flat' topology with all devices (controllers, workstations, …) connecting at the same physical network level

2. Memory and Processing:

a. 512MB of RAM and 4GB of non-volatile flash memory.
b. 32-bit microprocessor operating at a minimum of 600 MHz

3. Each individual controller shall have an embedded web-based HTML5 visual interface with the following functionality without reliance on any other controller for access:

a. Typical and custom control processes
b. Scheduling
c. Energy management applications
d. Alarm management applications
e. Historical/trend data for points specified
f. Maintenance support applications
g. Graphical interface

4. Shall be capable of monitoring/controlling the following types of inputs/outputs:

a. Digital inputs from dry contact closure, pulse accumulators, voltage sensing.
b. Analog inputs of 4-20 mA, 0-10 VDC, thermistor and RTD in the range 0 to 350,000 ohm.
c. Digital outputs including Form C relay outputs and Triac outputs
d. Analog outputs of 4-20 mA and 0-10 VDC.

5. A minimum of 10% spare capacity shall be provided for each point type for future point connection.
6. Any software required for programming shall be unlicensed and openly available.
7. Auto commissioning features shall be available for VAVs and FCUs to schedule automatic testing and record values (air flows, pressures, temperatures, etc.) for different operating modes. The auto commissioning feature shall be able to email reports and run commissioning on a specified schedule.
8. Power and Environmental Requirements:

a. 24 VAC with local transformer power

b. The controllers shall also function normally under ambient conditions of 32 ˚F to 122 ˚F and 0% to 90% RH (non-condensing).
c. Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly.

9. Code Compliance:

a. “FIPS 140-2 Level 1 Compliant” cryptographic module
b. BACnet Testing Laboratory (BTL listed) using Device Profile BACnet Building Controller (B-BC) with outlined enhanced features.
c. UL916 Energy management equipment
d. FCC rules part 15, subpart B, class B
e. UL94-V0 flammability rating

2.5 COMMUNICATION BACKBONE

A. To allow for future expandability, cyber security measures, optimal bandwidth, and enhanced data trending this project shall adhere to the below communication backbone requirements.

B. IP (CAT 5 / RJ45) Network:

1. For all projects with less than 10 levels (including rooftops/cellars), less than 100m between Ethernet connections, less than 500 controllers, and only BAS controls on the same network.
2. Gigabit Ethernet Switches shall be provided as needed to support a fully functional BAS.
3. Provide an industrial router as the interface between the BAS network and the single point connection to the Client Agency provided internet network.

a. Approved Manufacturer / Model: Teltonika (Model RUTX11)

C. BACnet IP: BACnet/IP communication protocol shall be used for all BAS manufacturer provided controllers (including terminal devices such as VAVs, FCUs, etc.)

D. Modbus RTU, Modbus TCP, and BACnet MS/TP (RS-485)

1. Modbus RTU and BACnet MS/TP shall only be used for third party systems / equipment that do not have IP provisions (VFDs, boilers, etc.)
2. Modbus TCP shall only be used for third party systems / equipment that do not support BACnet/IP.

2.6 CONTINUITY OF OPERATION AFTER ELECTRIC POWER INTERRUPTION

A. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems shall automatically return equipment and associated controls to operating state occurring immediately before loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

2.7 POWER CONDITIONING

A. Protect DDC system products connected to ac power circuits from irregularities and noise rejection. Characteristics of power-line conditioner shall be as follows:

1. At 85 percent load, output voltage shall not deviate by more than plus or minus 1 percent of nominal when input voltage fluctuates between minus 20 percent to plus 10 percent of nominal.
2. During load changes from zero to full load, output voltage shall not deviate by more than plus or minus 3 percent of nominal.
3. Accomplish full correction of load switching disturbances within five cycles, and 95 percent correction within two cycles of onset of disturbance.
4. Total harmonic distortion shall not exceed 3-1/2 percent at full load.

B. Ground Fault: Protect products from ground fault by providing suitable grounding. Products shall not fail due to ground fault condition.

2.8 CONTROL PANELS

A. Provide control panels with suitable brackets for wall mounting for each control system. Locate panel adjacent to systems served.

1. Fabricate panels of 16-gage furniture-grade steel, totally enclosed on four sides, with piano hinged door and keyed lock, with manufacturer's standard shop-painted finish and color.
2. Provide UL-listed cabinets for use with line voltage devices.
3. All panels powered by 120VAC circuits shall be provided with surge protection. This protection is in addition to any internal protection provided by the controller manufacturer. This protection shall meet UL, ULC 1449, IEEE C62.41B. A grounding conductor (min. 12 AWG) shall be brought to each control panel.
4. All control panels shall have a circuit breaker and available duplex outlet.
5. Control Transformers: Provide as required. Transformer loading shall not exceed 60% of capacity. All control transformers shall include primary and secondary circuit protection. Maintain enclosure environmental temperature within transformer operating range as recommended by transformer manufacturer.
6. Control panel shall be completely factory wired and piped, and all electrical connections made to a terminal strip. Control panel shall have standard manufacturer's color.
7. All gauges and control components shall be identified by means of nameplates.
8. All control tubing and wiring shall be run neatly and in an orderly fashion in open slot wiring ducts with cover.
9. Conduits shall not enter the top of panels.
10. Do not loop or coil excess wire in cabinet.
11. There shall be no drilling on the controller cabinet after the controls are mounted inside.
12. Careful stripping of wire while inside the cabinet is required to ensure that no wire strand fragments land on circuit boards.
13. Complete wiring and tubing termination drawings shall be mounted in or adjacent to each panel.
14. Indoor cabinets shall be NEMA 1 construction, unless noted otherwise. Cabinets located outdoors shall be NEMA 4X.
15. QA paper copy of the system control schematics from the as-built documentation, including I/O lists, control diagram identifying devices, etc., shall be provided in a plastic sleeve secured to the inside of the control panel door. A laminated, reduced size of the control diagram shall also be installed on the outside face of the panel.
16. Control panels containing more than 4 controllers shall be provided with a terminal strip for field wiring. All control wiring inside the panel shall be between a terminal strip and

controller inputs/outputs. All field control wiring shall be terminated at the terminal strip. Field control wiring inputs/outputs shall not be run directly to inputs/outputs of controller.

2.9 SEPARABLE SOCKETS (THERMOWELLS)

A. Comply with requirements Division 23 Section "Meters and Gages for HVAC Piping", including the use of heat-transfer compound.

2.10 PIPING, TUBING, AND VALVES

A. Water and Air Pressure Instrument Signal Tubing and Piping:

1. Products in this paragraph are intended for use with the following:

    a. Signal air between pressure instruments, such as sensors, switches, transmitters, controllers and accessories.
    b. Pressure signals to instruments connected to hydronic systems.

2. Copper Tubing:

    a. Seamless phosphor deoxidized copper, soft annealed or drawn tempered, with chemical and physical properties according to ASTM B 75.
    b. Performance, dimensions, weight and tolerance according to ASTM B 280.
    c. Diameter, as required by application, not less than nominal 0.25 inch.
    d. Wall thickness, as required by the application, but not less than 0.030 inch.

3. Copper Tubing Connectors and Fittings: Brass, compression or solder joint type.
4. Polyethylene Tubing (Air Signals ONLY):

    a. Fire-resistant black virgin polyethylene according to ASTM D 1248, Type 1, Class C and Grade 5.
    b. Tubing shall comply with stress crack test according to ASTM D 1693.
    c. Diameter, as required by application, of not less than nominal 0.25 inch.

5. Polyethylene Tubing Connectors and Fittings (Air Signals ONLY): Brass, barbed fittings or compression type fittings.

B. Steam System Tubing: Products in this paragraph are intended for signals to pressure instruments connected to steam systems.

1. Stainless-Steel Tubing: Seamless Type 316 stainless steel, Grade TP, cold drawn, annealed and pickled, free from scale.

    a. Chemical and physical properties according to ASTM A 269.
    b. Diameter, as required by application, of not less than nominal 0.25 inch.
    c. Wall thickness, as required by application, but not less than 0.035 inch.

2. Stainless-Steel Tubing Connectors and Fittings: Connectors and fittings shall be stainless steel, with stainless-steel collets, flareless type. Connect instruments to tubing with connectors having compression connector on one end and IPS or NPT thread on other end.

C. Air Static Pressure Tips:

1. Duct Applications: Constructed of brass or stainless steel tubing, with a mounting flange and a 90 degree bend, with four (4) 0.040" diameter, radially drilled sample holes located near the tip and set a minimum of 4" away from the duct or plenum wall. Dwyer A-301 or A-302 series, or approved equal.
2. Indoor Room Pressure Applications: Constructed of stainless steel, with a mounting flange for finished ceiling or wall installation. Dwyer A-414 or approved equal.
3. Outdoor Building Pressurization (Differential Pressure Measurement) Applications: Dwyer A-306 series probe for the low (outdoor) side with a Modus pneumatic surge dampener piped to both the high and low ports, or approved equal. Locate the outdoor probe as far away from building walls and other turbulence inducing objects/ obstructions as possible. Terminate the indoor probe in the ceiling space. The differential pressure sensor shall be located indoors and piping extended tot eh outdoor probe.

D. Pressure Snubbers: Comply with requirements Division 23 Section "Meters and Gages for HVAC Piping".

E. Manual Valves: Needle Type. Comply with requirements in Division 23 Section "Meters and Gages for HVAC Piping".

F. Syphons: Comply with requirements in Division 23 Section "Meters and Gages for HVAC Piping".

2.11 CONTROLS SYSTEMS FIELD DEVICES

A. Input Devices:

1. Airflow Low Differential Pressure Switch:

a. Rating: NEMA 1
b. Mounting: Duct Insertion.
c. Range: 0.05" to 5.0" WC, complete with field adjustable setpoint.
d. Protection: Overpressure to 1 PSIG
e. Output: Form C Contact, minimum 50VA
f. Reset: Automatic or manual reset as required by the sequence of operation.
g. Accessories: Provide complete installation kit including static pressure tips, tubing, fittings and air filters.

2. Airflow High Differential Pressure Switch:

a. Rating: NEMA 1
b. Mounting: Duct Insertion
c. Range: 1" to 10" WC, complete with field adjustable setpoint
d. Protection: Overpressure to 1 PSIG
e. Output: 2 Form C Contacts, minimum 360VA
f. Accessories: Provide complete installation kit including static pressure tips, tubing, fittings and air filters.

3. Air Differential Pressure and Static Pressure Sensors:

a. Enclosure Rating: NEMA 1 (indoors) or 4X (outdoors). Installing exterior units inside a field-provided NEMA 4X enclosure is also acceptable.
b. Accuracy: +/- 0.5% of natural span.

c. Mounting: Duct Insertion
d. Range: 0.05" to 5.0" WC
e. Protection: Overpressure to 1 PSIG
f. Output: 0-10vDC, 4-20mA
g. Accessories: Provide complete installation kit including static pressure tips, tubing, fittings and air filters.

4. Water Differential Pressure Transducer With Three Valve Manifold (for pump VFD control):

a. Provide differential pressure transmitter with three-valve Manifold.
b. Rating: NEMA 1.
c. Mounting: Pipe mounted.
d. Range: 0-25 PSI unidirectional
e. Accuracy: +/-0.25% of full scale.
f. Protection: 150 PSIG
g. Output: 4-20mA, 0-5 VDC, 0-10 VDC.
h. Accessories: Needle valves and snubbers.
i. Acceptable Manufacturer:

1) Transducer: Kele Model # 230, or approved equal by Veris.
2) Three valve manifold: Kele Model # M230-3VLV, or approved equal.

5. Water Differential Pressure Switch:

a. Materials: Brass bellows.
b. Mounting: Pipe mounted.
c. Range: 2-26 PSI, 1.2 PSI fixed differential.
d. Protection: 120 PSI Differential overpressure, 180 PSI static pressure.
e. Output: Form C contacts, 50 VA
f. Special: Pipe taps and shut off valves provided by Div. 23.

6. Pipe Liquid Pressure Sensors:

a. Construction: Wetted parts of transmitter constructed of Type 316 stainless steel.
b. Range: Minus 0 to 300 psig.
c. Span: Field adjustable.
d. Minimum Span: 3 psig.
e. Accuracy: Within 0.1% of span.
f. Process Temperature Limits: Minus 40 to 250 deg. F.
g. Ambient Temperature Limits: Minus 40 to 185 deg. F.
h. Analog Output: Two-wire, 4- to 20-mA.
i. Transmitter Enclosure: NEMA 250, Type 4X.
j. Accessories: Needle valves and snubbers.

7. Pipe Steam Pressure Sensors: As specified above for liquid pressure sensors, but provided with a pigtail steam syphon and pressure snubber between the pipeline and the sensor. Provide additional length of uninsulated tubing between the syphon and sensor to prevent the sensor's temperature rating from being exceeded. Prime syphon prior to startup and pipe in a manner such that condensate regularly formed in the line will maintain a seal in the syphon.

8. Pipe Liquid Temperature Sensors: Platinum 1000 Ohm RTD or thermistor type.

a. Materials: Stainless steel sheath.

b. Range: -50ºF to 250ºF
c. Accuracy: 0.1%
d. Drift: Within 0.5 deg. F. over 10 years.
e. Installation: In thermowell with heat transfer compound.

9. Steam Piping Clamp-on Temperature Sensor: 10K ohm, type 3 thermistor or 1K platinum RTD, with metallic housing. 4-20mA or 0-10 VDC output, with temperature range suitable for the application. Attach to pipe with stainless steel straps. Provide heat conductive paste if recommended by sensor manufacturer.

   a. Clamp-on sensors shall only be used when specifically indicated on the Drawings or sequences of operation.

10. Duct / Plenum Low Temperature Switches (FreezeStats): Capillary tube type with continuous sensing of temperature. Freezestats with discrete temperature sensing points are not acceptable.

    a. The low temperature limit switch shall be of the automatic reset type with Double Pole/Single Throw snap acting contacts rated for 16 amps at 120VAC.
    b. The sensing element of each freezestat shall be a minimum of 20 feet in length and shall react to the coldest 12 inch section.

11. Duct High Temperature Switches:

    a. The high temperature limit switch shall be of the automatic reset type with Single Pole / Double throw that opens with rise in temperature.
    b. Unit shall be UL approved
    c. Unit shall have an adjustable set point from 100 to 250 Degrees F with a 25 Degrees F differential deadband.
    d. The sensing element shall be 5" or 11" in order to fit the application.
    e. High Temperature Limit Switch shall be Kele Model TC-105 or TC-100, or approved equal.

12. Duct Temperature Sensors (Single Point): Platinum 1000 Ohm RTD type.

    a. Materials: Nickel element in a copper sheath.
    b. Range: -50ºF to 250ºF
    c. Accuracy: 0.1%
    d. Drift: Within 0.5 deg. F. over 10 years.
    e. Special: Duct element holder, gasket, and cover.
    f. Element Length: Shall span at least 33% of the duct.

13. Duct and Plenum Temperature Sensors (Averaging): Platinum 1000 ohm RTD type, with continuous wire strands to provide average temperature across entire length of sensor element. Averaging sensors with discrete sensing points (i.e. thermistor type) are not acceptable. The sensor shall have a sintered moisture protection coating protecting against condensation, mechanical stress, and vibration.

    a. Range: -50ºF to 250ºF
    b. Accuracy: 0.1%
    c. Drift: Within 0.5 deg. F. over 10 years.
    d. Special: Probe brackets to support turns in the element and prevent vibration during system operation.
    e. Length: As required by application to cover entire cross section of air tunnel or duct. The length of the averaging bulb shall be sufficient to cover the free area

from top to bottom. Each pass of the bulb shall not exceed 12 inches from the previous pass.

14. Relative Humidity Sensors: Thin-film capacitive type or complementary metal oxide semiconductor (CMOS) type, with nonvolatile memory.

    a. Mounting: Duct or Wall.
    b. Range: 10% to 90%.
    c. Accuracy: +/-2% of full scale.
    d. Long Term Drift: +/- 0.25%
    e. Protection: 0-100% non-condensing.
    f. Output: 0-10vDC, 4-20mA.
    g. Special: Duct or wall mounting kit.
    h. Acceptable Manufacturers: Subject to compliance with requirements, provide products by one of the following:

        1) Belimo
        2) Vaisala
        3) BAPI
        4) Setra
        5) Approved equal

    i. Wall Mounted Relative Humidity Sensors in Public Occupied Spaces: Space relative humidity shall be monitored by vandal-proof, flush-mount, stainless steel wall plate type sensors. The plate shall have no logos, and shall be single-gang size. The sensor shall be placed at perforations in the plate. Under no circumstances shall a conventional humidity sensor be utilized in public spaces.

15. DDC System Room Thermostats / Temperature Sensors:

    a. Room thermostats shall be compatible with the zone controller.
    b. Thermostats shall be unbranded (no logos).
    c. The temperature sensor shall be a IEC 751 Class A or B 1,000 Ohm platinum or nickel RTD, or 10k ohm thermistor.

        1) Resolution: +/- 0.2 deg. F.
        2) Accuracy: +/- 0.5 deg. F. at 77 deg. F. (25 deg. C.)
        3) Temperature Limits: -40 deg. F. to 120 deg. F.
        4) Temperature Range: As required by application, but no less than 32 deg. F. to 104 deg. F.
        5) Drift: No more than 0.3 deg. F. over 5 years.

    d. Room setpoint and current space temperature readout (backlit LCD display) integral to the main body of the thermostat. The setpoint value shall be the actual value, not a +/- local override amount.

16. Damper Position Switches (End Switches): Encapsulated (non-mercury) switch mounted on the damper crank arm. The use of auxiliary contacts on the actuator to indicate position is not acceptable. The switch shall be able to be mounted on a damper control shaft to give an indication of opened and closed damper position. The switch shall be open when the cable end of the switch is horizontal or above. The switch shall make when the cable end drops more than 15 degrees below horizontal. The unit shall have two (2) SPDT switches, plenum rated cable, and stainless steel housing.

    a. Switch shall be rated for outdoor use and rated at a minimum of 2A @ 120VAC

b. Acceptable Manufacturer: Kele 'TS-475' series, or approved equal.

1) A Kele 'TS-407' series encapsulated mercury type end switch may be acceptable where space constraints prohibit the use of the larger roller ball type. Confirm with the Client Agency that the use of an encapsulated mercury switch is acceptable prior to installation.

17. Water Flow Switch (Electronic Type):

a. Type: Thermal dispersion principle, incorporating no moving parts. Sensor head shall employ two temperature sensors and a low power heating source. Sensors shall be suitable for up to 350 deg F. fluid.
b. Construction: 316L stainless steel wetted parts. NEMA 4X electronics housing.
c. Rangeability: 300:1
d. Input Power: 24VDC.
e. Outputs:

1) Two (2) sets of dry contacts rated at 3A each for flow detection, with independent, adjustable switching setpoints.
2) 4-20 mA output for temperature.

f. Acceptable Product: Ameritrol Inc. "FX" series, or approved equal.

18. Current Switch:

a. Materials: Encased copper.
b. Rating: 600vAC.
c. Mounting: Split Core.
d. Range: 1.5 amps to 50 amps.
e. Action: Trip point adjustment.
f. Output: SPST, N.O.
g. Special: Status LED

19. Remote Current Switch / Command Relay Combination:

a. Mounting: Panel or Electrical Box
b. Range: .5 to 16 Amps
c. Trip Set-point: Adjustable
d. Sensor Power: Induced
e. Max. Operating Voltage: 250 VAC
f. Frequency Range: 50/60 Hz.
g. Humidity Range: 0 to 95% non-condensing
h. Operating Temperature: -15° to 60°C
i. Status Output: 1.0A @ 30 VAC/DC
j. Switch shall have HOA switch to override and troubleshooting
k. Switch shall include belt loss detection feature.
l. Manufacturer: Hawkeye H548 series, or approved equal

20. Current Transducer:

a. Mounting: Field Mounted.
b. Range: 60 Hz nominal.
c. Accuracy: +/-2% full scale.
d. Protection: 250 A max current.
e. Output: 4-20mA.

21. Carbon Dioxide (CO2) Sensors: Non-dispersive infrared (NDIR) type, with temperature compensation. Wall-mounted devices shall have an LCD display of current sensed concentration.

    a. Materials: Molded plastic enclosure.
    b. Mounting: Duct or wall.
    c. Range: 0 to 2000 ppm.
    d. Accuracy: +/- 50 ppm.
    e. Repeatability: +/- 20 ppm.
    f. Drift Stability: Less than 5% of full scale or max +/- 75 ppm over 3 years.

        1) Automatic background calibration.

    g. Response time: Less than 2 minutes.
    h. Barometric Drift / Compensation: Max. 1.5% change in reading per 0.15 psig deviation from 14.5 psig.
    i. Protection: 175psi, -40ºF to 140ºF
    j. Output: 0-10 VDC or 4-20mA
    k. Warranty Period: 3 years.
    l. Maximum Manufacturer's Recommended Calibration Interval: 3 years.
    m. Acceptable Manufacturers: Subject to compliance with requirements, provide products by one of the following:

        1) BAPI
        2) Honeywell
        3) Johnson Controls
        4) Siemens
        5) Vaisala
        6) Approved Equal.

    n. Calibration Kit: Provide a calibration kit that provides all required materials to enable the Client Agency to self-perform calibration of CO2 sensors. The kit shall include calibration gases at two levels of concentration (single point at 450 ppm, and span gas at 1,200 ppm), gas regulators, carrying case, flexible tubing and gas shroud (funnel), and instructions.

        1) Include enough calibration gases to perform at least 2 calibrations for each CO2 sensor provided on this project.

22. Space Override Request / Command Pushbutton Switches: Provide single or dual pushbuttons, as required by the sequence of operation. 1-inch diameter round button. Button shall not extend more than 1/2-inch from faceplate.

    a. Button Material: Bakelite.
    b. Button Color: Start command -green; stop command - red.
    c. Rating: 10amps. 600VAC max..
    d. Mounting: Wall, single gang.
    e. Output: SPDT Momentary Contact.
    f. Special: Provide with cover plate.

23. Single-Point Water Leak Sensors: Water leak sensor utilizing a single set of gold plated sensing probes on the bottom of the device itself. The height of the probes above the monitored surface shall be adjustable between 0.0 and 0.5 inches.

a. Output: Output: Two (2) Form C - 24V contacts rated for 3A each, each field configurable for NC or NO.
b. Acceptable Product: Vertiv / Liebert "Liqui-tect 410", or approved equal.

24. Cable-Type Water Leak Sensors: Water leak sensor utilizing a cable-type sensor up to 100 feet long. Detection of water along any portion of the cable shall trigger the device. Outputs shall be housed in a metal enclosure with a hinged top door providing access to the internal circuit board for wiring termination and configuration of DIP switches. The device shall include an adjustable alarm time delay.

    a. Output: Two (2) Form C - 24V contacts rated for 3A each, each field configurable for NC or NO.
    b. Local Indication: LEDs to indicate fault condition.
    c. Accessories: Cable hold-down clips and NEMA 4X enclosure to house sensor electronics.
    d. Acceptable Product: Vertiv / Liebert "Liqui-tect 460" combined with "LT500Y" sensing cable, or approved equals.

25. Water Level Switches: Float type, with a float arm hinge design that limits vertical movement to prevent sticking. Float shall be replaceable.

    a. Level Actuation and De-Actuation: 0.75-inch) deadband.
    b. Body Pressure Limit: 1000 psi
    c. Float Pressure Limit: 150 psig.
    d. Temperature Range: -4 to 275 deg. F.
    e. Switch Type: SPDT snap switch, with 10 A at 125/250-VAC electrical rating.
    f. Float and Rod: Type 316 stainless steel.
    g. Body: Brass or Type 316 stainless steel.
    h. Magnetic Keeper: Type 430 or 316 stainless steel.
    i. Enclosure: NEMA 250, Type 4.

26. Domestic Water Flow Metering (Compound, Wide Flow Range Type):

    a. Type: Flanged, cast bronze, coated ductile iron, or stainless steel main case.
    b. Flow Element: Compound type with both turbine and nutating disc flow elements OR single turbine element and magnetic drive meeting the low flow accuracy requirement of this Section.
    c. All materials shall be completely lead free and the meter shall meet NSF /ANSI Standard 61.
    d. Accuracy: AWWA Class II measuring element meeting accuracy requirements of AWWA C701 (+/- 1.5% for entire normal operating range). The 'normal operating range' shall extend to flows as low as 1.0 gpm in sizes 3" and smaller; and 5.0 gpm in sizes from 4" to 10".

        1) Provide plate type strainer and flow straightener upstream of meter.
        2) Straight distance requirements to meet the above specified accuracy shall not exceed 5 pipe diameters upstream and 2 pipe diameters downstream.

    e. Maximum working pressure: 150 psig at 80 deg. F.
    f. Interchangeable measuring element for in-line service.
    g. Signal Output: Scalable pulse output for totalization.
    h. Acceptable Manufacturers: Subject to compliance with requirements, provide one of the following products:

        1) Sensus 'OMNI C2' Meter

2) Neptune Technology Group 'TRU/FLO' Compound Meter
3) Badger Meter 'Recordall Compound Series'.

B. Relays:

1. Control Relays:

a. Materials: Gold Flash.
b. Rating: 10amps @ 120-277vAC.
c. Mounting: Standard Electrical Box.
d. Protection: NEMA 1 Housing.
e. Output: SPDT, DPDT.
f. Special: Provide LED for position indication. Provide with HOA switch, except when used in smoke control applications.

2. Remote Current Switch / Command Relay Combination:

a. Mounting: Panel or Electrical Box
b. Range: .5 to 16 Amps
c. Trip Set-point: Adjustable
d. Sensor Power: Induced
e. Max. Operating Voltage: 250 VAC
f. Frequency Range: 50/60 Hz.
g. Humidity Range: 0 to 95% non-condensing
h. Operating Temperature: -15° to 60°C
i. Status Output: 1.0A @ 30 VAC/DC
j. Switch shall have HOA switch to override and troubleshooting
k. Switch shall include belt loss detection feature.
l. Manufacturer: Hawkeye H548 series, or approved equal.

C. Controlled Output Devices:

1. Control Valves, General Requirements: All valve shall be tight closing, quiet in operation and be arranged to fail safe, in either a normally open or normally closed position in event of a power failure.

a. All modulating valves shall be fully proportioning.
b. Normal position shall be as indicated in the sequences of operation or on the Drawings.
c. All two-position valves shall have spring returns.
d. Valves sized 2" and larger shall have position indication.

2. Modulating, Pressure-Dependent, Two-Way and Three-Way Hydronic Characterized Bronze Ball Control Valves- 2 inches and smaller:

a. Forged bronze, stainless steel ball and blowout proof stainless steel stem and EPDM O-rings with minimum 600 psi CWP (WOG) rating. Modulating valves shall contain glass filled ball insert capable of providing equal percentage flow. Valves shall have allowable media temperature of 20 deg. F to 250 deg. F. Brass body valves are <u>not</u> acceptable.
b. Leakage Rating:

1) Valves 1" and smaller: FCI 70-2, Class III.
2) Valves 1-1/4" to 2": FCI 70-2, Class IV.

c. Rangeability: Minimum 150 to 1.
d. Close Off Rating:

1) 2-Way Valves: 100 psid.
2) 3-Way Valves 70 psid.

e. Medium: Valves shall be used with hot water or cold water with up to 50% glycol.
f. Modulating Valve Flow Characteristics:

1) 2-way valves serving heat exchange devices (e.g. coils, heat exchangers, etc.) shall have equal percentage characteristics by way of a shaped characterizing disc with a V-shaped opening. The characterizing disc shall be located on the inlet side of the ball and secured in place between the ball and seat. Discs secured by C-clips (i.e. 'circlips' or snap rings) will not be acceptable.
2) 2-way hydronic bypass valves maintaining minimum system flowrates shall have linear flow characteristics.
3) 3-way valves shall have an equal percentage characteristic through the control port, and a linear characteristic through the bypass port.

g. Subject to compliance with requirements, provide valves by one of the following manufacturers:

1) Belimo
2) Bray International
3) Honeywell
4) Johnson Controls Inc.
5) Siemens

h. Refer to Part 3 this Section for sizing requirements.

3. Two-Position, Two-Way and Three-Way Hydronic Bronze Ball Control Valves- 2 inches and smaller:

a. Forged bronze, stainless steel ball and blowout proof stainless steel stem and EPDM O-rings with minimum 600 psi CWP (WOG) rating. Valves shall have allowable media temperature of 20 deg. F to 250 deg. F. Brass body valves are not acceptable.
b. Leakage Rating:

1) Valves 1" and smaller: FCI 70-2, Class III.
2) Valves 1-1/4" to 2": FCI 70-2, Class IV.

c. Close Off Rating:

1) 2-Way Valves: 100 psid.
2) 3-Way Valves 70 psid.

d. Medium: Valves shall be used with hot water or cold water with up to 50% glycol.
e. Subject to compliance with requirements, provide valves by one of the following manufacturers:

1) Belimo
2) Bray International
3) Honeywell

4) Johnson Controls Inc.
5) Siemens

f. Refer to Part 3 this Section for sizing requirements.

4. Pressure-Dependent Two-Way Hydronic Butterfly-Type Control Valves, sized 2.5 inches to 4 inches, and Three-Way Valves sized 2.5 inches and larger:

a. Butterfly valves shall be ASTM A126 cast-iron or ASTM A536 ductile-iron, with a lug-wafer body and rated at 150 psig except where otherwise noted. Extended neck design.
b. 3-Way Valves: Two (2) - two-way butterfly valves, independently actuated, with control signals arranged so that the valves work in opposition for mixing or blending action, as required.
c. Stem: Stainless steel with field replaceable EPDM sleeve and stem seals.
d. Disc: Stainless steel or elastomer-coated ductile iron.
e. Seat: EPDM.
f. Leakage Rating: ANSI / FCI 70-2 Class VI ('bubble tight' shutoff).
g. Rangeability: Minimum 10:1 for 30° to 70° stroke range.
h. Close Off Rating:

1) Chilled Water: Minimum 150 psi close off.
2) Other than Chilled Water: Minimum 100 psi close off on 2-way valves and 70 psi on 3-way valves

i. Medium: Valves shall be used with hot water or cold water with up to 50% glycol, with temperatures up to 210 deg. F.
j. Subject to compliance with requirements, provide valves by one of the following manufacturers:

1) Belimo
2) Bray International
3) Honeywell
4) Johnson Controls Inc.
5) Siemens

k. Refer to Part 3 this Section for sizing requirements.

5. Globe Control Valves - Steam, sizes 1-1/2" and smaller:

a. Class 125 or 150, bronze body, stainless steel trim, rising stem, renewable composition disc, and screwed ends with back-seating capacity re-packable under pressure. Valves shall have stainless steel stems and allow for servicing including packing, stem, and disc replacement.
b. Flow Characteristics: Equal percentage.
c. Internal Construction: Replaceable plugs and seats of stainless steel. Teflon packing. Cage type trim, providing seating and guiding surfaces for plug on "top and bottom" guided plugs.
d. Leakage Rating: ANSI / FCI 70-2, Class IV.
e. Rangeability: Minimum 50 to 1.
f. Steam Rating: All components shall be suitable for up to 125 psig saturated steam (125 SWP).
g. Sizing: Refer to Part 3 this Section for sizing requirements.
h. Manufacturers: Subject to compliance with requirements, provide valves by one of the following manufacturers:

1) Belimo
2) Bray International
3) Honeywell
4) Johnson Controls Inc.
5) Schneider Electric
6) Siemens

6. Segmented V-Ball Control Valves - Steam, sizes 2" and larger:

a. Construction: Carbon Steel Body. Stainless steel stem, hardened stainless steel V-notch ball, field replaceable reinforced Teflon seat, and maintenance free spring loaded Teflon packing. -20 to 400 deg. F. temperature range.
b. Flow Characteristic: Equal Percentage.
c. ASME B16.10 Face to Face Dimensions
d. Leakage Rating: ANSI / FCI 70-2 Class VI ('bubble tight' shutoff)
e. Rangeability: 300:1.
f. Rated for no less than 250 psig at 400 deg. F.
g. Refer to Part 3 this Section for sizing requirements.
h. Subject to compliance with requirements, provide segmented V-ball steam control valves by one of the following manufacturers:

1) Belimo, "VB V-Ball" series.
2) Bray Intl. / Flow-Tek, "V Control" series.
3) DeZurik, "VPB" series.
4) Fisher, "Vee-Ball" series.
5) Trimteck, "OpVEE V-Notch" series
6) Valve Solutions Inc. (VSI), Series "V".

7. Control Dampers:

a. The DDC Contractor shall furnish all automatic control dampers not specified to be supplied integral to the HVAC equipment. These field-applied dampers shall be installed by the Division 23 Contractor.
b. Dampers shall be supplied with shaft / control rod extended to accommodate the specified operator. Only one control shaft per damper section. Only one actuator per damper shaft. Provide multiple damper sections mulled together when required to meet application requirements.
c. Damper actuators shall not be installed inside ducts unless specifically indicated on the Drawings, or approved by the Architect / Engineer.
d. Jackshaft Assemblies: Provide jackshafts for actuation, in lieu of using the damper's integral control rod, where required by the application, as recommended by the damper manufacturer. Jackshafts shall be TAMCO 'Horizontal Jackshaft' or 'Vertical Jackshaft', or approved equal.

1) Frame mounting brackets (i.e. bridge and side brackets) for the jackshaft shall be mill finish extruded aluminum, minimum 0.125-inch thickness.
2) Bearings: Minimum 1-inch inner diameter, maintenance-free, high-strength, abrasion and impact resistant thermoplastic polyamide. Sleeve bearings are not acceptable.
3) Bearing Housings: Mill finish extruded aluminum, bolted directly to the frame mounting bracket.
4) Blade Clips: Mill finish extruded aluminum and mounted directly to the drive blade. Formed blade clips are not acceptable.
5) Jackshaft: Minimum 1-inch diameter extruded aluminum tubing. No more than one jackshaft per damper section.

6) Crank arms, locking collars, and link bars shall be mill finish extruded aluminum. All non-aluminum parts are to be zinc-plated or galvanized steel.
7) Jackshaft rotation shall be 90 degrees and shall allow for direct mounting of actuators with no additional connectors or drive rods required.
8) Jackshafts shall be mounted directly over the drive blade in order to minimize length of the link bars.
9) Jackshaft linkage shall have fixed arms and bearings located at pivot points. Swivels are not acceptable.

e. Shape Applications:

1) For dampers shown on rectangular ducts, provide multi-bladed rectangular dampers matching the duct size. Damper frames shall have integral flanges for duct connections on each side (i.e. in-duct frame types are not acceptable). For dampers with heights less than 12", a single blade damper may be provided.
2) For dampers shown on round ducts, unless the damper size / shape is explicitly identified, the Contractor shall provide a square damper with duct transitions (physical space and system pressure and velocity requirements all permitting).

f. Material Applications:

1) Provide aluminum or galvanized steel damper construction (blades, frames, axles, and linkages) in galvanized duct systems.
2) Provide aluminum dampers (aluminum blades, frames, axles, and linkages) in aluminum duct systems.
3) Refer to Division 23 Section "Ductwork" for duct construction materials specified.

g. Rectangular Control Damper Blade Configuration:

1) All modulating / proportional dampers shall be opposed blade type.

a) Exception: Outdoor-air and return-air dampers as part of a mixed air arrangement shall be parallel blade.

2) Two-position dampers may be of the opposed or parallel blade type (Contractor's option).

h. Rectangular Control Dampers, Standard Construction:

1) Provide Standard Construction dampers where installed in galvanized steel ductwork, unless otherwise indicated.
2) Where indicated for installation in aluminum ductwork, provide damper with aluminum frames, blades, and axles.
3) Frames: Minimum 16 gauge galvanized steel structural hat channel with tabbed/reinforced corners. Extruded aluminum frames, minimum .080" thick, are also acceptable.
4) Blades: 14 gauge equivalent thickness galvanized steel. Blades shall be roll-formed airfoil type. Extruded 6000-series aluminum airfoil blades, minimum .060" thick, are also acceptable.
5) Blade Edge Seals: EPDM or extruded silicone suitable for -40°F to +212°F, mechanically locked into the blade edge. Adhesive or clip-on type seals are unacceptable.

6) Jamb seals: Flexible stainless steel, compression type to prevent leakage between blade end and damper frame. Blade end overlapping frame is unacceptable. EPDM or extruded silicone jamb seals are also acceptable in lieu of stainless steel.
7) Bearings: Corrosion resistant, permanently lubricated stainless steel sleeve or bronze oilite type turning in an extruded hole in the damper frame.
8) Axles: Minimum 7/16" cadmium plated steel or extruded aluminum. Hexagonal shape positively locked into the damper blade. Linkage shall be concealed out of air-stream, within the damper frame to reduce pressure drop and noise. Linkage bearings shall be stainless steel sleeve or bronze oilite.
9) Leakage Performance: Damper submittal shall include leakage, maximum airflow and maximum pressure ratings based on AMCA Publication 500. Dampers shall bear the AMCA 511 label for air leakage.

    a) Damper shall leak less than 3 cfm/sq. ft. at 1" of static pressure as per AMCA 500 (Class 1A damper), up to 60" blade width.

10) Pressure Drop Performance: A 36" x 36" sized damper shall have no more than .06 inches w.g. static pressure drop at 2,000 fpm face velocity, fully open.
11) Pressure and Velocity Ratings: Damper construction shall be suitable for up to 7" w.g. static pressure differential and 3,000 fpm face velocity in blade lengths up to 36".

i. Rectangular Insulated Control Damper Construction:

1) Dampers shall be as described above for Standard Construction, except for the following:

    a) Blades, frame, and axles shall be aluminum or stainless steel, or a combination thereof (i.e. galvanized steel is not acceptable).
    b) The internal volume of the blades shall be filled with high density expanded foam insulation, and the blades shall have an R-value of no less than 2.3.
    c) Frame shall be thermally broken with polyurethane resin pockets and thermal cuts. If the frame is not thermally broken, damper will still be acceptable if the damper has an AMCA Std. 500-D Thermal Efficiency Ratio of no less than 340%.

j. Round Control Damper Construction: Single blade, butterfly type with actuator mounting bracket. Minimum 20-gauge frame, and minimum 16 gauge blade (with higher gauges as required to meet pressure and velocity requirements). Bronze oilite bearings. Closed cell neoprene or EPDM damper frame or damper bade edge seal. Suitable for up to 4" w.g. static pressure and 3,000 fpm face velocity. AMCA licensed as a Class 1 damper.

1) Galvanized: Galvanized steel blade and frame. Cadmium plated steel shaft and control rod.

k. Subject to compliance with requirements, provide one of the following products:

1) Rectangular, Standard Construction:

    a) Ruskin 'CD50' (aluminum) or 'CD60' (galv. steel)

b) TAMCO '1500 Series'
c) Arrow 'AFD-20'
d) Greenheck 'VCD-33' (galv. steel) or 'VCD-40' (aluminum)
e) Johnson Controls 'VD-1330' (aluminum) or 'VD-1630' (galv. steel)
f) Pottorff 'CD-51/52' (aluminum) or 'CD-45/46' (galv. Steel)

8. Electric Actuators: The actuators shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the entire rotation of the actuator. Mechanical end switches or magnetic clutch to deactivate the actuator at the end of rotation are not acceptable.

a. For power-failure and safety applications, an internal mechanical spring return mechanism shall be built into the actuator housing. Non-mechanical forms of fail-safe operation are not acceptable. All spring return actuators shall be capable of either clockwise or counterclockwise spring return operation by simply changing the mounting orientation.
b. Actuators shall be designed for a minimum of 65,000 full stroke cycles at the actuator's rated torque and shall have a 2-year manufacturer's warranty, starting from the date of Substantial Completion.
c. Actuators shall be UL listed.
d. Electric Damper Actuators: Provide one actuator per damper section / damper shaft. Multiple actuators installed on a given shaft (i.e. "tandem mounting") is not acceptable.

1) Rating: NEMA 1 or 2 enclosure where located indoors. NEMA 4X where located outdoors.
2) Mounting: Direct mount on the associated damper shaft.
3) Location: Outside the ductwork.
4) Minimum actuator resolution: 100:1
5) Maximum actuator hysteresis: 2%
6) Stroke Time: 90 seconds end to end full stroke, 15 seconds return to normal for spring return.
7) Protection: Electronic stall protection.
8) Control Input: 0-10 VDC or 0-20mA DC.
9) Power: Nominal 24 VAC.
10) Torque: Size for minimum 150% of required duty.
11) Duty Cycle: rated for 65,000 cycles.
12) Special: Output position feedback, manual override, field selectable rotational/spring return direction, field adjustable zero and span.
13) Warranty: Two years, unconditional.
14) Provide built-in auxiliary switch for interfacing or signaling.

a) This switch shall not be utilized to provide position indication if an independent end switch device is required elsewhere by this Specification, or is indicated in the Sequences of Operation or on the Drawings.

e. Electric Valve Actuators: Provide one actuator per valve. Multiple actuators installed on a given shaft (i.e. "tandem mounting") is not acceptable.

1) Rating: NEMA 1 or 2 Enclosure where located indoors. NEMA 4X where located outdoors.

2) Mounting: Direct mount only.

a) Linkages, gearboxes, and rack/pinion arrangements are NOT acceptable, except on steam service globe valves where they are permitted.
b) Three-way butterfly control valve arrangements shall utilize two independent actuators (one per valve) controlled to a common pilot signal.

3) Minimum actuator resolution: 100:1
4) Maximum actuator hysteresis: 2%
5) Stroke Time: 90 seconds end to end full stroke, 15 seconds return to normal for spring return.
6) Control Input: 0-10 VDC or 0-20mA DC.
7) Power: Nominal 24 VAC.
8) Protection: Stall protection.
9) Torque: Size for minimum 150% of required duty.
10) Duty Cycle: rated for 65,000 cycles.
11) Warranty: Two years, unconditional.
12) Special: Output position feedback, manual override, field selectable direction, field adjustable zero and span.

a) For spring return (all valves except those 6" and larger), provide field selectable spring return direction.
b) Provide built-in auxiliary switch for interfacing or signaling.

f. Acceptable Manufacturers: Subject to compliance with requirements, provide actuators by one of the following manufacturers:

1) Belimo
2) Bray International
3) Honeywell
4) Johnson Controls Inc.
5) Schneider Electric
6) Siemens
7) IMI-TA

D. Miscellaneous Accessories:

1. Weather- and Sun-Shields: Provide for temperature sensors located outdoors shall prevent the sun from directly striking the sensor. The weathershield shall be provided with adequate ventilation so that the sensing element responds to the ambient conditions of the surroundings. The weathershield shall prevent rain from directly striking or dripping onto the sensor. Weathershields installed near or in outside air intake ducts shall be installed such that normal outside airflow does not cause rainwater to strike the sensor. Weathershields shall be constructed of unpainted aluminum or white PVC.

a. The shield shall be a BAPI 'Weather Shade' or approved equal.

2. Protective and Anti-Tamper Thermostat Guard: White epoxy coated 16-gauge perforated steel enclosure with hinged cover and integral key lock. Guard shall be Chase Security Systems 'PTG' series, or approved equal.

E. Non-DDC Thermostats:

1. On-Off Electric Thermostats:

a. Electric (line voltage) thermostats shall be of the single temperature, two-position type with concealed adjustment, On / OFF / Auto selector switch. Thermostats shall be suitable for the motor or heater load and voltage, single or two pole as required.
b. Low-Voltage, On-Off Thermostats: NEMA DC 3, 24-V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed set-point adjustment, 55 to 85 °F set-point range, and 2° F maximum differential.

2.12 CONTROL AND COMMUNICATION WIRING AND CABLES

A. Electric control wiring shall be in accordance with the National Electrical Code and Divisions 26 and 27 of these specifications, and shall not be in conflict with state and local codes. No control wiring shall be installed in the building lighting and power circuit system.

B. All conduit, fittings, hangers and accessories for control wiring installed under Division 23 shall conform to the levels of quality specified under Divisions 26 and 27.

C. Control wiring operating at voltages higher than 30VAC shall be single conductor solid or stranded copper not less than No. 12 AWG, 90 degrees C., with 600 volt Type THHN/THWN insulation. Wiring in panel construction may be No. 16 or No. 18 AWG copper provided same is properly protected and/or is in accordance with the NEC.

D. Low Voltage Cabling (30VAC and less): Twisted (six turns per foot) minimum 22 AWG wire, with 90 degrees C., 600 volt THHN/THWN insulation. Cable shall have a characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 17 pF per foot. The number of conductors (2, or 3 with a ground conductor) shall be as recommended by the ATC system manufacturer.

1. Shielded cable shall be provided for analog inputs, for communications between controllers, and for runs exceeding 500 feet. Both foil and braided type shields are acceptable. Ground at <u>one</u> end only; cap the other end. Capacitance between conductors and the shield shall be less than 60 pF per foot.
2. Use 20 AWG in runs exceeding 500 feet, but not exceeding 1,000 feet.
3. Use 18 AWG in runs exceeding 1,000 feet, but not exceeding 2,000 feet.
4. Use 16 AWG in runs exceeding 2,000 feet. Maximum length permitted is 4,000 feet.
5. Cable used on BACnet MS/TP networks shall be specifically designed and intended by the manufacturer to be used for RS-485 communication.
6. Cable shall be as manufactured by Alpha Wire Company, Belden Wire Company, Standard Wire and Cable, or approved equal.

E. Ethernet Cabling: Cat5e or Cat6, copper unshielded twisted pair (UTP), ETL verified to ANSI/TIA-568.2-D. Do not exceed 330 feet of cable length. Provide additional Ethernet switches or hubs to accommodate runs longer than 330 feet. Use solid conductors for runs longer than 50 feet. Conductor shall be min 24 AWG, except cabling to power-over-Ethernet (POE) devices shall utilize minimum. 22 AWG conductors. Cable shall be as manufactured by Leviton (Berk-Tek), Belden, Commscope, or approved equal.

1. All DDC system cabling connecting to the Client Agency's LAN shall be in full compliance with the Client Agency's requirements and the provisions of Division 27. In the event of

a conflict, between this Section and the Client Agency's Requirements or Division 27, this Section shall NOT take precedence.

F. Plenum Rated Wiring and Cables: Where plenum rated wiring and cables are required, the cable shall have with a peak optical density not greater than 0.50, average optical density not greater than 0.15, and a flame spread distance not greater than 5 feet, when tested in accordance with NFPA 262, as required by the NEC and International Mechanical Code.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verify that conditioned power supply is available to control units and operator workstation.

B. Verify that duct-, pipe-, and equipment-mounted devices and wiring are installed before proceeding with the balance of the control system installation.

C. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Architect for resolution before starting rough-in work.

D. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to the Architect for resolution before starting rough-in work.

E. Examine the contract documents (Drawings and Specifications) for work of other suppliers and Divisions. Report inadequate headroom or space conditions or other discrepancies to Architect and obtain written instructions for changes necessary to accommodate the work of this Section with work of other Divisions or suppliers. The controls contractor shall perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.2 DEMOLITION AND REUSE OF EXISTING MATERIALS AND EQUIPMENT

A. The Contractor shall assume that existing equipment that is specifically indicated on the Drawings to be reused is in good condition and is operable. The Contractor during the course of work, shall inspect these devices and determine if any devices are in need of replacement or repair. The Contractor shall prepare an itemized list of suggested repairs/replacement. This repair/replacement will be at the discretion of the Client Agency and may be accomplished under separate contract, at the Client Agency's direction.

B. Existing wire, conduit, and control panel cabinets may be reused at the Contractor's discretion, but only if such materials or equipment comply with the applicable specification for new materials and equipment. Such materials shall not be reused if visibly damaged or otherwise unsuitable for the intended service. Materials shall not be reused if visibly damaged or otherwise unsuitable for the intended service. The Client Agency does not guarantee the suitability of any such existing materials or equipment for reuse in accordance with the requirements for new materials and equipment.

C. Where such materials are reused, the contractor's shop drawings shall reflect the existing wiring designation. If existing labeling is illegible or otherwise does not comply with the applicable specification for labeling, wiring runs shall be relabeled in accordance with the requirements specified elsewhere.

D. Existing controllers and point expansion modules that are being replaced as part of this project shall be turned over to the Client Agency. All other existing control devices and panels that will not be reused shall be disposed of by the Contractor.

E. Existing electrical service to control panels or devices that are indicated to be demolished or otherwise will not be reused shall be properly terminated and secured per NEC requirements. Label wire with the panel and circuit breaker it is served by. Label wire as "HOT" if circuit cannot be de-energized. If existing electrical circuits only provide power to demolished control panels or devices, then the circuit shall be removed in its entirety (conduit, wire, and supports) back to the originating panel board circuit breaker. Update the panel schedule to reflect the circuit breaker as a "spare".

F. The Contractor shall clean and lubricate all damper linkages of control dampers being re-used under this Project.

G. Other materials and equipment not specifically mentioned herein may be reused only if specifically allowed by indications on the Drawings.

H. Where existing wall-mounted devices are removed in finished spaces, patch and paint the surfaces to match the adjoining surfaces.

I. Demolition of Control Points and Existing Programming and Graphics: All existing controllers, programming, and graphics associated with demolished HVAC systems / sub-systems shall be removed from the DDC system database / head end programming in a manner that permits all existing to remain DDC system controls to continue to function properly. The same applies to individual points being demolished on control sub-systems otherwise remaining in place. Menus and links containing references to the removed control sub-systems or individual points shall be removed. Existing to remain control loops utilizing data provided by the removed sub-systems and points shall be modified as required.

    1. For existing systems with existing workstation graphics being modified under this Project, the existing graphic shall be entirely removed from the system including all links and references and replaced with a new graphic meeting all requirements of this Project. Even if the renovation to an HVAC sub-system is only partial, the entire system graphic shall be replaced including existing points that will remain. Graphics shall not be split between old and new points. Existing system points shall be released and all points shall be created or recreated to meet the requirements of this Contract.

J. Extend control power and communication wiring and conduit as required to accommodate the relocation or replacement of existing equipment or motor controllers, and as required to maintain existing equipment otherwise not affected by the scope of the project under full automatic control.

K. Relocate existing control devices as required to accommodate the relocation of equipment, and as required to maintain existing equipment otherwise not affected by the scope of the project under full automatic control, unless new control devices are explicitly indicated.

L. If areas served by HVAC systems undergoing controls replacement or modification will remain occupied during the Project, all work involving changeover of control functions from existing systems to the new or modified controls shall be performed in accordance with the following sequence in order to minimize the duration of equipment outages. The following descriptions are intended to indicate the general sequence in which the work shall be performed, not to define fully the scope of the work.

1. If an entirely new DDC system is being provided, install construction server, operator's terminal, peripherals, graphic software, and network cabling prior to placing any equipment under the control of the new controls.
2. The following sequence applies each an individually controlled HVAC sub-system that is being modified under this Project. Only one (1) such system shall be placed under manual control, as described below, at any given time.

    a. Install controllers adjacent to or within the existing control panel. Programming shall be complete, except for loading and debugging, prior to installation. Install all field devices which do not require interruption of the existing system.
    b. Install all conduit, wiring, and pneumatic tubing which does not require interruption of the existing system.
    c. Remove existing controls including wiring, conduit, and tubing (except materials to be reused in accordance with provisions specified elsewhere) which must be removed to facilitate installation of new controls materials and equipment.
    d. Remove existing digital points. Install and calibrate remainder of new control materials and equipment for this subsystem. Load controllers software. Connect controllers to the network.
    e. Perform all field testing and calibration.
    f. Notify the Client Agency prior to this next step: Place the system under the control of the new controls equipment. Conclude field testing and submit field-testing report prior to placing the next subsystem under control. The Client Agency shall be given a password with a priority level that allows monitoring.
    g. Remove remaining existing materials and equipment, except materials to be reused in accordance with provisions specified elsewhere. All existing equipment for those subsystems that have not yet been fully transitioned to new controls work shall remain intact, on-line, and fully functional.

3.3 INSTALLATION - GENERAL REQUIREMENTS

A. Install equipment level and plumb.

B. Install software in control units and operator workstation. Implement all features of programs to specified requirements and connect and configure equipment and software as appropriate to achieve the sequence of operation.

C. Do not install control equipment and devices inside airstreams (e.g. inside ducts or air handling equipment air tunnels) unless the proper functioning of the device or equipment demands such an installation, or the equipment/device manufacturer recommends or requires such an installation. Devices and equipment may be installed in above-ceiling spaces that are used as return air plenums.

D. All control sensing devices shall be installed as to be accessible from the outside of the airstream served.

E. Verify location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation. Locate all devices that have a manual adjustment or visual read out feature in accordance with ADA regulations, 48-inches above the floor, unless noted otherwise on the Drawings. Field coordinate with the work of other trades, and subsequently verify all proposed locations with the Architect prior to proceeding.

F. Installations of controllers and input / output control devices outside the building shall be inside NEMA 4X enclosures. Factory devices with a housing of equivalent rating and intended by the manufacturer for exterior installations may be installed outside of enclosures.

1. Wherever possible, install damper motors, duct mounted sensors, and similar devices on outside of duct in weather-protected and warm areas, not in locations exposed to weather and outdoor temperatures.

    a. Where exterior damper actuator installation cannot be avoided, provide a NEMA 4X enclosure for mounting of the damper actuator, or provide an actuator with an equal or better NEMA rating.

G. Install labels and nameplates to identify control components according to Division 23 Section "Identification for HVAC."

1. Identify all control wires with labeling tape or sleeves using words, letters, or numbers that can be exactly cross-referenced with as-built drawings. Labels shall be provided within 3" of each wiring connection.
2. Identify all pneumatic and instrumentation pressure signal tubing with a label within 3" of at each connection.
3. All field enclosures, other than controllers, shall be identified with an equipment nameplate. The lettering shall be in white against cross-referenced with as-built drawings.
4. Junction box covers shall be marked to indicate that they are a part of the DDC system.
5. Provide engraved plastic laminate signage, in letters minimum 1/2-inch high, at all space fan start/stop momentary contact buttons, timing switches, etc. The signage shall indicate the switch/system function. A red plate with white letters shall be used for emergency functions, and white with black letters shall be used for normal / non-emergency functions.
6. Control valves shall be provided with a plastic tag with the design GPM and final balance GPM value written in permanent marker . The tag shall be secured to the valve.
7. Label space thermostats, relative humidity sensors, carbon dioxide sensors, and similar space sensors with the name/designation/number of the associated HVAC equipment / air system. For devices controlling a VAV terminal, the name of the VAV terminal only shall be indicated.

H. Install warning labels as follows:

1. Affix permanent warning labels to equipment that can be automatically started by the control system.

    a. Labels shall use white lettering (12-point type or larger) on a red background.
    b. Warning labels shall read as follows.

C A U T I O N
This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to "Off" position before servicing.

2. Affix permanent warning labels to motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.

    a. Labels shall use white lettering (12-point type or larger) on a red background.
    b. Warning labels shall read as follows.

C A U T I O N
This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.

I. The Division 23 Contractor shall install:

1. Hydronic instrument wells, valves, and other accessories according to Division 23 Sections "Hydronic Piping" and "Meters and "Gages for HVAC Piping".
2. Steam and condensate instrument wells, valves, and other accessories according to Division 23 Section "Steam and Condensate Heating Piping."
3. Install automatic dampers according to Division 23 Section "Air Duct Accessories."

J. Install control and interlock wiring according to applicable Division 26 Sections.

K. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.

3.4 ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. General: Provide a complete system of electric wiring for temperature control apparatus. In addition, provide 120 VAC power to terminal equipment controllers and various DDC panels, subpanels, damper actuators and valves if not specifically shown on contract drawings to be provided under Division 26. The ATC contractor shall be responsible for all electrical installation which is necessary to achieve a fully functional ATC system (and which may or may not be shown on the Electrical Drawings, or required by the Division 26 Electrical Specifications). All wiring shall also be in accordance with applicable local and national codes.

B. Furnish and install control wire and cable, raceways, boxes, and cabinets according to applicable Sections of Division 26, except as modified by Division 23.

C. Conceal cable and wire in panel enclosures and raceway.

1. Raceway shall be concealed except in mechanical rooms and areas where other conduit and piping are exposed.
2. Raceway and junction boxes shall be labeled "BAS".
3. Exception: Low voltage control wiring may be routed in plenum-rated cable, without raceway, above accessible ceilings only.

    a. Bundle and harness multi-conductor instrument cable in place of single cables where several cables follow a common path.
    b. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
    c. Run parallel with building lines and properly supported by "wedding ring" cable supports and tied neatly to prevent sagging of cable.

D. Raceway Materials:

1. Exterior raceway shall be rigid, hot-dipped galvanized steel conduit with liquid tight fittings, boxes, and connections of matching material.
2. Interior raceway shall be galvanized steel EMT, galvanized steel IMC, or rigid galvanized steel conduit. Exception: Type 304 stainless steel conduit, with liquid tight/rain tight fittings, boxes, and connections of matching material shall be used in wet or damp locations, and inside air handing equipment.
3. Direct buried, underground raceway and fittings shall be HDPE smooth wall conduit, Schedule 80, ASTM F 2160, with water tight connectors, or RNC, Type EPC-80 polyvinyl chloride (PVC), schedule 80 with solvent welded joints and fittings.
4. Connections to Equipment with External Vibration Isolation: Provide flexible raceway connections. Use maximum of 3 ft. length of galvanized flexible steel conduit meeting

UL1 for equipment subject to vibration, noise transmission, or movement; and for all motors. In wet or damp locations, and inside air handing equipment, use liquidtight flexible steel conduit with PVC jacket meeting UL 360. Install separate ground conductor across flexible connections.

E. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.

F. BACnet MS/TP networks shall utilize a series / daisy chain topology, and shall comply with the RS-485 (EIA-485) standard.

G. No temperature control wiring installed under this contract shall be installed in conduits for the building lighting and power circuit system.

H. Connect safety switches and similar high and low limit controls independent of manual-control switch positions.

I. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

3.5 FIBER OPTIC CABLE INSTALLATION

A. Fiber optic cable shall be installed in dedicated raceways.

1. Exception: Fiber optics can be run with Ethernet and RS-485 cabling as long as the conduit is bent to fiber optic standards and junction boxes are sized for fiber optic use.

B. During installation do not exceed maximum pulling tensions specified by cable manufacturer. Post-installation residual cable tension shall be within cable manufacturer's specifications.

C. Install cabling and associated components according to manufacturers' instructions. Do not exceed minimum cable and unjacketed fiber bend radii specified by cable manufacturer.

3.6 SPECIFIC INSTALLATION PRACTICES

A. Controls Systems Wiring:

1. All conduit raceways, wiring, accessories and wiring connections required for the installation of the Controls Systems shall be provided by the DDC Contractor except as explicitly shown on the Electrical Trade documents. All wiring shall comply with the requirements of applicable portions of the Electrical Trade work and all local and national electric codes and the requirements of the AHJ.
2. All Controls Systems wiring materials and installation methods shall comply with the original equipment manufacturer recommendations and standards.
3. The sizing type and provision of cable, conduit, cable trays and raceways shall be the design responsibility of the DDC Contractor.
4. Each run of communication wiring shall be a continuous length without splices when that length is commercially available. Runs longer than commercially available lengths shall have as few splices as possible using commercially available lengths.
5. Class 2 signal wiring and 24VAC power may be run in the same conduit. Power wiring 120VAC and greater shall not share the same conduit with Class 2 signal wiring.
6. Perform circuit tests using qualified personnel only. Provide necessary instruments and equipment to demonstrate that:

a. All circuits are continuous and free from short circuits and grounds.
b. All circuits are free from unspecified grounds; that resistance to ground of all circuits is no less than 50 megaohms.
c. All circuits are free from induced voltages.

7. Provide complete testing for all cables and wiring. Provide all equipment, tools, and personnel as necessary to conduct these tests.
8. Provide for complete grounding of all signal and communication cables, panels and equipment so as to ensure integrity of Controls Systems operation. Ground cabling and conduit at panel terminations. Do not create ground loops.
9. Each control wire termination at controllers / in control panels shall have wire-labels within 3" of each terminal connection. Wire labeling shall match the final as-built drawings. Labels shall be polyolefin heat shrink labeling sleeves.

B. Line Voltage Power Sources:

1. 120-volt AC circuits for the Controls Systems shall be taken by the DDC Contractor from electrical trade panelboards, circuit breakers, and/or junction boxes as designated on the Drawings.
2. Circuits used for the Controls Systems shall be dedicated to these Controls Systems and shall not be used for any other services.
3. DDC terminal unit controllers may use 120-volt AC power serving motor power circuits, but only upstream of the starter or VFD disconnect switch.
4. Provide disconnect switches at all points of 120V power connection to controllers and powered equipment.

C. Controls Systems Raceways:

1. All wiring shall be installed in conduit or raceway except as noted elsewhere in the Specification. Minimum conduit size 3/4".
2. Where it is not possible to conceal raceways in finished locations on existing masonry or concrete walls, surface raceway (e.g. "Wiremold") may be used. The raceway shall be painted to match that of the adjacent surfaces.
3. All conduits and raceways shall be installed level, plumb, at right angles to the building lines and shall follow the contours of the supporting surface.
4. UL/ULC Listed Flexible Metal Conduit shall be used for vibration isolation and shall be limited to 3 feet in length when terminating to vibrating equipment supported or hung with external vibration isolation devices.
5. Provide sealing bushings where cables exit conduits / enclosed raceways, except at connections to control panel enclosures.

D. Penetrations:

1. General: Penetrations shall only be made with sleeves, conduits, and enclosed raceways. Bare cables shall not penetrate walls, floors, roofs, ceilings, duct walls, and equipment casings.
2. Architectural Penetrations:

a. Firestopping and smoke stopping for all penetrations used by dedicated controls system conduits and raceways shall be by the HVAC contractor.
b. All openings in fire- or smoke- rated elements shall be closed with approved fire resistive sealant or fire stopping sleeves. Refer to Division 07 and Division 23 Section "Common Work Results for HVAC".
c. Sleeves shall be used for penetrations through drywall and non-bearing partitions, where cables are otherwise permitted to be installed outside of conduit / enclosed raceway.

d. No penetrations through building structural elements, slabs, ceilings and load bearing walls shall be made before receipt of written approval from the Architect.
e. Control signal and control power conduit penetrations of the roof not made inside equipment curbs shall be made through pre-fabricated pipe portals or roof pipe chases, to provide a weathertight installation.

3. Conduit Penetrations of Ducts:

a. Do not drill holes larger than required for passage of conduit / enclosed raceway or sensing element.
b. Seal opening with rubber grommet, duct sealant, or rubber gasket-backed flange, as appropriate for the installation.
c. Do not make penetrations on the bottom of outdoor air intake ducts.
d. Do not install penetrate the top of exterior ducts with fasteners, devices, or raceway.

4. Penetrations of and Air Handling Equipment (e.g. AHUs, fan coils, RTUs, etc.) Casings:

a. Drill holes only where approved by the unit manufacturer and in compliance with the manufacturer's recommendations. Do not cut structural frame elements. Do not drill holes larger than required for passage of conduit / enclosed raceway. Holes shall not compromise the structural integrity of the casing.
b. Do not install penetrate the top / roof of exterior HVAC equipment with fasteners, devices, or raceway.
c. Paint raw edges of galvanized steel sheet with cold galvanized paint.
d. Penetrations that are not exposed to the weather shall be sealed with silicone sealant and finished over on both sides with a brass or stainless steel escutcheon. Sealant shall fill the annular space between the hole and the conduit, filling the entire depth.

1) Tight fitting spool-shaped rubber grommets are also acceptable. Apply sealant around the hole, behind the lip of the grommet, on both sides of the penetration.

e. All exterior conduit penetrations in the housing and internal conduit penetrations across the cooling coil sections and humidifier sections, and all sections downstream of the cooling coil and humidifier sections shall be internally sealed with foam sealant to prevent the migration of water vapor in the conduit.
f. Penetrations that are exposed to the weather shall be made with CSI Designs "Pipetite" seals.
g. Control cable inside equipment shall be routed in conduit or other enclosed raceway.

E. Controls Systems Identification Standards:

1. Controller and Control Panel Identification: All individual controllers and control panels shall be identified by a permanent label fastened to the outside of the enclosure. Labels shall be suitable for the panel's environmental location.
2. Cable shall be labeled at every termination with cross-referencing to record documentation.
3. Raceway Identification: Exposed covers to junction and pull boxes of the raceways shall be identified at primary points.
4. Wire Identification: All low and line voltage wiring shall be identified by a number, as referenced to the associated shop and record drawing, at each termination.
5. Wires and cabling shall not be spliced between terminations. Cable shields shall be single end grounded - typically at the panel end outside the panel.

F. Field Panel and Device Installations And Locations:

1. The Controls Systems panels, enclosures and cabinets shall be located as coordinated with the Architect at an elevation of not less than 2 feet from the bottom edge of the panel to the finished floor. Each cabinet shall be anchored per the manufacturer's recommendations.
2. All field devices shall be installed per the manufacturer recommendation and in accessible locations as coordinated with the Architect.
3. Panels shall not be installed in exposed, finished areas of the building unless specifically indicated on the Drawings. Locate indoor panels in unfinished rooms and above accessible ceilings.
4. Do not install panels inside airstreams (e.g. inside ducts or air handling equipment air tunnels). Panels may be installed in above-ceiling spaces that are used as return air plenums.
5. Panels to be located in damp areas or areas subject to condensation shall be mounted with wall standoffs.
6. Conduit configurations entering or leaving panels and devices shall be such as to preclude condensation traps.

G. Input / Output Control Device Specific Installation Requirements: Install all devices in accordance with the manufacturer's recommendations and requirements. In the event of a direct conflict with the manufacturer's instructions and this Section, the manufacturer's instructions shall take precedence.

1. Pressure and Differential Pressure Sensors and Switches:

   a. Differential pressure transmitters used for flow measurement shall be sized to the flow-sensing device.
   b. Differential pressure transmitters shall be supplied with tee fittings and shut-off valves in the high and low sensing pick-up lines.
   c. The transmitters shall be installed in an accessible location.
   d. Install pressure-sensor needle valve and snubber in piping to pressure gages.
   e. Provide syphons and needle valves on piping to steam pressure sensors.

2. Indoor-Outdoor Differential Air Pressure Applications:

   a. The transmitter's exterior (low pressure) port shall be piped through a high volume accumulator and terminated with a shielded static air probe to reduce pressure fluctuations caused by wind. Pipe high-pressure port to a location behind a thermostat cover.
   b. The interior tip shall be located in an inconspicuous location approved by the Architect/Engineer prior to installation.

3. Exterior Duct, Plenum and AHU Differential Air Pressure Applications:

   a. The transmitter's exterior (reference) port shall be piped through a high volume accumulator and terminated with a shielded static air probe to reduce pressure fluctuations caused by wind.
   b. Provide the duct, plenum, or AHU pressure port all with static pressure tips, tubing, fittings and air filter.

4. Indoor Duct and AHU Air Differential Pressure Sensors and Status Switches:

   a. Install with static pressure tips, tubing, fittings and air filter.

5. Medium to High Differential Air Pressure Applications (Over 10" w.g.):

    a. In addition to other requirements specified above, provide air bleed units, bypass valves, and compression fittings.

6. Outdoor Air Temperature Sensors:

    a. Sensors shall be mounted on a wall selected to minimize solar radiant heat impact or be located in a continuous intake flow adequate to monitor outside air conditions accurately.
    b. Sensors shall be installed with a weather shield.
    c. Sensors shall be mounted on the North wall (and provided with a weather / sun shield) to minimize solar radiant heat impact or located in continuous intake airflow adequate to monitor outside air conditions accurately.
    d. Do not locate sensors near exhaust or relief air discharges. Maintain minimum 20 foot separation.
    e. Do not locate above doors or operable windows.
    f. Locate a minimum of 10 feet above adjacent finished grade and roof surfaces.

7. Duct and Plenum Temperature Sensors:

    a. Duct mount sensors shall mount in an electrical box through a hole in the duct and be positioned so as to be easily accessible for repair or replacement.
    b. The sensors shall be insertion type and constructed as a complete assembly including lock nut and mounting plate.
    c. Use averaging type sensors in ductwork greater in any dimension than 48 inches, where air temperature stratification exists (such as a mixed air plenum), immediately downstream of an air blender, and immediately downstream of any heat exchanging element (coil, furnace, energy recovery heat exchanger, etc.)
    d. Install averaging elements in ducts and plenums in a zigzag pattern, with evenly spaced passes. When horizontal stratification is anticipated, the pattern of passes shall be a vertical zigzag. When vertical stratification is anticipated, the pattern shall be a horizontal zigzag. When the stratification is unknown or complex, the element passes shall be set at approximately a 45 degree angle. Element length shall be sufficient such that each square foot of flow area of the duct, plenum, cabinet /air tunnel, or associated coil is provided with no less than 1 linear foot of sensing element. Provide multiple sensors as required.
    e. The sensor shall be mounted to suitable supports using factory approved element holders.
    f. Support each bend in capillary with approved safe radius clips. Clips shall be non-metallic. Dwyer series 'CC1' or approved equal.

8. Low Temperature Limit Switches (Freezestats):

    a. Install on the discharge side of the first water coil or steam coil in the air stream, or as indicated on the Drawings or in the sequences of operation.
    b. Mount element horizontally across duct in a uniform, horizontal serpentine pattern insuring each square foot of coil is protected by no less than 1 linear foot of sensing element. Provide as many freezestats as required for full coverage.
    c. Element shall be exposed to all areas that encounter low temperature, including along the bottom of the coil(s), from end to end.
    d. Mount freezestats across the coil face in accordance with manufacturers recommended installation procedures. Do not kink or compress the sensing tube. Ensure that there are no sharp bends in the element and there are no kinks in the capillary tube. Tubes that are kinked shall require the freezestat to be discarded and replaced.

e. Support bends in the capillary element with approved safe-radius clips. Clips shall be non-metallic. Dwyer series 'CC1' or approved equal.
f. Provide intermediate supports to prevent excessive vibration of the element, or contact with other items.
g. Install a rubber grommet or bushing where the sensing element passes through sheet metal openings to both seal the opening and protect element from vibrational wear on the opening.
h. Allow unrestrictive access to the manual reset button, and label the device.
i. Unless explicitly indicated otherwise, provide wiring, relays, and related work to affect the required sequence of operation (e.g. fan shutdown, fully closing outdoor air dampers, fully opening heating valves, etc.) via hardwiring, and without the use / intervention of a DDC system controller.

9. Actuators: All control actuators shall be sized capable of closing against the maximum system shut-off pressure. The actuator shall modulate in a smooth fashion through the entire stroke.

    a. Damper actuators shall not be installed inside ducts unless specifically indicated on the Drawings, or approved by the Architect / Engineer.

10. Control Valve Protection: Coordinate with the work of other suppliers in this Division to ensure that control valves are protected with a local strainer as detailed on the Drawings, upstream of the control valve, with a straining element of a mesh size appropriate to protect the valve performance and maintain the valve warranty and comply with the control valve manufacturer's recommendations.
11. Control Valve and Actuator Installation Orientation:

    a. Quarter-Turn Control Valves (Butterfly, Ball, V-Ball)

        1) For hydronic applications, preferred valve orientation is with shaft oriented horizontally. Valve shall not be installed such that shaft is oriented vertically downward (i.e. with actuator at bottom).
        2) For steam applications, valves/actuators shall be installed such that shaft is oriented horizontally. In no case shall valve be oriented in vertically upward position. (vertical upward orientation results in overhearing of actuator and accessories).

    b. Globe Control Valves:

        1) For hydronic applications, valve shall be installed such that the stem is oriented within 45 degrees of the vertical upward position. If this orientation cannot be practically achieved, valve may be installed such that stem is oriented horizontally. In no case shall valve be installed such that stem is oriented vertically downward.
        2) For steam applications, valve shall be installed such that stem is not oriented in the vertically upward position (to prevent overheating of actuator and accessories). Preferred orientation is 45 degrees from vertically upward position. If this orientation cannot be practically achieved, valve may be installed such that stem is oriented horizontally. In no case shall the valve be installed such that stem is oriented vertically downward.

12. Control Valve Sizing:

    a. Modulating Pressure-Dependent Control Valves: Modulating valves shall be sized for proper flow control with equal percentage characteristics for 2-way hydronic

valves and steam, and linear characteristics for 3-way hydronic and steam valves, and for 2-way hydronic minimum system flow bypass valves. Use the sizing criteria below to determine the required Cv for each valve. When the Cv required is between two available valve sizes, select the larger size.

1) Correction Factors: The Cv ratings used for selection of control valves shall be effective CV ratings that are corrected to recognize the effect of any difference in the connecting line size indicated on the Drawings, and the selected control valve body size. Corrections shall also be made for transitions or other fittings directly connected to the valve, for fluids other than plain water (e.g. glycol solutions), and for steam superheat, as applicable.
2) Modulating Hydronic Applications: Unless indicated otherwise, the required valve pressure drop for modulating hydronic applications (both 2-way and 3-way types) shall be for 3 psi at design maximum capacity Valves also be sized so they will not cavitate with an absolute inlet pressure of 20 psig at the maximum anticipated operating fluid temperature.

a) Exception: Hydronic minimum flow bypass valves shall be sized for the required minimum system flowrate at the lowest available differential pressure anticipated at the location of the bypass valve. Round up to the nearest available Cv value / valve size.

3) Modulating steam valves with 15 psig inlet steam (or less) shall be sized for 5 psi at design maximum capacity.

b. Two-Position Pressure-Dependent Control Valves: All two-position valves (all services - both hydronic and steam; both 2-way or 3-way) shall be full line size.

13. Flow Switches: Use correct product for pipe diameter. Adjust flow switch according to manufacturer's instructions.
14. Space Thermostats and Temperature Sensors: Room thermostats and temperature sensors shall be installed at locations indicated on the Drawings, however the control manufacturer shall carefully check the Architectural and Electrical Drawings to verify the locations indicated. Any relocation of room thermostats to avoid conflict with other trades or at the control manufacturer's recommendation to improve performance, shall be only as approved by the Architect.
15. Space Control Device Guards: All room temperature sensors, thermostats, humidity sensors, space CO2 sensors, and similar wall-mounted control devices shall be protected with guards securely anchored to the wall.

3.7 COORDINATION WITH THE TESTING ADJUSTING AND BALANCING AGENT

A. Refer to Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures requiring manipulation of DDC system control parameters.

B. Coordinate with the TAB Agent / sub-contractor and with the Commissioning Agent to fine tune control settings that are determined from balancing procedures. Record the following control settings as obtained from TAB contractor, and note any TAB deficiencies in writing:

1. Optimum duct static pressure setpoints for VAV air handling units.
2. Minimum outside air damper settings for constant volume air handling units.
3. Optimum differential pressure setpoints for variable speed pumping systems.
4. Calibration parameters for flow control devices such as VAV boxes / air valves and duct and piping flow measuring stations/ meters.

C. Assist the TAB Agent in performing testing and balancing of variable volume air and hydronic distribution systems, and testing of such systems that have flow diversity by manipulating air and water flow at each control terminal or valve through the DDC system, as directed by the TAB Agent.

D. Airflow Control Terminals: BAS Contractor shall provide a hand held device as a minimum to the TAB Agent to facilitate airflow control terminal (e.g. VAV box) calibration. Connection for any given device shall be local to it (i.e. at the VAV box or at the thermostat). Portable operator's terminal shall allow querying and editing of parameters required for proper calibration and start up.

1. Train the Testing and Balancing Agent to use control system interface tools.
2. Provide a qualified technician to assist with testing and balancing the first 20 terminal units.

3.8 COMMISSIONING OF THE CONTROL SYSTEM BY THE DDC SYSTEM SUPPLIER / SUB-CONTRACTOR

A. Commissioning of the system shall be complete before acceptance by the Client Agency.

B. Pre-Testing Quality Control: Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment, and retest. Verify the following:

1. Verify operation of human machine interface.
2. Verify local control units including self-diagnostics.
3. Verify that the specified I/O capacity has been provided.
4. Verify that DDC controller power supply is from emergency power supply, where applicable.
5. Verify that wires at control panels are tagged with their service designation matching that shown on the shop drawings.
6. Check control valves. Verify that they are piped with the flow in correct direction.
7. Check dampers to verify proper blade arrangement, either parallel or opposed, has been provided, and that the dampers fully close and open.

C. General Testing Procedures: Each phase of testing shall be completed and accepted before proceeding to the next step of testing. It shall be the responsibility of the DDC system supplier to coordinate and schedule the required trades and technicians required to complete testing. Project completion delays caused by inadequate coordination and scheduling or delays caused by failure to meet these commissioning specifications shall be the responsibility of this Contractor.

1. Test plans shall be developed for each phase of testing by the DDC system supplier and shall define all the tests required to ensure that the system meets all requirements of the Contract Documents. The test plans shall define milestones for the tests; identifying simulation programs, equipment, personnel, facilities, and supplies required. The test plans shall identify the capabilities and functions to be tested.
2. Test reports shall be used to document the results of each test.
3. Testing shall be performed in two basic phases:

    a. Phase One - General Performance Testing verifies the accuracy of the sensors and end devices and general system operation, flexibility and response.

1) Written permission shall be obtained from the Client Agency that this phase of testing has been successfully completed with the proper documentation before proceeding with the next phase of testing.

b. Phase Two - Functional Testing is operational sequence testing which verifies the proper operation of control strategies to match the sequence of operation.

D. Phase One Testing - General Performance Testing: Calibration of each instrumentation device connected to the DDC system shall be performed by making a comparison between the reading at the respective device and the display at the supervisory HMI using a standard which is traceable to the National Bureau of Standards and shall be at least twice as accurate as the device to be calibrated.

1. All input devices (flow measuring stations, sensors / transducers, etc.) shall be tested to verify that they meet the accuracy as specified.

a. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
b. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
c. Equipment and procedures used for calibration shall meet instrument manufacturer's recommendations.
d. Provide diagnostic and test equipment for calibration and adjustment.
e. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
f. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
g. If, after-calibration-indicated performance cannot be achieved, replace out-of-tolerance instruments.
h. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements of the device manufacturer, and to supplement requirements indicated.

2. The Phase One General Performance Tests shall be used to demonstrate the specified overall system performance and accuracy of the DDC system. System performance shall be verified on all systems on the specified failure modes upon DDC system failure or loss of power, and that all systems return to DDC system control automatically upon resumption of DDC system operation or return of power. Exercises shall be performed on the system according to the written test procedures in order to verify response time of all system activities (i.e., control loop response, alarm response, updating of temperatures, and other values). This testing shall also include a point-by-point log to validate 100% of the input and output points of the DDC system operation.

a. Network:

1) Controller to controller data transfer time.
2) Supervisory console to controller transfer time.
3) Network reconfiguration.
4) Network error recovery.

b. System Controller and HMI:

1) Scan rate.
2) Analog input/output accuracy.
3) Battery back-up duration.
4) Screen refresh rate.

c. Sensors:

1) Visually inspect for proper installation and electrical connections.
2) If the process variable can be simulated, input 0% range value and record the measured process variable, device output and displayed value at the DDC system terminal. Repeat this process for 50% and 100% of the process variable range.
3) If the process variable cannot be simulated, use the ambient value for the process variable and record the measured process variable, device output and displayed value at the DDC system terminal. Simulate the device output signal current/voltage for 0% and 100% of the process variable range and record the measured device output signal and the displayed value at the DDC system terminal.

d. Transducers:

1) Visually inspect for proper installation and electrical connections.
2) Enter 0% range value at the DDC system terminal and measure and record the device's input and output signal values. Repeat for 50% and 100% of device's range.

e. Control Valves and Dampers:

1) Visually inspect for proper installation and electrical connections.
2) Enter 0% range value at the DDC system terminal and measure and record the device's input and output signal values. Repeat for 50% and 100% of device's range.
3) Step the final element from 0% to 100% range value at the DDC system terminal and measure and record the device's 0% to 100% speed. Repeat for 100% to 0% of device's range.

f. Control Valve Leak Check: Verify proper close off of all control valves. Ensure the valve seats properly by simulating the maximum anticipated pressure difference across the circuit. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Via the operator's interface / workstation, command the valve to close. Energize fans. After 5 minutes observe air temperature difference across coil. If a temperature difference is indicated, and the piping surface temperature entering the coil is within 3°F of the water supply temp, leakage is probably occurring. If it appears that it is occurring, close the isolation valves to the coil to ensure the conditions change. If they do, this validates the valve is not closing. Remedy the condition by adjusting the stroke and range, increasing the actuator size/torque, replacing the seat, or replacing the valve as applicable.

g. Miscellaneous:

1) Verify that binary output devices such as relays, solenoid valves, two-position actuators and control valves, and magnetic starters, operate properly and that normal positions are correct.

2) Verify that analog output devices such as I/Ps and actuators are functional, that start and span are correct, and that direction and normal positions are correct. Check control valves and automatic dampers to ensure proper action and closure. Make necessary adjustments to valve stem and damper blade travel.
3) Check each alarm with an appropriate signal at a value that will trip the alarm.
4) Trip interlocks using field contacts to check logic and to ensure that actuators fail in the proper direction.
5) Test interlock actions by simulating alarm conditions to check initiating value of variable and interlock action.

3. Documentation: Prepare a report documenting results. Include a log documenting startup testing of each input and output device, with technician's initials certifying each device has been tested and calibrated.

E. Phase Two Testing - Operational Sequence / Functional Testing: Operational sequence testing shall be performed to verify compliance of the completed DDC system with the Contract Documents. Using approved test procedures, all physical and functional requirements of the project shall be tested. Provide and schedule operational testing for each season (winter, summer, etc.) applicable to specific control sequence.

1. Phase Two - Operational Sequence / Functional Testing as specified shall not be started until after successful completion of the Phase 1 - General Performance Testing as specified above and submission of the Phase 1 report.
2. Phase Two testing for systems and equipment that incorporate factory mounted and packaged controls shall involve the participation of the Installing Contractor, representatives of the equipment supplier or manufacturer, and the DDC system provider. Refer to other Division 23 specifications for the equipment and related systems requiring this form of cooperative testing effort.
3. The Architect / Engineer and Commissioning Agent reserve the right to observe Phase 2 testing. Notify these parties no less than 7 days before testing begins.
4. Testing procedures shall include the following:

a. Simulate and observe each individual control loop during each applicable operational mode by overriding and varying inputs and schedules.
b. Tune all control loops to obtain the fastest stable response without hunting, offset or overshoot. Where auto-tuning software is used record the final operating parameters. Auto-tuning software shall not be allowed to continuously adjust parameters as this may lead to masking other device or system problems. Record tuning parameters and response test results for each control loop.

1) Obtain graphical trend data output showing each DDC loop's response to a setpoint change representing an actuator position change of at least 25% of full range. Trend sampling rate shall be from 10 seconds to 3 minutes, depending on loop speed. Each sample's trend data shall show setpoint, actuator position, and controlled variable values. Perform further tuning of each loop that displays unreasonably under- or over-damped control.

c. Test the building fire alarm system interface.
d. Verify that the relative priority of each competing control loop to each control point is correct. Comply with the following hierarchy, in order of highest priority to lowest priority:

1) Control modes dictated by life safety functions, the fire alarm system, or smoke control modes.

2) Control modes triggered by safety devices, such as gas detectors, duct pressure sensors / switches, vibration cut out switches, freezestats, and water overflow and leak sensors / switches.
3) Manual overrides at the DDC system workstation.
4) Normal automatic modes.

e. Test all safety/alarm devices and associated safety modes of operation. Test that the system returns to normal control once alarm conditions have been cleared.
f. Test demand limiting modes of operation by obtaining trend data output showing demand-limiting algorithm action. Trend data shall document action sampled each minute over at least a 30-minute period and shall show building kW, demand-limiting setpoint, and status of setpoints and other affected equipment parameters.

5. Documentation: Submit a report of testing results with trend data where appropriate. An operational test verification form shall be completed for each control loop. Any deviations or unsatisfactory results shall be noted in the remarks and signed and dated by the DDC system supplier's field engineer.

F. Functional Performance Demonstration: At the request of the Architect / Engineer or the, Commissioning Agent, the DDC system provider shall provide a demonstration of the system performance. During this demonstration, the DDC system provider shall demonstrate actual field operation of each sequence of operation of each system in a manner similar to the Functional Performance Testing specified above. Provide at least two persons equipped with two-way communication. Demonstrate response of any input and output points requested by the Architect / Engineer or Commissioning Agent. Provide and operate test equipment required to prove proper system operation. Verify calibration of field devices where requested.

3.9 SOFTWARE OPTIMIZATION ASSISTANCE

A. The BAS Contractor shall provide the services of a controls technician as specified above at the project site to be at the disposal of the Client Agency, Architect/Engineer, and Commissioning Agent. The purpose of this requirement is to make changes, enhancements and additions to control unit and/or workstation software and sequence of operation that have been identified by during the commissioning of the project or during the warranty period that are beyond the specific requirements of the contract documents.

B. The cost for a total of 16 hours of this service shall be included with the bid. The allotted hours may occur over as many as four (4) separate service calls. Unused training hours shall be used for additional software optimization assistance, at the Client Agency's request.

C. The controls technician provided shall be thoroughly trained in the programming and operation of the controller and workstation software. If the controls technician provided cannot perform every software task requested in a timely fashion, contractor shall provide additional qualified personnel at the project site with deduction from the allotted hours of service.

3.10 CLIENT AGENCY DEMONSTRATION AND TRAINING

A. The Controls Contactor shall provide the following training services for the Client Agency's key personnel at common sessions.

1. Training shall occur at the project site.

2. Training shall not be less than a total of 16 hours, spread out over as many as 4 days (4 hours per day). Unused software optimization assistance hours shall be used for additional training, at the Client Agency's request.
3. Specific schedules shall be established by the Client Agency and at the convenience of the Client Agency. The classes may be spread out during the Warranty Period as per the Client Agency's wishes.
4. Training shall not begin prior to system commissioning and acceptance by the Client Agency.
5. Training shall be conducted by field engineers who are fully knowledgeable of the specific installation details of the Project. No less than one (1) controls contractor employee who worked on the project's physical installation shall be present at the training. No less than one (1) controls contractor employee who is familiar with the controls sequences and programming of the project shall be present at the training.

B. Prior to beginning training, conduct a walk-through of the Project to identify panel and device locations and to explain system operation.

C. The training program(s) shall be designated to provide a comprehensive understanding and basic level of competence with the system. It shall be sufficiently detailed to allow customer personnel to operate the system independent of any outside assistant. The training shall be completed on the actual installed direct digital control system.

D. Online context sensitive HELP screens shall be incorporated into the system to further facilitate training and operation.

E. The training plan shall include detailed session outlines and related reference materials. The customer personnel shall be able to utilize these materials in the subsequent training of their co-workers.

F. Training sessions shall enable students to accomplish the following objectives, at the minimum.

1. Understand the Project 'as-built' documentation.
2. Understand naming conventions.
3. Proficiently operate system.
4. Understand control system architecture and configuration.
5. Understand DDC system components.
6. Understand system operation, including DDC system control and optimizing routines (algorithms)
7. Operate workstation and peripherals.
8. Log on and off system.
9. Access graphics, point reports, and logs.
10. Adjust and change system setpoints, time schedules, and holiday schedules.
11. Recognize common HVAC system malfunctions by observing system graphics, trend graphs, and other system tools.
12. Understand system drawings and Operation and Maintenance manual.
13. Understand job layout and location of control components.
14. Access data from DDC controllers.
15. Operate portable operator's terminals.
16. Create and change system graphics.
17. Create, delete, and modify alarms, including configuring alarm reactions.
18. Create, delete, and modify point trend logs (graphs) and multi-point trend graphs.
19. Configure and run reports.
20. Add, remove, and modify system's physical points.
21. Create, modify, and delete application programming.
22. Add operator interface stations.
23. Add a new controller to the system.

24. Download firmware and advanced applications programming to a controller.
25. Configure and calibrate I/O points.
26. Interface with job-specific, third-party operator software.
27. Maintain software and prepare backups.
28. Understand system cybersecurity features and functions.
29. Understand procedures for software updates and applying security patches.
30. Add new users and set access restrictions.
31. Understand password security procedures, including 2-factor authentication.

END OF SECTION