Section 25 50 00

Building Automation System

جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

KAUST Standards

This standard will serve as specific engineering requirements in the design and construction of all KAUST facilities within KAUST vicinity to address electrical, civil/structural, integrated automation, plumbing, HVAC, fire suppression, electronic safety and security aspects.

The standard is a “live” and on-going document that is to be updated as the need arises. It is governed by KAUST procedure SAP-P-007-2015 and related forms for initiating updates and approving any waiver requests developed by E&PM.

SECTION 25 50 00 – BUILDING AUTOMATION SYSTEM

PART 1 – GENERAL

1.1. RELATED DOCUMENTS

A. Drawings and general provisions of the contract, including general and supplementary conditions and specification sections is not included but applicable to this section
B. All related referenced codes and standards in this section corresponds to IBC 2009 edition.

1.2. SUMMARY

A. This Section includes control equipment for HVAC systems and components, including control components for terminal heating and cooling units not supplied with factory wired controls.
B. To Integrate all building automation systems to single KAUST Integrated Automation System
C. Related Sections include the following:
    1. Division 23 Section "Meters and Gages for HVAC Piping" for measuring equipment that relates to this Section.

1.3. SHOP DRAWINGS AND PRODUCT DATA

A. Submit shop drawings and product data in accordance with the general provisions. Supply complete ladder logic diagram, parts list, components layout inside cabinets and terminal blocks schedule.

1.4. SYSTEM PERFORMANCE

A. Comply with the following performance requirements:
    1. Graphic Display: Display graphic for all control points with current data within 10 seconds.
    2. Graphic Refresh: Update graphic with minimum 20 dynamic points with current data within 8 seconds.
    3. Object Command: Reaction time of less than two seconds between operator command of a binary object and device reaction.
    4. Object Scan: Transmit change of state and change of analogue values to control units or workstation within six seconds.
    5. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.
    6. Program Execution Frequency: Run capability of applications as often as five seconds, but selected consistent with mechanical process under control.
    7. Performance: Programmable controllers shall execute DDC PID control loops and scan and update process values and outputs at least once per second.
    8. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows
        a. Water Temperature: Plus or minus 0.5 deg C.
        b. Water Flow: Plus or minus 5 percent of full scale.
        c. Water Pressure: Plus or minus 2 percent of full scale.
        d. Space Temperature: Plus or minus 0.5 deg C.

e. Ducted Air Temperature: Plus or minus 0.5 deg C.
f. Outside Air Temperature: Plus or minus 1.0 deg C.
g. Dew Point Temperature: Plus or minus 1.5 deg C.
h. Temperature Differential: Plus or minus 0.15 deg C.
i. Relative Humidity: Plus or minus 5 percent.
j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
k. Airflow (Measuring Stations): Plus or minus 5 percent of full scale.
l. Airflow (Terminal): Plus or minus 10 percent of full scale.
m. Air Pressure (Space): Plus or minus 2.5 Pa.
n. Air Pressure (Ducts): Plus or minus 25 Pa.
o. Carbon Monoxide: Plus or minus 5 percent of reading.
p. Carbon Dioxide: Plus or minus 50 ppm.
q. Electrical: Plus or minus 5 percent of reading.

B. Manufacturers Requirements:
1. Provide the services of control manufacturer's representative to be on site during the entire time that the start-up, testing and balancing procedures, detailed in Part 3 of this specification, takes place. Representative shall be part of manufacturer's service organization and shall be skilled in the adjustment and calibration of all control devices as well as being capable of modifying and checking system software.
2. Certify maintenance of local office within 80 Km radius of job site, staffed with factory trained engineers capable of providing instructions to Owner's personnel and performing routine and emergency maintenance on ALL system components. Upon Architect's request, submit list of personnel staffing field office and their professional disciplines.
3. Provide DDC system supplier's warranty of performance of entire system including pneumatic components, as required by Contract documents. Performance and components requirements are established by control sequences and diagrams on Drawings and by this Paragraph.
4. Supplier to make available all necessary system protocol and point data to the site-wide systems integrator so as to allow integration of the system onto the Integrated KAUST Integrated Automation System.
5. Supplier shall provide all necessary network hardware such as gateways, routers, hubs, or other equipment, including software and configuration to support integration of the supplier's system onto a BACnet/IP/Ethernet backbone.
6. Supplier to provide suitably qualified personnel to support the site-wide Systems Integrator so as to allow integration of the supplier's system onto the Integrated KAUST Integrated Automation System.
7. Universal protocol should be used for all the automation systems so that it can integrate to KAUST Integrated Automation System.

1.5. SEQUENCE OF OPERATION

A. Refer to Mechanical Division 23 Control Drawings for all sequence of operations.

1.6. SUBMITTALS

A. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, and performance characteristics, electrical characteristics finishes for materials, and installation and start up instructions for each type of product indicated.
   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.
   2. Control System Software: Include technical data for operating system software, operator interface, Colour graphics, and other third-party applications.
   3. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   1. Bill of materials of equipment indicating quantity, manufacturer, and model number.
   2. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
   3. Wiring Diagrams: Power, signal, and control wiring.
   4. Details of control panel faces, including controls, instruments, and labelling.
   5. Written description of sequence of operation.
   6. Schedule of dampers including size, leakage, and flow characteristics.
   7. Schedule of valves including flow characteristics.
   8. DDC System Hardware:
      a. Wiring diagrams for control units with termination numbers.
      b. Schematic diagrams and floor plans for field sensors and control hardware.
      c. Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between operator workstation and control unit locations.
   9. Control System Software: List of Colour graphics indicating monitored systems, data (connected and calculated) point addresses, output schedule, and operator notations.
   10. Controlled Systems:
      a. Schematic diagrams of each controlled system with control points labelled and control elements graphically shown, with wiring.
      b. Scaled drawings showing mounting, routing, and wiring of elements including bases and special construction.
      c. Written description of sequence of operation including schematic diagram.
      d. Points list.

C. Data Communications Protocol Certificates: Certify that each proposed DDC system component complies with ASHRAE 135.
D. Samples for Initial Selection: For each Colour required, of each type of thermostat or sensor cover with factory-applied Colour finishes.
E. Samples for Verification: For each Colour required, of each type of thermostat or sensor cover.
F. Software and Firmware Operational Documentation: Include the following:
    1. Software operating and upgrade manuals.
    2. Program Software Backup: On a magnetic media or compact disc, complete with data files.
    3. Device address list.
    4. Printout of software application and graphic screens.
    5. Software license required by and installed for DDC workstations and control systems.
G. Software Upgrade Kit: For Owner to use in modifying software to suit future systems revisions or monitoring and control revisions.
H. Qualification Data: For installer and manufacturer.
I. Field quality-control test reports.
J. 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 and compressed-air station.
    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.

1.7. QUALITY ASSURANCE

A. Installer Qualifications: Automatic control system manufacturers authorized representative who is trained and approved for installation of system components required for this Project.
B. Electrical Components, Devices, and Accessories: Listed and labelled as defined in
C. NFPA 70, Article 100, 2014 edition, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
D. Comply with ASHRAE 135 for DDC system components as appropriate for proposed system.
E. Quality Control of KAUST needs to approve all the materials and site inspections.

1.8. DELIVERY, STORAGE, AND HANDLING

A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.
B. System Software: Update to latest version of software at Project completion.

1.9. COORDINATION

A. Coordinate location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation.
B. Coordinate equipment with Section "Intrusion Detection" to achieve compatibility with equipment that interfaces with that system and with building master clock.
C. Coordinate equipment with Division 28 Section "Access Control" to achieve compatibility with equipment that interfaces with that system.
D. Coordinate equipment with Section "Clock Systems" to achieve compatibility with equipment that interfaces with that system.
E. Coordinate equipment with Section "PLC Electronic Detention Monitoring and Control Systems" to achieve compatibility with equipment that interfaces with that system.
F. Coordinate equipment with Division 26 Section "Network Lighting Controls" to achieve compatibility with equipment that interfaces with that system.
G. Coordinate equipment with Division 28 Section "Digital, Addressable Fire-Alarm Systems" to achieve compatibility with equipment that interfaces with that system.
H. Coordinate supply of conditioned electrical branch circuits for control units and operator workstation.
I. Coordinate equipment with Division 26 Section "Electrical Power Monitoring and Control" to achieve compatibility of communication interfaces.
J. Coordinate equipment with Division 26 Section "Panel boards" to achieve compatibility with starter coils and annunciation devices.
K. Coordinate equipment with Division 26 Section "Motor-Control Centers" to achieve compatibility with motor starters and annunciation devices.
L. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases.
M. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

1.10. EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
    1. Replacement Materials: One replacement diaphragm or relay mechanism for each unique pneumatic damper motor, valve motor, controller, thermostat, and positioning relay.
    2. Maintenance Materials: Four (4) thermostat adjusting key(s).
    3. Maintenance Materials: Two (2) pneumatic thermostat test kit.

PART 2 - PRODUCTS

2.1. GENERAL

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection.
    1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufactures specified.
    2. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.

2.2. CONTROL SYSTEM

A. Control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, accessories, and software connected to distributed controllers operating in multiuser, multitasking environment on token passing network and programmed to control mechanical systems. An operator workstation permits interface with the network via dynamic Colour graphics with each mechanical system, building floor plan, and control device depicted by point-and-click graphics.
B. Control system shall include the following:
    1. Building intrusion detection system specified in Division 28 Section "Intrusion Detection."
    2. Building clock control system specified in Division 27 Section "Clock Systems."
    3. Building lighting control system specified in Division 26 Section "Network Lighting Controls."
    4. Fire alarm system specified in Division 28 Section "Fire Detection and Alarm."
C. Direct Digital Control (DDC) shall provide local control and monitoring to BAS and Integrated KAUST Integrated Automation System (IAS).
D. HVAC equipment and building lighting shall be controlled using DDC, BAS and IAS.
E. BAS Shall be:
    1. Capable of multiple man machine interface points throughout the network
    2. Capable of unattended operation with manual interaction
    3. Programmable by trained operator
    4. Monitored for system integrity
    5. Web accessible
    6. BAC net compliance and tested.
F. The BAS and IAS shall provide effective management of the building through report generation, histories, logs, trending, maintenance management and dynamic Colour graphic displays
G. Building systems shall be controlled through optimization software for energy management strategies including optimum start/stop, unoccupied setbacks, on-off control, demand limiting, duty cycling, water and air system temperature reset, pressure reset, flow reset and other items.
H. Provisions shall be made for database backup and redundancy to insure the integrity of the system
I. Operating schedules of HVAC, and other equipment shall be fine turned to match the actual occupied hours.
J. Each building shall be provided with a standalone lighting control system, not part of the Building Automation systems
K. Each building shall be occupied with building electric meter connected to a standalone power monitoring system, not part of the Building Automation system that monitors
    1. Building KVA
    2. Building KW
    3. Building KWH
    4. Voltage by phase

5. Current by phase
6. Power Factor.

L. Each building shall be equipped with electrical sub metering to monitor building electrical load (KW) and usage (KWH) by following load categories through a standalone power monitoring system, not part of Building Automation System:
   1. Lighting
   2. Tenant Power
   3. HVAC
   4. Domestic Water Heating
   5. Vertical Transportation
   6. Plumbing

M. Each building shall be equipped with a building water meter connected to Building Automation System to monitor instantaneous flow rate and usage over time

N. Each building shall be equipped with water sub metering to monitor building water usage by the following categories through the Building Automation System:
   1. Irrigation
   2. HVAC or Process Water
   3. Domestic Hot water

O. Each building chilled water distribution loop shall be equipped with a chilled water energy meter connected to BAS to monitor instantaneous energy usage and usage over time. Values shall be updated and displayed for daily, weekly, monthly, yearly, and since installed energy usage. With each building chilled water distribution loop energy sub meters shall be installed to monitor different HVAC systems served by the chilled water distribution system.

P. Input and output to DDC controllers shall be accomplished using electric and electronic field instruments. Control loops shall be controlled by software algorithms residing in the controller.

Q. Each DDC controller (except unitary type) shall have at least 20 percent spare points, and not less than 2 of each type (DI, DO, AI and AO)

R. Controlled equipment shall be capable of manual override at the equipment motor controller. Analog outputs to dampers and valves shall be provided with supervised hand-off-auto (HOA) switches to provide manual override

S. Buildings with Laboratory control systems (LCS) controlling individual labs shall function as standalone and shall also interface to building automation system. All data available through the LCS shall be available to BAS and IAS. ASHRAE 135 (BACnet) shall be communication protocol used for the interface

T. LCS shall be DDC with electronic actuators. The potential to use PLCs (programmable logic controllers) and industrial grade components (not commercial grade) should be evaluated.

U. BAS and LCS controllers shall be powered through uninterruptable power supplies (UPS) units located locally at the controllers and workstations.

2.3. DDC EQUIPMENT

A. Operator Workstation: One PC-based microcomputer for each separate building with minimum configuration as follows: Each building's workstation shall be connected to the KAUST network.
    1. Computer with latest configuration and features available in the market (Not prior to approval from the client/Commissioning authority)
    2. Operating system: Operating system should be installed which comply with all the available devices in the loop.
    3. Printer: Configuration of the printer should be submitted for approval before installation
    4. Internet Access: High speed internet access should be provided with all the computers
    5. UPS: Uninterrupted power supply should be provided with a minimum of 30minutes backup
    6. Keyboard and Mouse: Wireless keyboard and mouse should be provided with all the computer devices installed
    7. Application Software:
        a. I/O capability from operator station.
        b. System security for each operator via software password and access levels.
        c. Automatic system diagnostics; monitor system and report failures.
        d. Database creation and support.
        e. Automatic and manual database save and restore.
        f. Dynamic Colour graphic displays minimum of 10 screen displays at once.
        g. Custom graphics generation and graphics library of HVAC equipment and symbols.
        h. Alarm processing, messages, and reactions.
        i. Trend logs retrievable in spreadsheets and database programs.
        j. Alarm and event processing.
        k. Object and property status and control.
        l. Automatic restart of field equipment on restoration of power.
        m. Data collection, reports, and logs. Include standard reports for the following:
            (1) Current values of all objects.
            (2) Current alarm summary.
            (3) Disabled objects.
            (4) Alarm lockout objects.
            (5) Logs.
        n. Custom report development.
        o. Utility and weather reports.
        p. Workstation application editors for controllers and schedules.
        q. Maintenance management.
B. Custom Application Software:
    1. English language oriented.
    2. Full-screen character editor/programming environment.
    3. Allow development of independently executing program modules with debugging/simulation capability.
    4. Support conditional statements.

5. Support floating-point arithmetic with mathematic functions.
6. Contains predefined time variables.

C. Diagnostic Terminal Unit: Provide two (2) portable notebook-style, PC based microcomputer terminal capable of accessing system data by connecting to KAUST network.
   1. Computer device Configuration should be submitted for approval before installation and it should be supplied with all the necessary requirements such as USB port, Ethernet port, audio system etc.

D. Control Units: Modular, comprising processor board with programmable, non-volatile random-access memory; local operator access and display panel; integral interface equipment; and backup power source.
   1. Units monitor or control each I/O point; process information; execute commands from other control units, devices, and operator stations; and download from or upload to operator workstation or diagnostic terminal unit.
   2. Stand-alone mode control functions operate regardless of network status. Functions include the following:
   3. Global communications.
   4. Discrete/digital, analogue, and pulse I/O.
   5. Monitoring, controlling, or addressing data points.
   6. Software applications, scheduling, and alarm processing.
   7. Testing and developing control algorithms without disrupting field hardware and controlled environment.
   8. Standard Application Programs:
      a. Electric Control Programs: Demand limiting, duty cycling, automatic time scheduling, start/stop time optimization, night setback/setup, on-off control with differential sequencing, staggered start, anti-short cycling, PID control, DDC with fine tuning, and trend logging.
      b. HVAC Control Programs: Optimal run time, supply-air reset, and enthalpy switchover.
      c. Chiller Control Programs: Control function of condenser-water reset, chilled-water reset, and equipment sequencing.
      d. Programming Application Features: Include trend point; alarm processing and messaging; weekly, monthly, and annual scheduling; energy calculations; run-time totalization; and security access.
      e. Remote communications.
      f. Maintenance management.
      g. Units of Measure: SI (metric).
   9. Local operator interface provides for download from or upload to operator workstation or diagnostic terminal unit.
   10. Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) data link/physical layer protocol.

E. Local Control Units: Modular, comprising processor board with electronically programmable, non-volatile, read-only memory; and backup power source.
   1. Units monitor or control each I/O point, process information, and download from or upload to operator workstation or diagnostic terminal unit.

2. Stand-alone mode control functions operate regardless of network status. Functions include the following:
    a. Global communications.
    b. Discrete/digital, analogue, and pulse I/O.
    c. Monitoring, controlling, or addressing data points.
3. Local operator interface provides for download from or upload to operator workstation or diagnostic terminal unit.
4. Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) data link/physical layer protocol.

F. I/O Interface: Hardwired inputs and outputs may tie into system through controllers. Protect points so that shorting will cause no damage to controllers.
1. Binary Inputs: Allow monitoring of on-off signals without external power.
2. Pulse Accumulation Inputs: Accept up to 10 pulses per second.
3. Analogue Inputs: Allow monitoring of low-voltage (0- to 10-V dc), current (4 to 20mA), or resistance signals.
4. Binary Outputs: Provide on-off or pulsed low-voltage signal, selectable for normally open or normally closed operation with three-position (on-off-auto) override switches and status lights.
5. Analogue Outputs: Provide modulating signal, either low voltage (0- to 10-V dc) or current (4 to 20 mA) with status lights, two-position (auto-manual) switch, and manually adjustable potentiometer.
6. Tri-State Outputs: Provide two coordinated binary outputs for control of three point, floating-type electronic actuators.
7. Universal I/O s: Provide software selectable binary or analogue outputs.

G. Power Supplies: Transformers with Class 2 current-limiting type or overcurrent protection; limit connected loads to 80 percent of rated capacity. DC power supply shall match output current and voltage requirements and be full-wave rectifier type with the following:
1. Output ripple of 5.0 mV maximum peak to peak.
2. Combined 1 percent line and load regulation with 100-mic.sec. Response time for 50 percent load changes.
3. Built-in overvoltage and overcurrent protection and be able to withstand 150 percent overload for at least 3 seconds without failure.

H. Power Line Filtering: Internal or external transient voltage and surge suppression for workstations or controllers with the following:
1. Minimum dielectric strength of 1000 V.
2. Maximum response time of 10 nanoseconds.
3. Minimum transverse-mode noise attenuation of 65 db.
4. Minimum common-mode noise attenuation of 150 dB at 40 to 100 Hz.

2.4. UNITARY CONTROLLERS

A. Unitized, capable of stand-alone operation with sufficient memory to support its operating system, database, and programming requirements, and with sufficient I/O capacity for the application.
1. Configuration: Local keypad and display; diagnostic LEDs for power, communication, and processor; wiring termination to terminal strip or

card connected with ribbon cable; memory with bios; and 72-hour battery backup.
2. Operating System: Manage I/O communication to allow distributed controllers to share real and virtual object information and allow central monitoring and alarms.
3. Perform scheduling with real-time clock. Perform automatic system diagnostics; monitor system and report failures.
4. Communicate using read (execute and initiate) and write (execute and initiate) property services defined in ASHRAE 135. Reside on network using MS/TP data link/physical layer protocol and have service communication port for connection to diagnostic terminal unit.
5. Interior Enclosure: Dustproof rated for operation at 0 to 50 deg C.
6. Exterior Enclosure: Waterproof rated for operation at 5 to 65 deg C.

2.5. ANALOG CONTROLLERS

A. Step Controllers: 6- or 10-stage type, with heavy-duty switching rated to handle loads and operated by electric motor.
B. Electric, Outdoor-Reset Controllers: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range, adjustable set point, scale range minus 23 to plus 21 deg C, and single- or double-pole contacts.
C. Electronic Controllers: Wheatstone-bridge-amplifier type, in steel enclosure with provision for remote-resistance readjustment. Identify adjustments on controllers, including proportional band and authority.
    1. Single controllers can be integral with control motor if provided with accessible control readjustment potentiometer.
D. Fan-Speed Controllers: Solid-state model providing field-adjustable proportional control of motor speed from maximum to minimum of 55 percent and on-off action below minimum fan speed. Controller shall briefly apply full voltage, when motor is started, to rapidly bring motor up to minimum speed. Equip with filtered circuit to eliminate radio interference. Verify that fan speed controller is compatible with fan motor.
E. Receiver Controllers: Single- or multiple-input models with control-point adjustment, direct or reverse acting with mechanical set-point adjustment with locking device, proportional band adjustment, authority adjustment, and proportional control mode.
F. Remote-control-point adjustment shall be plus or minus 20 percent of sensor span, input signal of 21 to 90 kPa.
G. Proportional band shall extend from 2 to 20 percent for 35 kPa.
H. Authority shall be 20 to 200 percent.
I. Air-supply pressure of 124 kPa, input signal of 21 to 103 kPa, and output signal of zero to supply pressure.
J. Gages: 38 mm in diameter, 2.5 percent wide-scale accuracy, and range to match transmitter input or output pressure.

2.6. ELECTRONIC SENSORS

A. Description: Vibration and corrosion resistant; for wall, immersion, or duct mounting as required.
B. Thermistor Temperature Sensors and Transmitters:
    1. Accuracy: Plus or minus 0.3 deg Cover minimum operating range, 1,000 ohm or greater.

2. Wire: Twisted, shielded-pair cable.
3. Insertion Elements in Ducts: Single point, 460 mm long; use where not affected by temperature stratification or where ducts are smaller than 0.84 sq. m.
4. Averaging Elements in Ducts: Minimum coverage of 300 mm per 0.6 m of duct; use where prone to temperature stratification or where ducts are larger than 1 sq. m.
5. Insertion Elements for Liquids: Brass or stainless-steel socket with minimum insertion length of 64 mm.
6. Room Sensor Cover Construction: Manufacturer's standard locking covers.
    a. Set-Point Adjustment: Concealed in public and multi-occupancy spaces, exposed in private offices.
    b. Set-Point Indication: Concealed in public and multi-occupancy spaces, exposed in private offices.
    c. Thermometer: Concealed in public and multi-occupancy spaces, exposed in private offices.
    d. Colour: As selected by Architect.
    e. Orientation: Vertical.
    f. After hours occupancy switch (momentary).
    g. Plug-in jack for network communication terminal.
    h. Insulated base for sensors located as exterior walls.
7. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
8. Room Security Sensors (where indicated): Stainless-steel cover plate with insulated back and security screws.
9. Minimum Operating Ranges
    a. Wall mount space sensor: 4.4 deg C to 37.8 deg C.
    b. Duct mount sensor: - 6.7 deg C to 48.9 deg C.
    c. Chilled water sensor: 0 deg C to 26.7 deg C.
    d. Condenser water service: 4.4 deg C to 37.8 deg C.
    e. Hot water service: 0 deg C to 98.9 deg C.
    f. Outside air service: - 28.9 deg C to 48.9 deg C.
    g. Mixed air temperature: -1.1 deg C to 48.9 deg C.

C. RTDs and Transmitters:
1. Accuracy: Plus or minus 0.2 percent over minimum operating range.
2. Wire: Twisted, shielded-pair cable.
3. Insertion Elements in Ducts: Single point, 460 mm long; use where not affected by temperature stratification or where ducts are smaller than 0.84 sq. m.
4. Averaging Elements in Ducts: Minimum coverage of 300 mm per 0.6 m of duct; use where prone to temperature stratification or where ducts are larger than 0.84 sq. m; length as required.
5. Insertion Elements for Liquids: Brass socket with minimum insertion length of 64 mm.
6. Room Sensor Cover Construction: Manufacturer's standard locking covers.
    a. Set-Point Adjustment: Concealed in public and multi-occupancy spaces, exposed in private offices.

b. Set-Point Indication: Concealed in public and multi-occupancy spaces, exposed in private offices.
c. Thermometer: Concealed in public and multi-occupancy spaces, exposed in private offices.
d. Colour: As selected by Architect.
e. Orientation: Vertical.
f. After hours occupancy switch (momentary).
g. Plug-in jacket for network communication terminal.
h. Insulated base for sensors located on exterior walls.

7. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
8. Room Security Sensors: Stainless-steel cover plate with insulated back and security screws.
9. Minimum Operating Ranges
   a. Wall mount space sensor: 4.4 deg C to 37.8 deg C.
   b. Duct mount sensor: -6.7 deg C to 48.9 deg C.
   c. Chilled water sensor: 0 deg C to 26.7 deg C.
   d. Condenser water service: 4.4 deg C to 37.8 deg C.
   e. Hot water service: 0 deg C to 98.9 deg C.
   f. Outside air service: - -28.9 deg C to 48.9 deg C.
   g. Mixed air temperature: -1.1 deg C to 48.9 deg C.

D. Humidity Sensors: Bulk polymer sensor element.
1. Accuracy: 2 percent full range with linear output, single point calibration potentiometer.
2. Room Sensor Range: 20 to 80 percent relative humidity.
3. Room Sensor Cover Construction: Manufacturer's standard locking covers.
   a. Set-Point Adjustment: Concealed.
   b. Set-Point Indication: Concealed.
   c. Colour: As selected by Architect.
   d. Orientation: Vertical.
   e. Insulated base for sensors located on exterior walls.
4. Duct Sensor: 0 to 100 percent relative humidity range with element guard and mounting plate.
5. Outside-Air Sensor: 0 to 100 percent relative humidity range with mounting enclosure, suitable for operation at outdoor temperatures of minus 40 to plus 76 deg C.
6. Provide hand held field calibration tool, to Owner, compatible with calibration plug on humidity sensors. Calibration tool shall have the ability to read the humidity of airstream, humidity of mounted sensors and differential between calibration tool and mounted sensor.

E. Pressure Transmitters/Transducers:
1. Static-Pressure Transmitter: Non-directional sensor with suitable range for expected input, and temperature compensated. Sensor shall withstand up to 150 percent of rated pressure. Sensor shall have separate zero and span adjustments for field calibration. Sensors shall be manufactured and calibrated through system acceptance by Modus.

a. Accuracy: +1 percent of full scale (RSS method) with repeatability of 0.5 percent. Temperature effect shall contribute error less than +0.4 percent over the full scale of measurement.
b. Output: 4 to 20 mA.
c. Building Static-Pressure Range: -62 to 62 Pa.
d. Duct Static-Pressure Range: 0 to 1240 Pa.
e. Filter Differential Pressure Range: 0 to 496 Pa.

2. Water Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 1034-kPa operating pressure; linear output 4 to 20 mA.
3. Water Differential-Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 1034-kPa operating pressure and tested to 2070-kPa; linear output 4 to 20 mA.
4. Differential-Pressure Switch (Air or Water): Snap acting, with pilot-duty rating and with suitable scale range and differential.
   a. Air differential pressure switch shall have integral manual reset for low and high duct static pressure alarming. Field selectable set point 24.8 to 1763 Pa adjustments and differential 24.8 to 124 Pa. Switch shall withstand maximum differential pressure of 2480 Pa
   b. Water differential pressure switch shall provide field selectable set point (69345 kPa) and differential adjustments (14 kPa) switch shall withstand maximum differential pressure of 1034 kPa
5. Pressure Transmitters: Direct acting for gas, liquid, or steam service; range suitable for system; linear output 4 to 20 mA.

2.7. PNEUMATIC SENSORS

A. Pneumatic Transmitters: Vibration and corrosion resistant.
   1. Space-Temperature Sensors: Linear-output type, 10 to 38 deg C range, with blank locking covers matching room thermostats.
   2. Room Return-Air Temperature Sensors: Linear-output type with bimetal sensing element and corrosion-proof construction, 10 to 38 deg C range, designed to be mounted in light troffers.
   3. Duct-Mounted or Immersion-Type Temperature Sensors: Range as required for 21- to 103-kPa output signal.
   4. Temperature Transmitters: Rigid-stem type with bimetal sensing elements unless averaging is required, 21- to 103-kPa output signal.
      a. Averaging-Element Sensors: Single- or multiple-unit capillary elements.
      b. Tamperproof Sensors: Corrosion-resistant construction, suitable for mounting on vibrating surface with exposed capillary protected with temperature-compensated armor or protective tubing.
      c. Pipe mounted Temperature-Sensing Elements: Rod-and-tube type; with separable wells filled with heat-conductive compound.
      d. Outdoors: Provide bulb shield with mounting bracket.
   5. Space and Duct Humidity Transmitters: One pipe, directly proportional, with minimum sensing span of 20 to 80 percent relative humidity for

21- to 103-kPa output signal, corrosion resistant and temperature compensated, and with factory-calibrated adjustment.
   a. Space Mounting: With covers to match thermostats.
6. Differential-Pressure Transmitters: One pipe, direct acting for gas, liquid, or steam service; pressure sensor and transmitter of linear-output type; with range of 0 to 344 kPa, and 21- to 103-kPa output signal.
7. Differential-Air-Pressure Transmitters: One pipe, direct acting, double bell; unidirectional with suitable range for expected input; and temperature compensated.
   a. Accuracy: 5 percent of full range and 2 percent of full scale at midrange.
   b. Output Signal: 21 to 103 kPa.

B. Digital-to-Pneumatic Transducers: Convert sensors shall be non-bleed type with no air consumption at steady state. Sensors shall be capable of field calibration, or continuous proportional current (4-20 mA) or voltage (0-10 VDC) to 0 to 140 kPa.
C. Pneumatic Valve/Damper Position Indicator: Potentiometer mounted in enclosure with adjustable crank-arm assembly connected to damper to transmit 0 to 100 percent valve/damper travel.

2.8. STATUS SENSORS

A. Status Inputs for Fans: Differential-pressure switch with pilot-duty rating and with adjustable range of 0 to 1240 Pa. Air flow status for constant volume systems shall be by differential pressure switch or current transducers. Only current transducers shall be used with VAV systems. If more than one fan, pump, or other piece of equipment is started from one start/stop, each shall have differential pressure switch or current transducers for status.
B. Status Inputs for Pumps: Differential-pressure switch with pilot-duty rating and with adjustable pressure-differential range of 55 to 414 kPa, piped across pump. Water flow status shall be sensed by differential pressure switch piped across pump. One piping connection shall be made at pump suction, the other at pump discharge before the discharge check valve. Protect or alarm equipment switch or system headers if switch is used to indicate system flow status. If switch senses system differential pressure switch shall indicate flow when at least one pump is missing.
C. Status Inputs for Filters: Differential pressure switch with pilot duty rating and with adjustable range of 0 to 1240 Pa. Static pressure shall be calibrated for accurate status indication at minimum VAV discharge to eliminate nuisance alarms.
D. Status Inputs for Electric Motors: Comply with ISA 50.00.01, current-sensing fixed- or split-core transformers with self-powered transmitter, adjustable and suitable for 175 percent of rated motor current.
E. Voltage Transmitter (100- to 600-V ac): Comply with ISA 50.00.01, single-loop, self-powered transmitter, adjustable, with suitable range and 1 percent full-scale accuracy.
F. Power Monitor: 3-phase type with disconnect/shorting switch assembly, listed voltage and current transformers, with pulse kilowatt hour output and 4- to 20-mA kW output, with maximum 2 percent error at 1.0 power factor and 2.5 percent error at 0.5 power factor.

G. Current Switches: Self-powered, solid-state with adjustable trip current, selected to match current and system output requirements. Switches shall be accurate to +3 percent of full scale current and capable of reading 125 percent of full load amps (FLA).
H. Electronic Valve/Damper Position Indicator: Visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.
I. Water-Flow Switches: Bellows-actuated mercury or snap-acting type with pilot-duty rating, stainless-steel or bronze paddle, with appropriate range and differential adjustment, in NEMA 250, Type 1 enclosure.

2.9. GAS DETECTION EQUIPMENT

A. Carbon Monoxide Detectors: Single or multichannel, dual-level detectors using solid-state plug-in sensors with a 3-year minimum life; suitable over a temperature range of 0 to 40 deg C with 2 factory-calibrated alarm levels at 50 and 100 or 35 and 200 ppm as indicated.
B. Carbon Dioxide Sensor and Transmitter: Single detectors using solid-state infrared sensors; suitable over a temperature range of minus 5 to plus 55 deg C and calibrated for 0 to 2 percent, with continuous or averaged reading, 4- to 20-mA output; for wall mounting.
C. Occupancy Sensor: Passive infrared, with time delay, daylight sensor lockout, sensitivity control, and 180-degree field of view with vertical sensing adjustment; for flush mounting.
D. Oxygen Sensor and Transmitter: Oxygen depletion monitors and alarm system shall consist of solid state sensing panel with integral sampling station. System shall be capable of up to a minimum of 10 remote sensing heads/points.
    1. Sensing shall be suitable over a temperature range of 0 to 50 deg C and calibrated for 0 to 5 percent, with continuous or averaged reading.
        a. Sensing Range: 0-25% Oxygen.
    2. Output: 4- to 20-mA output, Alarm dry-contact (minimum 3 amp relay).
    3. Alarm Strobe: Furnish and provide red alarm strobe activated by the system as shown on the contract documents.
    4. Mounting: Wall-Mounted, Aluminum Enclosure.
    5. Local Indication: Panel shall be provided with local interface for visual indication of sensed oxygen concentration, and fault / alarm / trouble.
    6. Manufacturer: Ox-An Gas Detection, Oxigraf Inc. or approved equal.

2.10. FLOW MEASURING STATIONS

A. Duct Airflow Station: Multiport, self-averaging Pitot tube station.
    1. Casing: Material to match ductwork.
    2. Sensing Manifold: Copper manifold with bullet-nosed static pressure sensors positioned on equal area basis. Provide stainless steel manifold for corrosive airstreams such as laboratory exhaust, moisture laden airstreams, or other similar contaminants.
B. Traverse stations shall be connected to ductwork with bolts at flanges; stations shall be removable for cleaning. Each probe mounted within the station shall contain multiple total and static pressure sensors placed at equal distances (for rectangular ducts) or at concentric area centers (for circular ducts). As an alternative, flow measurement devices may employ thermal anemometer technology. The number of sensors provided with each flow station shall comply with the ASHRAE standards for duct traversing. The

airflow traverse station shall produce a steady non-pulsating flow signal without need for correction factor or special calibration. The station shall be capable of measuring airflow through the station to within 2% of actual flow.

C. The probes shall be installed perpendicular to the velocity profile gradient.
D. Traverse probes or stations which incorporate honey comb grid or tube type airflow straighteners are not acceptable.
E. Traverse stations shall be constructed out of the same type material as the duct material.
F. Provide a differential pressure transmitter for each Pitot tube flow station or analogue signal average for thermal anemometer flow stations. Provide transmitters with applicable square root extractor, scaling multiplier and output filter with a magnahelic scaled in L/sec and M/sec, Mounted on the front of the control panel. For outdoor measurement provide a LCD display meter, scaled in L/sec, mounted on the control panel in lieu of the magnahelic. The combined accuracy of the components shall be +/-0.5%.
G. All traverse stations must be shown on the sheet metal shop drawings. This requirement will be strictly enforced by the Architect.

2.11. THERMOSTATS

A. Combination Thermostat and Fan Switches: Line-voltage thermostat with push-button or lever-operated fan switch.
    1. Label switches "FAN ON-OFF", "FAN HIGH-LOW-OFF", or "FAN HIGH-MEDLOW-OFF" as appropriate to match motor.
    2. Mount on single electric switch box.
B. Electric, solid-state, microcomputer-based room thermostat with remote sensor.
    1. Automatic switching from heating to cooling.
    2. Preferential rate control to minimize overshoot and deviation from set point.
    3. Set up for four separate temperatures per day.
    4. Instant override of set point for continuous or timed period from 1 hour to 31 days.
    5. Short-cycle protection.
    6. Programming based on every day of week.
    7. Selection features include degree F or degree C display, 12- or 24-hour clock, keyboard disable, remote sensor, and fan on-auto.
    8. Battery replacement without program loss.
    9. Thermostat display features include the following
        a. Time of day.
        b. Actual room temperature.
        c. Programmed temperature.
        d. Programmed time.
        e. Duration of timed override.
        f. Day of week.
        g. System mode indications include "heating," "off," "fan auto," and "fan on."
C. 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, 13 to 30 deg C set-point range, and 1 deg C maximum differential.

D. Line-Voltage, On-Off Thermostats: Bimetal-actuated, open contact or bellows-actuated enclosed, snap-switch or equivalent solid-state type, with heat anticipator; listed for electrical rating; with concealed set-point adjustment, 13 to 30 deg C set-point range, and 1 deg C maximum differential.
    1. Electric Heating Thermostats: Equip with off position on dial wired to break ungrounded conductors.
    2. Selector Switch: Integral, manual on-off-auto.
E. Remote-Bulb Thermostats: On-off or modulating type, liquid filled to compensate for changes in ambient temperature; with copper capillary and bulb, unless otherwise indicated.
    1. Bulbs in water lines with separate wells of same material as bulb.
    2. Bulbs in air ducts with flanges and shields.
    3. Averaging Elements: Copper tubing with either single- or multiple-unit elements extended to cover full width of duct or unit; adequately supported.
    4. Scale settings and differential settings are clearly visible and adjustable from front of instrument.
    5. On-Off Thermostat: With precision snap switches and with electrical ratings required by application.
    6. Modulating Thermostats: Construct so complete potentiometer coil and wiper assembly is removable for inspection or replacement without disturbing calibration of instrument.
F. Pneumatic Room Thermostats: Two pipes, fully proportional with adjustable throttling range and tamperproof locking settings, pneumatic relay, pneumatic feedback, direct or reverse acting as required. Factory calibrated at 17.2 kPa/deg C.
    1. Factory Calibration: 17.2 kPa/deg C.
    2. Range: 7 to 30 deg C.
    3. Sensitivity Adjustment Range: 7 to 27.6 kPa/deg C.
    4. Dual-Temperature Thermostats: Automatic changeover from normal setting to lower setting for unoccupied cycles, with manual-reset lever to permit return to normal temperatures during unoccupied cycles, with automatic reset to normal during next cycle of operation.
    5. Room Thermostat Cover Construction: Manufacturer's standard locking covers.
        a. Set-Point Adjustment: Concealed in public and multi-occupancy areas, exposed in private and single occupancy rates.
        b. Set-Point Indication: Concealed in public and multi-occupancy areas, exposed in private and single occupancy rates.
        c. Thermometer: Exposed, red-reading glass in private and single occupancy areas.
        d. Colour: As selected by Architect.
        e. Orientation: Vertical.
    6. Room thermostat accessories include the following:
        a. Adjusting Key: As required for calibration and cover screws.
        b. Set-Point Adjustment: 13-mm- diameter, adjustment knob.
G. Immersion Thermostat: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range and adjustable set point.

H. Airstream Thermostats: Two-pipe, fully proportional, single-temperature type; with adjustable set point in middle of range, adjustable throttling range, plug-in test fitting or permanent pressure gage, remote bulb, bimetal rod and tube, or averaging element.
I. Electric, Low-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual reset switch that trips if temperature sensed across any 300 mm of bulb length is equal to or below set point.
    1. Bulb Length: Minimum 6 m.
    2. Quantity: One thermostat for every 2 sq. m of coil surface.

2.12. HUMIDISTATS

A. Pneumatic Room Humidistats: Wall-mounting, proportioning type with adjustable throttling range, 20 to 90 percent operating range, and cover matching room thermostat cover.
B. Duct-Mounting Humidistats: Electric insertion, 2-position type with adjustable, 2 percent throttling range, 20 to 80 percent operating range, and single- or double-pole contacts.
C. Pneumatic Duct-Mounting Humidistats: Proportioning type with adjustable throttling range, 20 to 90 percent operating range, in galvanized-steel duct box.

2.13. ACTUATORS

A. Electric Motors: Size to operate with sufficient reserve power to provide smooth modulating action or two-position action:
    1. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
    2. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.
    3. Non spring-Return Motors for Valves Larger than DN 65: Size for running torque of 16.9 N x m and breakaway torque of 33.9 N x m.
    4. Spring-Return Motors for Valves Larger than DN 65: Size for running and breakaway torque of 16.9 N x m.
    5. Non spring-Return Motors for Dampers Larger than 2.3 sq. m: Size for running torque of 16.9 N x m and breakaway torque of 33.9 N x m.
    6. Spring-Return Motors for Dampers Larger than 2.3 sq. m: Size for running and breakaway torque of 16.9 N x m.
B. Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-strokes cycles at rated torque.
    1. Valves: Size for torque required for valve close off at maximum pump differential pressure.
    2. Dampers: Size for running torque calculated as follows:
        a. Parallel blade Damper with Edge Seals: 86.8 kg-cm/sq. m of damper.
        b. Opposed blade Damper with Edge Seals: 62 kg-cm/sq. m of damper.
        c. Parallel blade Damper without Edge Seals: 49.6 kg-cm/sq. m of damper.

d. Opposed blade Damper without Edge Seals: 37.2 kg-cm/sq. m of damper.
e. Dampers with 500 to 750 Pa of Pressure Drop or Face Velocities of 5 to 13 m/s: Increase running torque by 1.5.
f. Dampers with 750 to 1000 Pa of Pressure Drop or Face Velocities of 13 to 15 m/s: Increase running torque by 2.0.

3. Coupling: V-bolt and V-shaped, toothed cradle.
4. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
5. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on non-spring-return actuators.
6. Power Requirements (Two-Position Spring Return): 24V ac.
7. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-Vdc.
8. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
9. Temperature Rating: Minus 30 to plus 50 deg C.
10. Temperature Rating (Smoke Dampers): Minus 30 to plus 121 deg C.
11. Run Time: 12 seconds open, 5 seconds closed unless indicated otherwise.

C. Pneumatic Valve Operators: Rolling-diaphragm, spring-loaded, piston type with spring range as required and start-point adjustment and positioning relay. Operator shall maintain full shutoff at maximum pump differential pressure.

D. Pneumatic Damper Operators: Rolling-diaphragm, piston type with adjustable stops and spring return, sized to operate with sufficient reserve power to provide smooth modulating action or two-position action. Where actuators operate in sequence, provide pilot positioners.

1. Pilot Positioners: With the following characteristics
   a. Start Point: Adjustable from 14 to 83 kPa.
   b. Operating Span: Adjustable from 35 to 90 kPa.
   c. Linearity: Plus or minus 10 percent of output signal span.
   d. Hysteresis: 3 percent of span.
   e. Response: 1723-Pa input change.
   f. Maximum Pilot Signal Pressure: 140 kPa.
   g. Maximum Control Air-Supply Pressure: 410 kPa.
2. Actuator Housing: Molded or die-cast zinc or aluminum. Terminal unit actuators may be high-impact plastic with ambient temperature rating of 10 to 60 deg C unless located in return-air plenums

2.14. CONTROL VALVES

A. Control Valves: Factory fabricated, of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated. Control valves shall be sized by the control contractor and shall be guaranteed to meet heating and cooling loads specified. Valves shall be sized and selected to operate accurately and with stability from 10 to 100 percent of maximum design flow. Valves shall be quiet in operation and fail safe in either normally open or normally closed position as indicated in control sequences in the event of control air or power failure.

B. Hydronic system globe valves shall have the following characteristics:
   1. DN 50 and Smaller: Pressure and temperature ratings shall match pressure rating of valves of each specific system as specified in Division 23, bronze body, bronze trim, rising stem, renewable composition disc, and screwed ends with back seating capacity repack able under pressure.
   2. DN 65 and Larger: Pressure and temperature ratings shall match pressure ratings of valves of each specific system as specified in Division 23, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.
   3. Internal Construction: Replaceable plugs and stainless-steel or brass seats.
      a. Single seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom.
      b. Double seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom.
   4. Sizing: 35-kPa maximum pressure drop at design flow rate or the following:
      a. Two Position: Line size.
      b. Two-Way Modulating: The value specified above.
      c. Three-Way Modulating: Twice the load pressure drop, but not more than value specified above.
   5. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.
   6. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system (pump) head for two-way valves and 100 percent of pressure differential across valve or 100 percent of total system (pump) head.

C. Butterfly Valves: 1380-kPa, 1034-kPa maximum pressure differential, ASTM-A 126 cast-iron or ASTM A 536 ductile-iron body and bonnet, extended neck, stainless-steel stem, field-replaceable EPDM or Buna N sleeve and stem seals.
   1. Body Style: Lug.
   2. Disc Type: Aluminum bronze.
   3. Sizing: 7-kPa maximum pressure drop at design flow rate.

D. Terminal Unit Control Valves: Bronze body, bronze trim, two or three ports as indicated, replaceable plugs and seats, and union and threaded ends.
   1. Rating: Class 125 for service at 860 kPa and 121 deg C operating conditions.
   2. Sizing: 21-kPa maximum pressure drop at design flow rate, to close against pump shutoff head.
   3. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.

2.15. DAMPERS

A. Dampers: AMCA-rated, parallel and opposed-blade design as indicated below; 2.8- mm- minimum thick, galvanized-steel or 3.2-mm- minimum thick, extruded-aluminum frames with holes for duct mounting; damper blades

shall not be less than 1.6-mmthick galvanized steel with maximum blade width of 152 mm and length of 1220 mm.

1. Secure blades to 13-mm- diameter, zinc-plated axles using zinc-plated hardware, with nylon blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade. Bushings that turn in bearings shall be oil impregnated sintered bronze.
2. Operating Temperature Range: From minus 40 to plus 93 deg C.
3. Edge Seals, Low-Leakage Applications: Use inflatable blade edging or replaceable rubber blade seals and spring-loaded stainless-steel side seals, rated for leakage at less than 40 L/s per sq. m of damper area, at differential pressure of 1000 Pa when damper is held by torque of 5.6 N x m; when tested according to AMCA 500D.
4. Blade Type
    a. Two position and mixing operation - parallel blades.
    b. Modulating operation - opposed blades.

2.16. AIR SUPPLY

A. Control and Instrumentation Tubing: Copper tubing complying with ASTM B 88M, Type A or ASTM B 280 Type ACR.
    1. Fittings: Cast-bronze solder fittings complying with ASME B16.18; or wrought copper solder fittings complying with ASME B16.22, except forged-brass compression-type fittings at connections to equipment.
    2. Joining Method: Soldered or brazed.
B. Control and Instrumentation Tubing: ASTM D 2737 Type FR plenum-rated polyethylene, flame-retardant, non-metallic tubing rated for 207 kPa and ambient temperature range of minus 13 to plus 65 deg C with flame-retardant harness for multiple tubing.
    1. Fittings: Compression or push-on polyethylene fittings.
C. Air Piping Applications: Provide air-tight tubing of sufficient size. Air piping in finished spaces shall be run concealed. Polyethylene tubing shall be black type FR; tubing in plenums shall be fire resistant.
    1. Exposed: Hardened copper tubing, single tube polyethylene in metal jacket, or multi-tube polyethylene with vinyl jacket. Multi-tube bundles shall be terminated in panels or junction boxes. Final termination to control devices may be made with short run of single tube polyethylene.
    2. Main and signal air for smoke exhaust and pressurization systems tubing including risers and run outs: copper.
    3. Concealed: Hard or soft copper tubing or single or multi-tube polyethylene.
    4. Concrete Buried: Hard or soft copper tubing or polyethylene tubing enclosed in metal conduit with pull boxes to facilitate replacement of tubing.
    5. Inside Panels and Unit Enclosures: Polyethylene tubing.
    6. 345 kPa or Greater Compressed Air Mains and Risers: rigid copper, with drawn copper fittings and 95/5 solder.
D. Provide for 100 mm expansion/contraction of lines that pass building expansion loops.

E. Tank: ASME storage tank with drain test cock, automatic moisture removal trap, tank relief valve, and rubber-cork vibration isolation mounting pads.
F. Duplex Air Compressor: Capacity to supply compressed air to temperature-control system.
    1. Pressure control with adjustable electric contacts, set to start and stop both compressors at different pressures.
    2. Electrical alternation set with motor starters and disconnect to operate compressors alternately or on time schedule.
    3. Each compressor shall be provided with its own separate disconnect and starter, wired for a common feed to the air compressor unit.
G. Compressor Type: Reciprocating, oil lubricated belt drive with belt guards.
H. Size compressor and tank to operate compressor not more than 20 minutes during a 60-minute period based on compressed air consumption in approved consumption calculation tabulation.
I. Compressor Accessories: Low-resistance intake-air filters, and belt guards. System Accessories: Air filter rated for 97 percent efficiency at rated airflow, and combination filter/pressure-reducing station or separate filter and pressure-reducing station.
J. Refrigerated Air Dryer: Self-contained, refrigerated air dryer complete with heat exchangers, moisture separator, internal wiring and piping, and with manual bypass valve. Dryer shall be sized for fill compressor capacity.
    2. Heat Exchangers: Air-to-refrigerant coils with centrifugal-type moisture separator and automatic trap assembly.
    3. Refrigeration Unit: Hermetically sealed, operating to maintain dew point of minus 11 deg C at 140 kPa, housed in steel cabinet with access door and panel.
    4. Accessories: Air-inlet temperature gage, air-inlet pressure gage, on-off switch, high-temperature light, power-on light, refrigerant gage on back, air-outlet temperature gage, air-outlet pressure gage, and with contacts for remote indication of power status and high-temperature alarm.
    5. Effluent air shall have dew point of less than 15 deg F (-9 deg C) when reduced to control operating pressure required.
K. Desiccant Dryer: Obtains dew point in pneumatic air piping between compressor and tank at least minus 9 deg C below inlet-air dew point at design conditions.
L. Air Filter Assembly: Provide necessary coalescing filter, charcoal filter, and air pressure reducing station to provide air to devices at required pressures. Reducing station shall maintain required reduced pressure within maximum variance of 1.7 kPa. Provide valve filter bypass piping.
M. Pressure Gauges: Black letters on white background, 64 mm in diameter, flush or surface mounting, with front calibration screw to match sensor, and having a graduated scale in kPa.
N. Instrument Pressure Gauges: Black letters on white background, 38 mm in diameter, stem mounted, with suitable dial range.
O. Diaphragm Control and Instrument Valves: 6-mm forged-brass body with reinforced polytetrafluoroethylene diaphragm, stainless-steel spring, and color-coded phenolic handle.
P. Gage Cocks: Tee or level handle, bronze, rated for 860 kPa.

Q. Relays: For summing, reversing, and amplifying highest or lowest pressure selection; with adjustable I/O ratio.
R. Switches: With indicating plates and accessible adjustment; calibrated and marked.
S. Pressure Regulators: Zinc or aluminum castings with elastomeric diaphragm, balanced construction to automatically prevent pressure build-up, and producing flat reduced pressure curve.
T. Particle Filters: Zinc or aluminum castings with 97 percent filtration efficiency at rated airflow, quick-disconnect service devices, and aluminum or plastic bowl with metal guard and manual drain cock.
U. Combination Filter/Regulators: Zinc or aluminum castings with elastomeric diaphragm, balanced construction to automatically prevent pressure build-up, and producing flat reduced- pressure curve; with threaded pipe connections, quick-disconnect service devices, and aluminum or plastic bowl with metal guard and manual drain cock.
V. Airborne Oil Filter: Filtration efficiency of 99.9 percent for airborne lubricating oil particles of 0.025 micron or larger.
W. Pressure Relief Valves: ASME rated and labelled.
    1. High Pressure: Size for installed capacity.
    2. Low Pressure: Size for installed capacity of pressure regulators and set at 20 percent above low pressure.
X. Pressure-Reducing Stations: Two parallel pressure regulators.

2.17. CONTROL CABLE

A. Electronic and fiber-optic cables for control wiring are part of Communications Horizontal Cabling.

2.18. SMOKE DETECTION AND DAMPERS IN AIR HANDLING UNITS

A. Install duct smoke detectors furnished under Division 28 where shown on Drawings. Wire to fan control. Wiring to fire alarm system shall be part of work of Division 28.
B. Provide normally closed smoke dampers in return and supply air ducts to close automatically upon fan shutdown due to fire or smoke detection or upon manual shutdown.
C. Smoke dampers shall be controlled so that fans shall not start until dampers are open and fans shall stop before smoke dampers are fully closed. End switches, damper switches, and other components required shall be by temperature control manufacturer.

PART 3 - EXECUTION

4.1. EXAMINATION

A. Verify that standby power supply is available to control units and operator workstation.
B. Verify that pneumatic piping and duct-, pipe-, and equipment-mounted devices are installed before proceeding with installation.

4.1. INSTALLATION

A. Install software in control units and operator workstation(s). Implement all features of programs to specified requirements and as appropriate to sequence of operation.

B. Connect and configure equipment and software to achieve sequence of operation specified.
C. Mount compressor and tank unit on vibration isolation devices as specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Isolate air supply with wire-braid-reinforced rubber hose. Secure and anchor according to manufacturer's written instructions and seismic-control requirements.
    1. Pipe manual and automatic drains to nearest floor drain.
    2. Supply instrument air from compressor units through filter, pressure reducing valve, and pressure relief valve, with pressure gauges and shutoff and bypass valves.
D. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices at mounting heights in accordance with Americans with Disabilities Act (ADA), or as otherwise directed by the Architect.
    1. Install averaging elements in ducts and plenums in crossing or zigzag pattern.
E. Install guards on thermostats in the following locations:
    1. Entrances.
    2. Public areas.
    3. Where indicated.
F. Install automatic dampers according to Division 23 Section "Air Duct Accessories."
G. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.
H. Install labels and nameplates to identify control components according to Division 23 Section "Identification for HVAC Piping and Equipment."
I. Install hydronic instrument wells, valves, and other accessories according to Division 23 Section "Hydronic Piping."
J. Install refrigerant instrument wells, valves, and other accessories according to Division 23 Section "Refrigerant Piping."
K. Install duct volume-control dampers according to Division 23 Sections specifying air ducts.
L. Install electronic and fibre-optic cables according to Section "Communications Horizontal Cabling."

4.1. PNEUMATIC PIPING INSTALLATION

A. Install piping in mechanical equipment rooms inside mechanical equipment enclosures, in pipe chases, or suspended ceilings with easy access.
    1. Install copper tubing with maximum unsupported length of 915 mm, for tubing exposed to view.
    2. Install polyethylene tubing in metallic raceways or electrical metallic tubing. Electrical metallic tubing materials and installation requirements are specified in Division 26 Section "Raceway and Boxes for Electrical Systems."
B. Install terminal single-line connections, less than 460 mm in length, with copper or polyethylene tubing run inside flexible steel protection.
C. In concealed locations such as pipe chases and suspended ceilings with easy access, install copper, polyethylene bundled and sheathed, or polyethylene tubing in electrical metallic tubing. Electrical metallic tubing

materials and installation requirements are specified in Division 26 Section "Raceway and Boxes for Electrical Systems."

D. In concrete slabs, furred walls, or ceilings with no access, install copper or polyethylene tubing in electrical metallic tubing or vinyl-jacketed polyethylene tubing.
    1. Protect embedded-copper and vinyl-jacketed polyethylene tubing with electrical metallic tubing extending 150 mm above finished slab and 150 mm into slab.
    2. Install polyethylene tubing in electrical metallic tubing extending 150 mm above floor line; pull tubing into electrical metallic tubing after pour.
E. Install tubing with sufficient slack and flexible connections to allow for vibration of piping and equipment.
F. Purge tubing with dry, oil-free compressed air before connecting control instruments.
    1. Bridge cabinets and doors with flexible connections fastened along hinge side; protect against abrasion. Tie and support tubing.
G. Number-code or color-coded control air piping for future identification and service of control system, except local individual room control tubing.
H. Pressure Gauges or Test Plugs: Install on branch lines at each receiver controller and on signal lines at each transmitter, except individual room controllers.

4.1. ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. Install raceways, boxes, and cabinets according to Division 26 Section "Raceway and Boxes for Electrical Systems." 24V control transformers are to be provided by the supplier.
B. Install building wire and cable according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."
C. Install signal and communication cable according Communications Horizontal Cabling.
    1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
    2. Install exposed cable in EMT raceway.
    3. Install concealed cable in EMT raceway.
    4. Bundle and harness multi conductor instrument cable in place of single cables where several cables follow a common path.
    5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
    6. Number-code or color-coded conductors for future identification and service of control system, except local individual room control cables.
    7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.
D. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.
E. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.
F. Electrical Wiring: Wiring and connections required for temperature control system shall be provided under this Section, unless shown otherwise on Drawings, and shall comply with applicable requirements of Division 26,

Electrical. Necessary normal and emergency power wiring to control devices shall be provided under this section.

G. Electrical circuits for all controls shall be dedicated only to the control system. Wiring from and including the dedicated circuit breakers to the point of use shall be a part of this work of this section.

4.1. FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:
   1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
   2. Test and adjust controls and safeties.
   3. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
   4. Pressure test control air piping at 207 kPa or 1.5 times the operating pressure for 24 hours, with maximum 35-kPa loss.
   5. Test calibration of pneumatic and electronic controllers by disconnecting input sensors and stimulating operation with compatible signal generator.
   6. Test each point through its full operating range to verify that safety and operating control set points are as required.
   7. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
   8. Test each system for compliance with sequence of operation.
   9. Test software and hardware interlocks.

C. DDC Verification:
   1. Verify that instruments are installed before calibration, testing, and loop or leak checks.
   2. Check instruments for proper location and accessibility.
   3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
   4. Check instrument tubing for proper fittings, slope, material, and support.
   5. Check installation of air supply for each instrument.
   6. Check flow instruments. Inspect tag number and line and bore size, and verify that inlet side is identified and that meters are installed correctly.
   7. Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.
   8. Check temperature instruments and material and length of sensing elements.
   9. Check control valves. Verify that they are in correct direction.
   10. Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment, either parallel or opposed, has been provided.
   11. Check DDC system as follows:

a. Verify that DDC controller power supply is from emergency power supply, if applicable.
b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
c. Verify that spare I/O capacity has been provided.
d. Verify that DDC controllers are protected from power supply surges.

D. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

4.1. ADJUSTING

A. Calibrating and Adjusting:
1. Calibrate instruments.
2. Make three-point calibration test for both linearity and accuracy for each analogue instrument.
3. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
4. Control System Inputs and Outputs:
a. Check analogue inputs at 0, 50, and 100 percent of span.
b. Check analogue outputs using mill ampere meter at 0, 50, and 100 percent output.
c. Check digital inputs using jumper wire.
d. Check digital outputs using ohmmeter to test for contact making or breaking.
e. Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.
5. Flow:
a. Set differential pressure flow transmitters for 0 and 100 percent values with 3-point calibration accomplished at 50, 90, and 100 percent of span.
b. Manually operate flow switches to verify that they make or break contact.
6. Pressure:
a. Calibrate pressure transmitters at 0, 50, and 100 percent of span.
b. Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.
7. Temperature:
a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
b. Calibrate temperature switches to make or break contacts.
8. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.
9. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
10. Provide diagnostic and test instruments for calibration and adjustment of system.

11. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating start up procedures.

B. Adjust initial temperature and humidity set points.

C. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to three visits to Project during other than normal occupancy hours for this purpose.

4.1. DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls. Refer to Division 01 Section "Demonstration and Training."

4.1. COMMISSIONING

A. Building Automation System Contractor Commissioning Responsibilities

1. Completely install and thoroughly inspect start up, test, adjust, calibrate and document systems and equipment for Building Automation System.
2. Provide laptop computer, software and training to accommodate TAB Contractor in system balancing.
3. Maintain database of control parameters submitted by TAB Contractor subsequent to field adjustments and measurements.
4. Provide control systems start up schedule and coordinate with Commissioning and Project Management so that Commissioning Authority may witness the control system point-to-point “check-out” and document completion. Provide on-site technician skilled in software programming and hardware operation to demonstrate control system point-to-point “check-out” tests to Commissioning Authority.
5. Provide on-site technician skilled in software programming and hardware operation to exercise sequences of operation and to correct control deficiencies identified during functional performance testing including opposed season/deferred testing.
6. Provide, for use during commissioning, instrumentation, computer, software and communication resources necessary to demonstrate total operation of building systems during point-to-point “check-out”, functional performance testing, and opposed season testing of control system equipment.
7. Attend commissioning kick-off meeting and other commissioning team meetings.
8. Attend Owner training kick-off meeting conducted by Commissioning Authority
9. Prepare training plans with commissioning authority and project management and execute training as specified in Division 23 and 25 of these specifications. Attend Owner training kick-off meeting and other coordination meetings as required to complete training plans.
10. Maintain comprehensive system calibration and checkout records. Submit records to Commissioning Authority.
11. Set up trend logs as required by Commissioning Authority to substantiate proper systems operation.

12. Participate in two warranty review meetings with the Owner and O&M staff to review the commissioning systems performance 3 months and 10 months into the warranty period.

PART 4 - MANUFACTURERS

4.1. ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the requirements of this specification, provide control system by one of the following manufacturer:
   1. Alerton, Inc.
   2. Honeywell International, Inc., Home and Building Control
   3. Johnson Controls, Inc.; Controls Group
   4. Siemens Building Technologies, Inc.
   5. Any other approved equal.

END OF SECTION 25 50 01