NISTIR 4606

Guide Specification for Direct Digital Control Based Building Automation System

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Prepared for:
General Services Administration
Public Buildings Service
Office of Real Property Development
Washington, DC 20405

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Guide Specification for Direct Digital Control Based Building Automation System

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Abstract

This publication is intended for building system designers' use in specifying direct digital control (DDC) based building automation systems (BAS) for construction of Federal buildings. This guide specification conforms with the format of guide specifications used by the General Services Administration (GSA) and its professional services contractors.

Key Words: automatic control, building automation system, building control, building design, construction specification, direct digital control, guide specification

Preface

General Services Administration (GSA) constructs and manages Federal office buildings to provide safe, energy efficient, and appropriate working environments for the majority of Federal agencies. GSA uses a set of construction specifications to guide its own design personnel and contract architect-engineer firms engaged in designing GSA projects. The contents of these specifications basically follow those of the guide specifications of MASTERSPEC developed by the AIA Service Corporation, an affiliate of the American Institute of Architects.

Since the early 1980's, very sophisticated electronic control systems have been available to compete with conventional systems in controlling heating, ventilating, and air conditioning (HVAC) systems as well as fire safety and building security systems. These building automation systems (BAS) use direct digital control (DDC) techniques to provide reliable, versatile, and economic operation of building systems. The trend of using DDC based BAS to replace conventional control systems is accelerating. This trend prompted GSA to develop this guide specification.

Since DDC based BAS is still rapidly developing, rigid design requirements are not appropriate. Specification writers of building control systems should specify the Government's basic and ensuing requirements and let the control contractors provide control schemes and equipment to achieve the goals at the lowest costs. Appropriate details, where necessary, should also be specified so that construction quality can be assured. It is based upon these principles that this guide specification has been developed. The format of this specification follows that of other sections of GSA guide specifications.

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GENERAL SERVICES ADMINISTRATION GSA: 15980
WASHINGTON, DC 20405

GSA/PBS
GUIDE SPECIFICATION

BUILDING AUTOMATION SYSTEMS (BAS)

INSTRUCTIONS FOR USE

1. This Guide Specification MUST be edited prior to incorporation in project specifications.

2. General Services Administration (GSA) personnel may obtain either printed copy or word processor media from Central Office. Professional Services contractors to GSA will be provided printed copy for sections as required on a project basis. GSA does not distribute word processor media. This guide specification may be edited by either manual or word processor means at the user's option.

3. Compliance problems arising from the use of this document or any requests for copies of this specification for other than GSA projects should be referred to the Director, Building Technology and Standards Division, Public Buildings Services General Services Administration, Washington, D.C. 20405.

SECTION 15980 - BUILDING AUTOMATION SYSTEMS (BAS)

THIS SECTION COVERS BAS TO INCLUDE DIRECT DIGITAL CONTROL (DDC) BASED SYSTEMS FOR HVAC, FIRE AND SECURITY. THIS SPECIFICATION IS INTENDED TO BE USED FOR NEW CONSTRUCTION AND MAJOR RENOVATIONS WHERE NEW CONTROL SYSTEMS ARE INCLUDED.
FOR A COMPLETE DDC BASED BAS, THE CONTROL CONTRACTOR IS REQUIRED TO FURNISH CERTAIN WIRING, CONDUIT, EMT, OUTLET BOXES AND OTHER ELECTRIC WORK. THE SPECIFICATION REQUIREMENTS COVERING THIS WORK ARE INCLUDED IN DIVISION 16 SECTIONS. THE SPECIFICATION WRITER MUST THEREFORE INCLUDE, AS A MINIMUM, THE FOLLOWING DIVISION 16 SECTIONS IN ANY CONTROL PROJECT. IF THESE SECTIONS ARE FURNISHED AS PART OF THE BUILDING CONSTRUCTION SPECIFICATION, THE BAS SPECIFICATION WRITER SHOULD EXAMINE THESE SECTIONS AND COORDINATE HIS WIRING REQUIREMENTS WITH THE WIRING AND CONDUIT FURNISHED UNDER DIVISION 16. AS A MINIMUM INCLUDE THE FOLLOWING DIVISION 16 SECTIONS:

BASIC ELECTRICAL REQUIREMENTS - 16010
BASIC ELECTRICAL MATERIALS AND METHODS - 16050
RACEWAYS AND FITTINGS - 16110
CONDUIT - 16112
WIRE AND CABLE - 16120
CONTROL/SIGNAL WIRING - 16126
ELECTRICAL BOXES AND FITTINGS - 16130

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. Scope: The work of direct digital control (DDC) based building automation system (BAS) is indicated on the drawings and schedules and by the requirements of this section, and Section 15010, MECHANICAL BASIC REQUIREMENTS. The work includes:

1. The provision of a complete and operational monitoring and control system, including all devices necessary to perform the functions herein described or indicated on the drawings.

2. The provision of 120 and 208 line voltage and 5, 24, or other volt low voltage wiring, conduit, installed in accordance with the NEC, and Division 16 of these

specifications.

3. All drilling, cutting and patching associated with the installation of BAS.

B. Other Sections: Refer to other sections of Division 15 for:

Testing and balancing of air and water distribution system.

Controls furnished as an integral part of factory manufactured equipment.

Meters and gauges on instrumentation indicating panels.

C. Other Divisions: Refer to other divisions of the specification for:

Extent of power wiring to motor controllers and relays.

1.02 DEFINITIONS

Alarm - 1. An annuciation, either audible of visual or both, which alerts an operator to an off-normal condition that may require corrective action. 2. An abnormal condition detected by a device or controller that implements a rule or logic specifically designed to look for that condition.

Algorithm - A step by step procedure for solving a problem by using a set of well defined rules.

Analog - A physical quantity (temperature, pressure, etc.) that varies through a continuous ranges of values.

A/D Converter - A circuit whose input information in analog form is converted to digital form proportional to the analog input.

ASCII - American Standard Code for Information Interchange.

Byte - A sequence of adjacent binary digits operated upon as a unit, usually eight in number.

D/A Converter - A circuit whose input information in digital form is converted to analog form proportional to the digital input.

Direct digital control (DDC) - Closed-loop modulating control of equipment by means of a digital computer.

Downloading - The process of transferring of an executable program

or database to a remote device where it may be executed.

Field panel - A remotely located panel containing microprocessors that monitors and controls certain pieces of mechanical or electrical equipment. The panel alone performs all functions of monitoring and control. It is also connected to the host computer for supervisory control and reporting.

Firmware - Computer instructions residing in non-volatile memory.

Host computer - A computer that coordinates information from various intelligent field devices.

Local Loop Control - The control of equipment by a predetermined algorithm of the field panel.

Modem - A device to interface a computer with telephone lines to exchange information through the lines.

Multidrop - A communications system configuration using a single channel or line to serve multiple devices, normally requiring some protocol control mechanism.

Multitasking - A computer which executes a number of programs concurrently by a computer.

Non-volatile Memory - Memory which retains information when power is removed.

Object Code - The machine language instructions generated by compilers.

RAM - Random access memory where information is lost when power is removed.

Supervisory Control - The control of equipment based on global considerations. Usually command information is sent from a host computer to field panels.

Uploading - The process of transferring an executable program image or a database from a remote device in such a manner as to allow subsequent download.

1.03 QUALITY ASSURANCE

A. General: Quality assurance for BAS includes a multistep program consisting of a system engineering, products and shop drawing phase; installation; testing and adjusting; reporting; final

functional testing and verifications; operating instruction and training; and the submission of maintenance and operating manuals.

B. BAS Subcontractor: BAS subcontractor shall meet qualifications listed under items 7, 8, and 9 below. Within 14 days after notice to proceed, submit to the Contracting Officer's representative a certified statement, signed by an official of the BAS manufacturer which includes the following:

1. Company name and address.

2. Address of the manufacturing plant and name.

3. Address and telephone number of the local representative.

4. General sales and engineering bulletin covering the full line of products manufactured.

5. General catalog information covering the characteristics of the systems proposed for this contract.

6. A detailed sketch of proposed system overview to include architecture of the BAS, the host computer systems, communication method, and major components of HVAC, fire, and security systems.

7. A certification stating that the manufacturer has been in continuous and successful installation of DDC based BAS for not less than 3 years and in installation of HVAC control in general for not less than 5 years. Submit a list of DDC based BAS projects of similar complexity and scope which are in operation.

8. A statement stating that the components and systems proposed will be maintained and supported by the manufacturer for parts and service for not less than 10 years.

9. A statement stating that the manufacturer is the BAS subcontractor and shall be responsible for the complete installation and associated work of the system.

10. A list of completed projects of similar size and complexity with DDC based BAS supplied and installed by the manufacturer. Provide names and addresses of the building owners or their representatives.

C. Project Foreman: Installation of the BAS shall be performed under the direct supervision of a field project foreman, employed by the

BAS manufacturer. Within 14 days after notice to proceed, submit for the BAS project foreman the following:

1. Project foreman's name, address, telephone number, and qualification of BAS experience.

2. A list of at least three DDC based BAS projects of comparable size and complexity to this contract, which were directly supervised by the proposed project foreman.

3. For each project list the name of the project, location, project description, construction cost, name and telephone number of the owner's representative, date installation started and date installation was completed.

The representative of the Contracting Officer will promptly review and act upon the qualification of the proposed project foreman. Should the Contracting Officer's representative approve the project foreman, then the subsequent steps of the quality assurance procedures may begin. If, in the opinion of the Contracting Officer's representative, the experience or the qualification of the proposed project foreman is not in accordance with the requirements of the project, then the proposed project foreman will be rejected and alternatives resubmitted for approval.

D. Systems Engineering: This phase shall include the selection and integration of components into a complete system which will meet the performance and prescriptive requirements of the contract, together with drawings, specifications, descriptions of operation, diagrams and other materials listed under SUBMITTALS paragraph of this section.

E. Testing and Adjusting During and After Installation:

1. Each component, subsystem, and the entire BAS shall be calibrated, tested, and adjusted during and after installation in accordance with the specified sequences of operation and other characteristics of the system.

2. The Construction Officer's representative may designate up to [4] Government operators to observe at the project site during the installation, testing, and adjusting as part of the operating personnel training program.

3. The testing specified in this paragraph shall not substitute for the testing required in FINAL FUNCTIONAL TESTING AND VERIFICATION paragraph.

F. Final Functional Testing and Verification: The final phase of the quality assurance program is the final functional testing and verification. This phase is to assure the Contracting Officer that the project is fully completed and that the systems are installed, debugged, tested, and are performing in accordance to specifications from end-to-end of the BAS. The contractor shall submit a detailed step-by-step final functional test procedure in writing to be used to demonstrate compliance with the specified requirements (see PART 3 for FINAL FUNCTIONAL TEST AND VERIFICATION). All test and verification results shall be documented and a test report, including set points and operating ranges of all components, shall be submitted.

G. Warranty: The control subcontractor shall warranty the entire BAS, including hardware, firmware, software, debugging, calibration, and adjustments, for a period of one year starting from the date the Government signs off for final acceptance. At the end of the warranty period, the BAS contractor shall update all documentation of hardware, software and firmware to reflect the final edition of the programs and data.

H. First Year Service and Maintenance: The BAS subcontractor shall service and maintain the BAS for a period of one year starting from the date the Government signs off for acceptance. As a minimum, the service shall include all necessary calibration, adjustment, repair, replacement, and reprogramming to keep the BAS operating and maintained as specified and updated. All maintenance services shall be accomplished in a timely manner.

I. Operating Instructions and Training: This phase of quality assurance involves training of Government operating personnel. The BAS subcontractor shall provide:

1. Adequate and appropriate training material.

2. Formal training before final functional test and Government acceptance.

3. Training at project startup and during final functional test.

4. Training during the first year of system operation.

Detailed training requirements are specified in PART 3 of this specification.

J. Maintenance Manuals: This phase includes the submission of at least [4] copies of hard bound operation and maintenance manuals.

The manuals shall include equipment cuts, operating and trouble shooting procedures, checkout procedures and test reports, approved copies of control diagrams, operator's reference material, preventive maintenance requirements and procedures, and copies of the manufacturers' certifications. Laminated control diagrams for air handling units, chiller plant, heating plant, and other major equipment shall be mounted where directed by the Contracting Officer. Two copies of manuals for software in separate volumes shall be provided. The documentation of the software shall be in sufficient details to allow qualified Government personnel to make needed future changes. The software manual shall include:

1. Programmer's reference material.

2. The latest version of annotated source code.

3. The latest version of object code on disk.

4. Program logic flow diagrams.

At the end of the first year period, the BAS subcontractor shall update all copies of the maintenance and software manuals.

1.04 SUBMITTALS

A. Qualification of Manufacturer and Project Foreman: Within 14 days after notice to proceed, submit four copies of the qualification data specified under paragraph QUALITY ASSURANCE for the manufacturer and the project foreman proposed. Upon receipt and approval of both manufacturer and project foreman's qualifications, proceed with the preparation of shop drawings and other submittal data.

B. Division 1: Conform to the requirements of Division 1, section 01300 SUBMITTALS.

C. Shop Drawings: For each system to be controlled, prepare drawings to include system flow diagrams, control diagrams, all components and communication lines, sequence of operation and schedule of components. Control diagrams shall be complete with end-to-end connections of piping and wiring from component terminals.

D. Manufacturer's Data: For each manufactured device or subsystem submit manufacturers' specifications and printed photograph of the proposed device or subsystem. Include engineering descriptions, principle of operation and application, and proposed model, style or size of sensors, control interface devices, controlled devices,

field panels, and protection devices. Also submitted are data sheets on host computers, video displays, printers, disk storage systems, protection and communication devices, and all software.

THE NUMBER OF AS-BUILT DRAWINGS REQUIRED DEPENDS ON PROJECT SIZE AND BUILDING MAINTENANCE ORGANIZATION. CONSULT PBS PERSONNEL FOR REQUIREMENTS.

E. As-Built Drawings: Submit to the Contracting Officer at the end of the construction [5] sets of as-built drawings reflecting all changes and updates of the BAS.

EVALUATE THE COMPLEXITY OF THE SYSTEM, THE AVAILABLE BUDGET, AND THE FUTURE AVAILABILITY OF OPERATING PERSONNEL TO DETERMINE WHETHER THE MAINTENANCE CONTRACT IS SPECIFIED. CONSULT GSA/PBS.

1.05 OPTIONAL MAINTENANCE CONTRACT

A. Optional Maintenance Contract: A detailed proposal of an optional maintenance contract to service and maintain the BAS system for a period of 2 years, starting immediately after the first year maintenance period as specified in the QUALITY ASSURANCE section, shall be submitted. The maintenance contract shall include, but not be limited to, all necessary adjustment, repair, replacement, reprogramming, and preventive maintenance to keep the BAS operating as specified and updated, the number of persons and their qualifications as well as the time to be assigned to the project. Also included shall be annual point verification and calibration. The contractor of the optional maintenance contract shall be the same subcontractor providing the BAS installation.

B. Bid Submission: The contractor shall submit two bids at the time of bidding: a base bid without the optional maintenance contract and a bid for the optional maintenance contract only. In the event the Government exercises the optional maintenance contract, it shall be executed directly between the Government and the BAS company. There shall be no other legal binding between the construction contract and the optional maintenance contract. The General Contractor of this project shall have no claim on fees from this maintenance contract.

PART 2 - PRODUCTS

2.01 BUILDING AUTOMATION SYSTEM (BAS)

A. General:

1. The BAS shall include monitoring and controlling of heating, ventilating, and air conditioning (HVAC) equipment, lighting system, fire safety system, and security system.

2. The BAS shall be a microprocessor based system where the process variables are continuously monitored by digital computers which perform control solution calculations and loop controls to accomplish the intended control functions.

3. The system shall be fully modular to allow future expansion of application software, computer memory, field panel, and other components.

B. System Configuration:

1. The BAS shall be a true distributed control system. The system shall have stand-alone microprocessor based field panels, a communications network, and have separate host computers for HVAC, fire safety, and security systems.

2. The system shall be operator programable, based on the user applications, to perform closed-loop, modulating control of building equipment. The field panels shall be connected through the communication network to share common data and report to host computers which shall be capable of being programmed to supervise the field panels. The control system shall perform monitoring, display, and control functions as required on the drawings and specifications. The system shall be capable of down-loading and up-loading of programs between host computer and field panels. Systems that rely only upon down-loading of programs and data from host computers will not be acceptable.

3. The system shall allow all host computers to share information and to communicate among the host computers. However, each host computer shall be dedicated to their individual functions (HVAC, fire safety, and security) during normal operation. Operators with proper access level shall be able to access any point of the BAS from any host computer. In the event any host computer system fails, system control shall continue to be performed.

4. Provide compatibility to connect the BAS to building telecommunication system when required in the specification. There shall be no interference between the two systems. The BAS subcontractor shall coordinate his work with the telecommunication contractor from the early stage of the construction.

C. Compatibility: Field panels shall be compatible to receive signals from industry standard sensors, transmitters, and other input devices.

D. HVAC Control Functions: The BAS shall perform closed loop automatic control using proportional, proportional plus integral, or proportional plus integral and derivative as application requires. Detailed control sequences shall be as listed under SOFTWARE and other paragraphs of this specification.

E. Building Monitoring: The BAS shall be capable of monitoring HVAC operation and building energy consumption, equipment maintenance programs, fire safety, and security. Detailed requirements shall be as listed in SOFTWARE and other paragraphs of this specification.

2.02 INSTRUMENTATION

A. Temperature

1. General: Temperature sensors shall be thermocouples, resistance temperature detectors (RTD), or thermistors. Transmitters shall not be used except for thermocouples measuring temperatures over 260 °C (500 °F). Temperature measurement ranges of the sensors shall be selected for the intended applications. The sensor insertion length for duct and pipe installations shall be selected to suit the duct and pipe arrangements to measure the average temperature of the measured medium. Sensors for liquid medium shall have thermowells. Sensors for space and outdoor air shall have protection covers. Sensors mounted on air ducts shall have gaskets to prevent air leakage. Sensor errors shall not exceed those listed in the following paragraphs, except for sensors used in chilled water energy computations. Sensors for chilled water energy computations shall have errors not exceeding +/- 0.3 °C (0.5 °F).

2. Thermocouples: The thermocouple wire errors shall not exceed those listed under Limits of Error in ANSI Standard MC96.1. Unless specified specifically to use Special Limits of Errors, Standard Limits of Errors shall apply.

Thermocouple wires shall be of the type suitable for the temperature of measurements. Extension wires shall be of the same material as the thermocouple wires. Thermocouple for duct and pipe installations shall be factory assembled units with 304 or 316 stainless steel sheaths or protection tubes.

3. Resistance Temperature Detectors (RTD): RTD's shall be platinum units having 1000-ohm minimum resistance (at 0 °C (32 °F)) with 304 or 316 stainless steel sheaths or protection tubes. The errors of the sensors shall not exceed +/- 0.6 °C (1.0 °F). Three or four-wire units shall be used if the lead wires are longer than 3 meters (10 feet).

4. Thermistors: Thermistor tips shall be epoxy or glass encapsulated. The errors of the sensors shall not exceed +/- 0.3 °C (0.5 °F)F. Thermistor units used for duct or pipe applications shall have corrosion resistent sheaths.

5. Thermowells: Thermowells shall be brass or monel for copper pipes, 304 or 316 stainless steel for steel pipes, and 316 stainless steel for flue gas pipes and shall have wire connection heads. The insertion length of thermowells shall be suitable for the temperature, pressure, and velocity of measured medium. Provide extension pieces where thermal insulation of pipes are required.

6. Sensor protection covers: Sensors located in occupied spaces for air temperature shall have tamperproof covers mounted on base plates with Allen head screws. Setpoint adjustment or settings shall not be visible or adjustable from outside sensor enclosure. Sensors located outdoors shall have adequately ventilated shields in white color to protect from direct sunlight.

7. Freeze-protection sensors: Where coils may be subjected to freezing conditions, freeze-protection type sensors which detect the lowest temperature along any one foot of its entire length shall be provided. These temperature sensing sensing probes shall be installed in a serpentine arrangement to protect coils from freezing due to cold air stratification. Manual resetting shall be required to reactivate the system.

8. Space temperature sensors for VAV systems shall have connection ports for operators to connect plug-in portable units for service. See the SYSTEM ACCESS paragraph for requirements.

9. Sensor temperature range shall match application span. Typical sensor ranges include:

   a. Conditioned space air: 10 to 32 °C (50 to 90 °F).

   b. Outdoor air: -35 to 55 °C (-30 to 130 °F).

   c. Ducted air (hot): 5 to 60 °C (40 to 140 °F).

   d. Ducted air (cold): 5 to 20 °C (40 to 70 °F).

   e. Chilled water: 0 to 35 °C (30 to 100 °F).

   f. Dual-temperature water: 0 to 120 °C (30 to 250 °F).

   g. Hot water: 35 to 120 °C (100 to 250 °F).

   h. Condenser water: 5 to 50 °C (40 to 120 °F).

   i. Low pressure steam: 95 to 150 °C (200 to 300 °F).

   j. Steam condensate: 35 to 120 °C (100 to 250 °F).

B. Humidity

1. General: Humidity instruments shall be standard products of the instrumentation manufacturers. Humidity instrument shall be packaged units of humidity sensors and matched transmitters to measure relative humidity or dew point of the air. Humidity measurement ranges shall be selected for the intended application (for both humidity and temperature). The measurement errors of the humidity instrument shall not exceed +/- 3% RH in the range of 20% to 80% RH.

2. Possible damage to sensors: For locations where the anticipated humidity level may exceed the sensor manufacturers' recommended ranges and may result in damage to the sensors, arrangement for heating the sampling air shall be employed. Shop drawings shall show the proposed arrangement and method of data manipulation.

3. Sensor protection covers: Sensors located in occupied spaces shall have tamperproof covers mounted on base plates with Allen head screws. Setpoint adjustment or settings shall not be visible or adjustable from outside sensor enclosures. Sensors located outdoors shall have adequately ventilated shields to protect from direct sunlight, snow,

ice, and rain. For humidity sensors also sensing temperature, shields shall be white in color.

4. Sensors requiring periodic salt retreatment to maintain performance shall not be acceptable.

5. Measurement ranges:

   a. Conditioned space air: 20 to 80% RH.

   b. Outdoor air: 10 to 100% RH.

C. Flow, Pressure, and Differential Pressure

1. General: All pressure and differential pressure instruments shall be standard products of the instrumentation manufacturers. Pressure and differential pressure transmitters shall withstand over-pressure of not less than 200 percent of the rated pressure and full vacuum without damage to the instruments.

2. Sensors for measuring flow rates shall have outputs within the required accuracies over the entire flow range.

3. Air flow rate measuring stations: Air flow measuring stations shall be factory assembled and tested units containing air straightening vanes and an array of flow measuring sensors with flanged galvanized sheet metal casings. The error of the units (sensors and transmitters) shall be less than +/- 3% of the calibrated span for air velocity over 3.6 meters per second (700 feet per minute). The maximum air friction of the units shall be less than 20 Pa (0.08-inch water gauge) at 10 meters per second (2,000 feet per minute) air velocity.

4. Fluid (water and steam) flow measurement: Orifices, flow nozzles, and Venturi tubes shall meet the requirements of ASME Power Test Code (Flow Measurement, Instruments and Apparatus). Factory fabricated straightening-vane units shall be provided unless the piping conditions satisfy the recommendations of ASME Power Test Code. When other types of flow measuring instruments are used, the recommended practices of the instrument manufacturers' shall be followed. Errors of measurement (sensors and transmitters) shall be less than +/- 1% of the calibrated span. Special attention shall be given to the selection of the instruments regarding the measurement error and flow range.

5. Flow and pressure transmitters: See TRANSMITTERS paragraph for additional requirements of flow and pressure transmitters.

SELECT CONTROL SPANS TO MATCH SENSOR RANGES AS CLOSELY AS POSSIBLE.

6. Selection ranges:

a. Differential pressure for air systems: [0 to 25 (0 to 0.1)] [0 to 60 (0 to 0.25)] [0 to 125 (0 to 0.5)] [0 to 250 (0 to 1)] [0 to 500 (0 to 2)] [0 to 2500 (0 to 10)]-Pa (inch water gauge).

b. Air flow measuring station: 3.6 to 12.5 meters per second (700 to 2,500 feet per minute) air velocity.

c. Fluid flow velocity: 0 to 3 meters per second (0 to 10 feet per second).

7. Fan and pump status: Sensing of fan/pump status shall be done by differential pressure measurements across fan/pump inlets and outlets.

D. Electric Meters: Provide interface devices from watt-hour meters to DDC system.

E. Transmitters

1. General: Temperature (see also paragraph 2.02 A.1. for requirement of temperature transmitters), humidity, and pressure transmitters shall be suitable for the sensors selected to provide signal conditioning and to produce linear outputs of 4 to 20 mA over the specified measurement range. Transmitters may be apart from the sensors providing the distances from the sensors do not exceed those recommended by the manufacturers.

2. Range selection: Transmitter ranges shall be selected within the manufacturer's recommendations and shall be adjusted to the smallest range sufficient to cover the normal system operating ranges.

3. Adjustments: Transmitters shall have individual zero and span adjustments.

2.03 FIELD PANELS

A. General

1. Field panels shall include microprocessor based controllers, power supply, input/output modules, communication devices, and other necessary components to function as a stand alone unit to perform required processing, memory, communication and field input/output functions.

2. Field panels shall operate properly in an environment of 0 to 50 °C (32 to 120 °F) and 10% to 90% RH.

3. Field panels shall operate properly from +10% to -15% of nominal voltage rating. If systems are not designed to operate properly within the +10% and -15% voltage fluctuation, a saturable core transformer shall be mounted in the field panel cabinet to supply 120 VAC power to the field panel to provide suitable stable power.

4. Fire safety and security systems shall have separate field panel from HVAC systems.

B. Controllers:

1. Set points and analog output values shall be adjustable. All controllers shall have test connections for measuring input and output signals.

2. A field panel may contain more than one controller for multiple control loops.

C. Battery Backup: Each field panel shall have battery backup with an automatic battery charger. Battery shall be able to support all random access memories (RAM) and clock/calendar for a minimum of 72 hours.

D. Automatic Restart: Each Field Panel shall be capable of automatic, unattended restart in the event of electrical power failure. In the event of electrical power failure all controlled devices shall move to their fail-safe positions. Upon the restoration of electrical power, the field panel shall automatically restart and provide control to its controlled devices.

E. Future Addition and Modular Design:

1. Each panel shall have sufficient input/output multiplex and

terminal strip capability to provide 2 or 15%, whichever is greater, spare capacity for each type of input/output point.

2. Field Panels shall be of modular construction having interchangeable components, circuit cards, and power supplies to facilitate quick repair and easy expansion of monitoring/control points and additional control loops.

F. Communications: Field panels shall be able to communicate with other field panels and host computers through communication wires or non-dedicated telephone wires.

G. Memory Allocation: Program firmware and microprocessor operating system shall reside in non-volatile memory.

H. Panel Access:

1. General: Field panels shall have built-in keypads or plug-in portable units for altering programs, control parameter values and diagnosing control functions. Plug-in units shall engage and disengage with the field panels easily. Provide one plug-in unit for each 10 field panels.

2. Field panels or plug-in units shall have an alphanumeric display to assist operators in entering data, adjusting parameters, viewing alarm indications, and diagnosing systems.

3. The operator shall be able to obtain the current sensor values for all connected sensors, the current operating status of controlled equipment and shall be able to issue control commands by use of the keypad or plug-in unit.

4. Access to the control system through keypads or plug-in units shall be security protected. Security protection shall be in the form of codes, passwords, or locally sensed switching. The operator in the field shall be able to perform the following functions:

Display the value of a measured variable

Start or stop equipment

Monitor the status of equipment being controlled

Display the setpoint of a control loop

Enable/disable control sequences

5. Regardless of the actual locations of the field panels, means shall be provided that the operators may access the system without using ladders.

I. Field Panel Functions:

1. Local loop control functions shall be executed by the field panels with direct digital control algorithms.

2. Field panels shall receive analog, binary, or other inputs from sensors, transmitters, switch closures, or transistor-transistor-logic signals, perform multiplexing, analog-to-digital or digital-to-analog conversion, perform signal conditioning, and store data in their memories for future interrogation.

3. Except for unitary equipment, all analog-to-digital conversion shall have a minimum of 12 bit resolution.

4. Microprocessors shall process the input signals based on the stored instructions of the software programs and make control decisions.

5. Field panels shall issue analog and/or binary output signals to electrical relays, solenoid valves, motor controllers, and other actuators to perform loop control of HVAC equipment.

6. Systems which generate output signals to actuators utilizing pulse width modulation (PWM) in lieu of true analog output are acceptable, providing analog outputs shall have analog feedback to control logic circuits of the actual output to the actuator.

7. Field panels shall have isolation protection against 180 VAC minimum input. All logic circuits shall be protected from high voltage surges.

8. When multiple outdoor temperature and humidity data are required for DDC logic, one master set of sensors processed by a field panel shall be provided. Data shall be transmitted to other systems through the communication network.

J. Construction:

1. Mount field panels on wall securely. Free-standing field panels shall have structural steel support.

2. Field panel cabinets shall be constructed of sheet steel or plastic. Cabinet doors shall be hinged and lockable. A master key shall fit to open all field panels for the project.

3. Field panels shall be listed by Underwriters Laboratories for fire and shock hazard and shall conform to NEMA 1 standard.

4. Field panels shall comply with Part 15 of F.C.C. rules.

5. Ground the field panel and power supply in accordance to National Electrical Code minimum grounding conductor size to the building earth ground system. Electrical resistence measured between the ground at the field panel and the building ground system shall be less than 5 ohms.

6. Provide a electrical power disconnect switch inside the field panel to disconnect all external power to the cabinet for maintenance and repair.

7. Provide screw type terminal strips in the field panel for the termination of all field wiring. Each termination shall be labeled.

8. Adequate space shall be provided for terminal connections and around field panels for wiring entrance.

9. Indicating lights, meters, and selector switches shall be flush mounted on the cabinet doors.

DELETE THE FOLLOWING PARAGRAPHS IF NO UNITARY EQUIPMENT IS REQUIRED IN THE PROJECT.

K. Field Panels for Unitary Equipment

1. Field panels for unitary equipment shall be factory packaged, programmed in non-volatile memory, and tested before delivered to the job site.

2. Each panel shall accept time schedule inputs via the communication trunk and provide a facility for local backup.

3. Analog to digital conversion shall have a minimum of 8 bit resolution.

4. Field panels containing controllers for VAV terminal units shall be mounted on the associated VAV boxes or remotely

mounted on walls or floor. They shall be connected to the building automation system so that operators can monitor and modify control operation of the VAV box without the need of reaching the individual boxes.

L. Pneumatic Display:

1. Provide pneumatic gauges to indicate pneumatic pressure where electric signals are interfaced to pneumatic signals.

2. See METERS AND GAUGES Section for display gauge requirements.

M. Software: See SOFTWARE paragraphs for requirements.

2.04 HOST COMPUTERS AND ASSOCIATED EQUIPMENT

A. General:

1. Provide general purpose personal computers and associated equipment. The computer systems shall be able to provide monitoring, control, and system management over the entire BAS system in spite of stand-alone control loops specified.

2. As a minimum, each host computer system shall have a color video display, a printer, necessary communication equipment, software, and other supporting equipment.

3. Host computer systems shall operate properly in an environment of 15 to 35 °C (60 to 90 °F) and 10% to 80% RH.

B. Host Computers

1. The host microcomputer shall have a 16-bit (minimum) processor, a minimum of 640K bytes of RAM, a clock/calendar with backup battery and charger, a 40 megabyte minimum hard disk, at least one 1.2 or 1.44 mega-byte minimum floppy disk, a keyboard with standard typewriter keys and special function keys, and a color graphic controller card for the video display. The processor speed shall not be less than 12 MHz.

2. The host computer systems shall be able to perform:

Real-time data transfer and manipulation

Real-time graphic display

Password security protection

Interactive operation of data and graphic editing

Full English data addressing and presentation

Operating and maintenance data storage

Data trend display and manipulation

Menu format with on-line help messages

Alarm annunciation

3. Operators with appropriate access level shall be able to perform the following from the host computer:

Enable/disable control loops to a system

Enable/disable points to a system

Assign sensors and/or actuators to a control strategy

Add, delete or change setpoint values and point alarm values

Acknowledge alarms

upload/download controller databases

Modify control programs

Initialization of remote controllers

C. Color Video Displays (minimum quality requirement): Video displays shall be compatible with the host computers. They shall have 80-character width columns, 16 colors, and minimum 640-pixel X 350-line resolution. The display screens shall be not less than 483 mm (19 inches) and shall have non-glare surfaces. The video displays shall have adjustable bright and contrast controls.

D. Printers (minimum quality requirement): Printers shall be tabletop units with sprocket pin-feed tractors to use standard fanfold 241 mm X 279 mm (9.5" X 11") paper. They shall have a 96 standard ASCII character set and shall print 80 characters per line under standard mode at a speed of at least 150 characters per second. They shall graphics capability.

E. Desk-Chair Set: The host computers and peripherals shall be

placed on a work station with a minimum 760 mm (30") wide X 1,520 mm (60") long table top. Matching chairs with castors shall be provided.

2.05 COMMUNICATION NETWORK

A. General: The BAS shall have microprocessor based communication processing devices and a multidrop digital transmission network to communicate between field panels and host computer systems.

B. Network Wiring: The communication lines shall be 18 gauge minimum twisted shielded pairs or coaxial cables.

C. Spare Wiring: If twisted-pairs wiring is used, provide two spare communication conductors over and above those conductors required for the system operation.

2.06 FIRE SAFETY SYSTEMS

A. The fire safety system shall monitor all smoke detectors (in space, in air handling units and ductwork), sprinkler system flow valves, pull stations, alarm bells and other required devices. The host computer and central control panel shall communicate with all detectors and addressable devices to verify their proper function and status.

B. Smoke detectors and other input/output contacts shall be connected to the system in addressable loops. In the event of a single wire trouble in the loop, the system shall continue to detect any alarm conditions. The fire safety system shall be listed by Underwriters Laboratories, Inc. and shall comply with the latest edition of UL Standard 864 (Standard for Control Units for Fire Protective Signaling Systems) and local fire codes. Power to all fire safety system components shall be provided from the main power supply in the central control panel.

1. Central control panel: The panel shall receive data from detectors and process the data to determine normal, alarm, or trouble conditions. All smoke and fire control programs shall reside in non-volatile programmable memory, and shall not be lost when all power fails. The panel shall be mounted on a wall in a cabinet with indicators on the face of the panel. The panel shall be modular in design for future expansion. Provide lock with keys. There shall be LEDs to indicate power-on, alarm, system trouble, and other pertinent conditions. Programming for control panel parameters, such as for alarm/trouble type assignment, point descriptor assignment, alarm messages shall be from the

control panel or through the fire safety system host computer.

2. Smoke detectors: Smoke detectors shall be [photoelectric type. The detectors shall operate on a multi-cell concept and the LED light intensity shall be controlled by a regulating photocell circuit matched to the smoke detection circuit. Sensitivity of smoke detection shall be adjustable in the field.] [dual-chamber ionization type. The detector shall be self-compensating for the effects of air temperature, humidity, and atmospheric pressure and shall be adjusted in the factory to UL standards. Restoration after a fire alarm shall not require replacement or readjustmant.] Detectors shall be ceiling mounted to bases without using tools and shall have integral LED lights to indicate alarm conditions. Detectors shall have test means to simulate alarm conditions and report to control panels. Such tests may be initiated at the detector or on command from control panels.

3. Pull stations: Pull stations shall not use mercury switches nor require breaking of a glass panel to initiate action. Pull stations shall have integral LED lights to indicate alarm conditions. Special keys or wrenches shall be required to reset the stations. The color of stations shall be painted red and shall be clearly marked with raised letters for instructions. They shall be semi-flush mounted.

4. Alarm bells: Alarm bells shall be electric type with a minimum sound pressure level of 85 dBA at 1.5 meters (5 feet) above the floor. Bell size shall be 150 mm (6 inches) in diameter.

5. Magnetic door holders: Magnetic door holders shall release self-closing fire and smoke doors automatically when the fire detection system goes into alarm. They shall be flush wall mounted.

6. Valve supervisory switches: Valve supervisory switches shall be mounted to monitor the position of sprinkler shut-off valves. Removal of the switch, or removal of the cover shall activate the trouble signal. The switches shall be mounted to activate the alarm after the first revolution of the valve wheels. Switches shall be constructed of corrosion-resistant metal.

C. The fire safety system shall have battery backup to provide 24-hour minimum supervisory operation with the capacity of sounding

general alarms for at least 15-minute duration.

D. Elevators shall be controlled under the fire safety system during smoke conditions. Coordinate installation and connection of controls with elevator contractor. (see SOFTWARE paragraphs for requirements)

THE FOLLOWING PARAGRAPH IS FOR A PERIMETER SECURITY SYSTEM ONLY. REVISE AND ADD DETAILED SPECIAL SECURITY REQUIREMENTS IF PROJECT NEEDS MORE THAN A PERIMETER SECURITY SYSTEM

2.07 BUILDING SECURITY SYSTEM

A. The building security system shall monitor and control entrance card units at all entrances and intrusion alarms at emergency exits and all ground floor openable windows. The system shall be listed by Underwriter Laboratories, Inc. and shall comply with the latest edition of UL Standard 1076 (Standard for Proprietary Burglar Alarm Units and Systems).

1. Entrance card units shall be microprocessor based units and shall read entrance cards and control entrance doors. These units shall be supervised by the security system host computer. In the event the communication with the host computer is interrupted, entrance control shall remain in effect without indication at the units of communication interruption. They shall be surface mounted.

2. Intrusion alarms: Provide an addressible contact closure type alarm at each emergency exit and ground floor openable window. The security host computer shall communicate with all detectors to verify their proper function and status. Individual alarms may be set at enable/disable positions from the host computer.

2.08 ACTUATORS

A. General

1. Provide pneumatic or electric actuators for automatic control valves, dampers, fans, and other HVAC equipment.

2. All actuators shall have position indicators or their positions shall be clearly visible. They shall return to their "fail-safe" positions when the control signal or power

is interrupted.

3. Actuators and associated linkages shall be selected to operate against the load of the controlled devices with the signals or power input they receive.

4. Actuators shall complete the full range of travel within two minutes.

B. Pneumatic Actuators: Actuators shall have pistons or diaphragms with counter acting springs to perform the required control sequencing of controlled devices.

1. Provide pilot positioners to prevent overlapping of sequenced control functions.

2. Pistons or diaphragms shall be easily replaceable.

3. Piston rods shall be stainless steel or plated steel with cadmium plated steel or bronze locknuts and linkages.

C. Electric Actuators: Provide hydraulic or gear type electric actuators.

1. Actuators operating under floating controls shall have a means to limit travel range.

2. Actuators with a net input power minus internal heater power between 100 and 400 watts shall have steel gears immersed in oil. The shaft shall be hardened steel with bronze, copper alloy or ball bearings. Operators and gear trains shall be totally enclosed in dustproof cast iron, cast steel or cast aluminum enclosures.

3. Actuators with a net input power minus internal heater power of less than 100 watts may use fiber or reinforced nylon gears with steel shafts, copper alloy or nylon bearings and pressed steel enclosures.

4. Actuators with a net input power minus internal heater power of greater than 400 watts shall have totally enclosed reversible induction motors with auxiliary hand cranks and permanently lubricated bearings.

5. Two position actuators shall be of the single direction, spring return or reversing type.

2.09 CONTROLLED EQUIPMENT

A. Dampers

1. Provide factory fabricated dampers of extruded aluminum, galvanized steel or stainless steel blades. Damper frames shall be constructed of welded galvanized steel or extruded aluminum.

2. Damper blades shall have cadmium plated steel shafts mounted in permanently lubricated bronze sleeve bearings, nylon or ball bearings.

3. Reinforced or ribbed blades shall not exceed 200 mm (8 inches) in width nor 1.2 meters (48 inches) in length. Damper sections exceeding 1.2 meters (4 feet) in width or 1.2 meters (4 feet) in height shall be constructed with multiple frames and linkages. Flat or unreinforced blades will not be acceptable.

4. Provide mechanically attached elastomer or neoprene blade tip seal along the full length of each blade edge and flexible stainless steel or elastomer seals along damper blade ends where the blades abut the frame. Adhesives or staples will not be acceptable.

5. For fan systems with less than 2.5-kPa (10-inch water gauge) static pressure, design and construct dampers to withstand a pressure of 7.2 kPa (150 pounds per square foot) without damage.

6. The maximum air leakage rate for outside air dampers shall not exceed 50 liters per second per square meter (10 cubic feet of air per minute per square foot) of damper face area at atmospheric pressure when closed against a 1-kPa (4-inch water gauge) static pressure.

7. Provide linkages to uniformly transmit damper operating forces to each damper blade. Construct linkages of galvanized or cadmium plated steel or stainless steel. Linkage joints shall have ball and socket or sleeve bearings of brass, bronze or stainless steel, with plated bolts and locking nuts.

8. Damper operators shall have sufficient power to open and close the dampers.

9. Use parallel blade dampers in mixing chambers and plenums.

Use opposed blade dampers for volume control, face and bypass dampers, fan discharge, and variable air volume control.

B. Automatic Control Valves

1. For chilled water, low temperature hot water and low pressure steam, provide valves conforming to ANSI B16.15 Class 125 or 250 bronze or ANSI B16.1 Class 125 or 250 cast iron. For steam above 350 kPa (50 psig) and water pressure/temperature ratings exceeding class 125 or 250 ratings, use ANSI B16.5 cast steel or stainless steel bodies. Select valve pressure class at minimum 150 percent of maximum working pressure.

2. For chilled water, low temperature hot water and low pressure steam, provide valves with flanged connections on sizes 64 mm (2-1/2 inches) and larger and threaded connections on valves 51 mm (2 inches and smaller). For high pressure steam, provide flange or union connections on valves 38 mm (1-1/2 inches) and larger.

3. For valves controlling low pressure and low temperature chilled or hot water sizes 51 mm (2 inches) and smaller, bodies shall be brass, bronze, cast iron or stainless steel with screwed, union or flare connections.

4. For valves 51 mm (2 inches) and smaller, furnish bronze or stainless steel trim with soft disc for tight close-off. Furnish replaceable U-cup or V-ring packing. Stems shall be 316L stainless steel. For valves larger than 51 mm (2 inches), furnish stainless steel trim and replaceable V-ring packing. All non-metallic parts of hot water and steam valves shall be designed for a minimum of 140 °C (250 °F) or 55 °C (100 °F) above system design temperature, whichever is higher for continuous duty.

5. Control valves shall provide tight shut off in the closed position at 150 percent of maximum working pressure.

6. Select valves to provide equal percentage control of water and linear control of steam. Modulating valves shall have V-port skirts for high pressure steam and tapered plugs for low pressure steam and water. Butterfly valves are not acceptable for modulating control. For two position water applications, butterfly valves may be used, providing the differential pressure across the valve when closed does not exceed 170 kPa (25 psi).

7. Provide valves of the sizes specified. If not specified, size steam valves with a pressure drop not to exceed 50 percent of the total differential between supply and return main at full indicated flow; size water valves with a maximum differential pressure of 30 kPa (10 feet water gauge) or 1/2 of the loss through the controlled apparatus, whichever is greater.

8. For pneumatically controlled valves on sizes 305 mm (12 inches) and larger, and in critical applications, provide hand crank operators.

2.10 TRANSIENT PROTECTION OF SYSTEM

A. General: Protect all equipment from power line surges. Equipment shall meet the spike susceptibility requirements of MIL-STD-461 Part 7, CS06. Provide protection near equipment in a separate metallic enclosure at ground potential and as necessary at the power panel to insure protection against surges. Fuses shall not be used for surge protection.

B. Sensor and Control Wiring: Protect sensors and control wiring against induced surges conforming to IEEE 472 surge withstand capability test.

C. Communication Wiring: Protect all communications equipment against surges induced on any communications link. All cables and conductors which serve as communications links between field panels and between field panels and host computers shall have surge protection installed at each end that conform to IEEE 472 surge withstand capability test. Provide protection near equipment in a separate metallic enclosure at ground potential.

2.11 AIR COMPRESSOR AND ASSOCIATED SPECIALTIES

A. General: Provide air compressor and associated equipment when pneumatically operated actuators are used.

B. Air Compressor

1. Provide a tank mounted [simplex] [duplex with automatic alternator], electric-motor-driven, oil lubricated, air-cooled, reciprocating, air compressor. The compressor shall be sized by the control system manufacturer to provide control air to the system. Compressor shall include side sealing piston rings and air-cooled after cooler. The compressed air shall not carry oil over 4 ppm.

2. Construct the tank in accordance with the ASME code for unfired pressure vessels and stamp for 250 psi working pressure. Electric control devices shall be listed and labeled to conform to UL requirements. Provide an ASME pressure relief valve set at 110 percent of pressure control setpoint.

3. For each compressor provide a squirrel cage induction motor, electrical contactor with thermal overloads, pressure controller, belt guard, automatic moisture drain valve, tank pressure gauge, and ASME system reducing valve.

4. Size each air compressor to start at 480kPa (70 psig) and stop at 620 kPa (90 psig) and to operate no more than 33 percent of the time with full system control load. Arrange compressors to automatically restart after power failure.

5. Provide dry type combination intake filter and silencer with baked enamel steel housing and filter rated 99 percent efficient on 10 micron particles.

6. Provide a refrigerated air dryer, sized for continuous operation at maximum air flow and arranged to reduce compressor air dew point at 140 kPa (20 psi) output to -6 °C (20 °F) at an average tank pressure of 550 kPa (80 psi). Design refrigerated dryer to operate between 15 to 50 °C (50 and 120 °F) ambient temperature under full load conditions. The dryer shall have a "high temperature" warning light on the face. Provide automatic condensate drain system.

7. Provide a dry type filter 99 percent efficient in removing oil and solid particulate matter of 0.03 micron size and smaller with baked enamel steel housing, and manual drain valve. House filter in transparent housing.

C. Pneumatic Tubing

1. Copper pneumatic tubing shall have a 4-mm (0.37-inch) minimum outside diameter and shall be in conformance with ASTM B75 or ASTM B88 with a minimum wall thickness conforming to Type M of ASTM B88. Copper tubing in exposed areas shall be racked in factory furnished tube racks and joined with sweat solder type fittings and sleeves conforming to ASTM B32. Polyethylene pneumatic tubing shall be type FR with a minimum burst pressure of 3,790 kPa (550 psi) at 25 °C (75 °F), a tensile strength of 12,000 kPa (1750 psi) conforming to ASTM D638.

2. Tubing in mechanical equipment rooms shall be rigid copper tubing or polyethylene tubing in conduit or protective raceway run in straight lines parallel to the building walls, supported from the building structure or columns.

3. Tubing run above ceilings and in concealed construction shall be copper, single polyethylene, or non-break polyethylene in conduit.

4. Tubing buried in concrete slabs shall be soft drawn annealed copper tubing conforming to ASTM B88, with no joints in these slabs.

5. Tubing inside field panels shall be copper or polyethylene.

2.12 SOFTWARE

A. General

1. Software of the host computer systems shall have supervisory, file manipulation, energy management, and maintenance management capabilities.

2. Software of the field panels shall have stand-alone local loop control and monitoring capabilities and shall operate independently of the host computers. Failure of the host computers shall not inhibit the operation or program execution of the field panels.

3. Four basic types of software shall be included:

a. Operating system software

b. Command software

c. Control application software

d. DDC software for local loop control

4. All software programs which interface with operators shall use plain English format, be window based, and shall have the option to be menu-driven or mouse-driven with prompts to accommodate easy use. When acronyms are used, they shall be descriptive for easy learning.

5. All video display and data printing shall include date and time.

B. System Software: System software shall include operating systems and certain utility programs of the host computers, the field panels, and unitary controllers.

1. The host computer operating system shall be a real-time multi-tasking system. The system shall coordinate the execution of the entire system, contain peripheral equipment controls, database management, and system self-test routines, and run system wide application programs.

2. Field panel and unitary controller software shall support the application programs that provide both supervisory control of field equipment and direct digital control of local loops either singularly and/or in hierarchial manner.

a. Field panels shall have self-test routines to periodically check microprocessor operation, communication with I/O devices, and status of the system. During startup, restart after power restoration, and shutdown, field panels shall go through programmed routines to monitor the system, detect and report errors.

b. Fail-safe conditions of equipment shall be initiated or maintained regardless of the nature of the system failure.

c. The microprocessor operating system shall be stored as firmware. Essential default values shall be stored in non-volatile memories.

d. Data of field panels shall be shared by other field panels through an interconnecting network. An operator, through one field panel, shall have access to other field panels without going through the host computer.

C. Command Software

1. Command and utility software shall include all programs which enable the operating personnel to communicate with the BAS through the host computer keyboards using words and acronyms. More specifically these programs shall include, but not be limited to, the following functions:

a. System monitoring:

Display of points on request to show a single point,

or a group of points

Update the displayed data automatically

Display and print alarms automatically

Alarm summary report

Report trend of selected point at selected time intervals

Energy usage report

Historical data display

Time and date display

b. System control:

Control of system access by operators

Override of setpoint and programmed operation by operators

Add or delete points from scan

Adjustment of setpoint values

Edit control parameters

Edit alarm limits

Add, delete, and edit programs

Edit graphics

Set time and date

Edit time schedules

Start and stop equipment

File transfer - upload and download

Copy data to back-up storage media

2. Commands shall be capable of being entered directly in abbreviated forms or selected from a menu of command

options. The system shall prompt the operator for input as required. The command function shall include, but not be limited to:

a. An index of all available commands.

b. An explanation of each command.

c. Commands to define and modify physical parameters and constrains assigned to the points.

d. Commands to request reports.

e. Commands to request graphic displays of equipment and systems.

f. Identification and description of alarms.

g. Ability to restrict access level of operators to specific software.

3. Commands shall over-ride automatic functions in emergency.

4. The video display screens shall have dedicated areas to show:

a. Logging data, including date, time, and operator.

b. Alarm data, including point of alarm, kind of alarm, time alarm detected, and advisory information.

5. Whenever a point exceeds preset limits or status, an alarm condition shall be triggered. There shall be three levels of alarms:

a. Level 1: Alarm conditions warrant attention without urgency.
Examples: Space temperature of non-critical rooms
Air filter conditions

b. Level 2: Alarm conditions warrant immediate attention.
Examples: Space temperature of critical rooms out of set limits
Detection of malfunction of safety and security sensors

c. Level 3: Alarm conditions concerns safety and

security.
Examples: Fire and smoke sensor alarm activation
Security sensor activation

Issuing of alarms shall be prioritized by alarm levels and nature of alarms. When Levels 2 and 3 alarms occur, video screens shall automatically display the associated graphics and data with the alarm points flashing and audible sound initiated. Level 3 alarm shall also automatically call the designated offices responsible for building fire and security. Only operator's acknowledgement of alarms silences the audible sound. Levels 2 and 3 alarm conditions shall be reported within 10 seconds of the occurrence of the conditions and shall be automatically printed with time of occurrence and other alarm messages.

6. An alarm summary shall be provided at the command of the operator to display the current alarms or alarms in a specified period up to 24 hours.

7. Group points logically by system (HVAC/fire safety/security), location, or purpose. Each point shall be identified and displayed for current value or state, setpoint, engineering unit, alarm limits, etc. Points which are detected to be erroneous by the system shall be noted to warn the operator. Identification of points by numerals only and requiring a cross reference schedule is not acceptable.

8. The trend report shall allow the operator to select the statring and ending time and date for display and the time interval of data points. The display time shall be between 1 hour to 5 days and the time interval shall be between 30 seconds to 1 hour. Trend data shall be displayed either in graphic or tabular form at the operator's selection.

9. Operators may select systems and points randomly for display on video displays and print on printers. Format of display shall be in plain English. Changing of format shall be from a computer keyboard and shall be allowed only by personnel with higher accesses.

10. For HVAC monitoring, the video display shall show graphics of operator selected systems or zones with all sensing points and their real-time values, and graphics of all major components of the system or zone and their real-time states. The graphics shall show, but not be limited to, pumps, fans, coils, dampers, chillers, boilers, cooling towers, engine

generators, major valves, electrical switch gears, and major circuit breakers. The zone, system, and location of equipment shall be labeled.

11. Store floor plans for graphic display. Floor plans shall show mechanical and electrical equipment spaces, stairs, elevators, smoke detectors, sprinkler valves, pull station locations, stand pipe locations, exits, and emergency exits.

12. All point values and states shown on display screens shall be dynamically updated at least once every 30 seconds.

13. Provide diagnostic programs allowing operator's command to detect malfunctions of system components, including, but not limited to, controllers, host computers, actuators, and sensors.

14. Energy flow amounts shall be calculated. The program shall allow the operator to display energy consumption of selected equipment at selected time intervals from 1/2 to 24 hours. Required energy calculation points are:

    a. Air handling unit preheat coils, heating coils, cooling coils and fans.

    b. Steam to hot water heat exchangers.

    c. Condenser water and chilled water energy flow and compressor input of refrigeration machines. COP of refrigeration machines.

    d. Cooling plant energy flow.

    e. Boiler energy flow and boiler efficiency.

    f. Heating plant energy flow.

15. When calculated points are displayed, the equations and constants shall be available to the operators.

16. Operator shall be able to modify the database stored and shall be able to perform on-line programming. At the operator's command, all database entries can be printed.

17. Provide inventory and preventive maintenance schedules. The computer shall accumulate run-time totals and issue reminder messages to the printer for the following equipment:

a. Air handling units: 2000 hours run time

b. Water chillers: 2000 hours run time

c. Air prefilters: 500 hours run time

d. Final filters: 1000 hours run time

e. Fans and pumps: 4000 hours run time

f. Cooling towers and convertors: 3 months calendar time

g. Calibration of instrumentation: 1 year calendar time

The schedule of equipment maintenance shall be distributed throughout the year initially. The reminder message shall include point description, maintenance instructions, and other pertinent information. The schedule shall be edittable by the operators at the keyboard.

18. System Access Protection

a. Access to the BAS shall be restricted by use of passwords and codes. Provide at least three levels of access.

b. Operators of the most restrictive access level shall have the capability to assign, delete, or change passwords or codes for access.

c. Cross access by operators of different groups (HVAC, fire safety, and security) shall be restricted unless special codes are used.

d. All access data such as time, date, password, and operator's name shall be recorded. A summary of access records shall be available.

e. Do not print passwords when they are being used for system access.

THE APPLICATION PROGRAMS VERY MUCH DEPEND ON THE TYPE OF HVAC SYSTEM, GEOGRAPHIC LOCATIONS, COMBINATION OF CONTROL STRATEGIES, AND OTHER FACTORS. WHEN SELECTING AND COMBINING THE CONTROL STRATEGIES, EDIT THE FOLLOWING PARAGRAPHS TO SUIT THE DESIRED DESIGN CONCEPT. SEE REFERENCE SECTION AT THE END OF THIS

SECTION.

D. Application Programs

1. General

a. The following application programs shall be stored in and executed by the local panels with the exception of the load shedding program which shall be implemented by the host computer system.

b. When an HVAC system control involves more than one of the following programs, the combined algorithm shall have priority built-in and shall be coordinated to be complementary.

2. Load shedding: Non-essential electric load shall be shed in accordance with the following priority list:

PROVIDE A LIST OF ELECTRIC USING EQUIPMENT IN THE ORDER OF LOW TO HIGH IMPORTANCE. SEE REFERENCE SECTION AT THE END OF THIS SECTION.

This program shall be suitable for the demand charge of the utility company. The minimum and maximum "off" period shall be selected in accordance to load character and need of the equipment. Minimum "on" periods shall also be provided. The control algorithm shall predict continuously the energy consumption at the end of the demand interval. An alarm message shall be shown on the video display and print on the printer when all sheddable loads have been shed and demand exceeded by prediction.

3. Electric equipment restart: Electric motors shall be restarted sequentially after power failure. The starting sequence shall be similar to that of the load shedding schedule except that certain equipment, such as refrigeration compressors, are added to, and lighting loads are deleted from the schedule.

LIST EQUIPMENT TO BE INCLUDED IN SCHEDULED START/STOP PROGRAM UNDER THE PARAGRAPH. SEE REFERENCE SECTION AT THE END OF THIS SECTION.

4. Scheduled start/stop control: Start and stop the equipment according to the list provided.

SEE REFERENCE SECTION AT THE END OF THIS

SECTION.

5. Optimum start/stop controls: The operation time of the [air handling unit,] [refrigeration machine,] [heating system,] [hot water convertor] shall be no more than necessary. The time of morning start and evening stop of this equipment shall be controlled by the start/stop program which shall be based on [the outdoor temperature, the indoor temperature of a representative zone served by the same air handling system, occupation schedule, response time of the building and contents, and the system capacity,] [the load size and schedule, system thermal response time, and the system capacity] [the occupancy schedule, the load size, the system thermal response time, and the system capacity,] so that the desired temperature at the beginning and at end of the occupied periods shall be met. The optimizing algorithm shall adapt to the data of recent building heating/cooling history. A learning period shall be used to accumulate historic data.

6. Outdoor air damper control during warm-up/cool-down period: Depending on the outdoor temperature and humidity, the position of the outdoor damper shall be fully closed or fully open during the warm-up and the cool-down periods before scheduled occupancy so that the maximum potential of energy savings shall be realized. The return air damper shall be appropriately positioned to maintain building pressure.

7. Unoccupied temperature setback: There shall be no heating energy dispensed during the unoccupied period (night, weekend, and holidays) unless the lowest temperature of any zone within the system (air handling or heating) reaches 12.5 °C (55 °F). During the setback period, the outdoor air damper shall be fully closed and the return air damper shall be fully open.

8. Summer/winter change-over: Based on outdoor temperature, change operating parameters and alarm limits from summer to winter operation and vise versa. Large enough differentials shall be programmed to prevent frequent change-over.

AIR HANDLING UNITS SHOULD HAVE EITHER DRY BULB ECONOMIZER CONTROL OR ENTHALPY ECONOMIZER CONTROL, DEPENDING ON ENERGY ANALYSIS AND ESTIMATED MAINTENANCE CAPABILITY. EDIT THE FOLLOWING TWO PARAGRAPHS AS THE TYPE OF ECONOMIZER CONTROL IS CHOSEN.

A CHANGEOVER TEMPERATURE MUST BE DETERMINED FOR THE DRY BULB ECONOMIZER CONTROL. SEE REFERENCE SECTION AT THE END OF THIS SECTION.

9. Dry bulb economizer control: A fixed changeover temperature of [ ] °C (°F) shall be used for determining the positions of the outdoor air and the return air dampers during the cooling season. When the outdoor air temperature is higher than the changeover temperature, the outside air damper shall be at its minimum position. When the outdoor temperature is between the changeover temperature and the supply air temperature, the outdoor damper shall be fully open and the cooling coil shall supplement the cooling requirements. When the outdoor temperature is below the supply air temperature, the outdoor damper shall be modulated to provide the desired supply air temperature and the cooling coil shall be deactivated. Upon further decreasing of the outdoor air temperature until the outdoor air damper reaches the minimum position, the heating coil shall be modulated to maintain the desired supply air temperature. The outdoor air, return air, and relief air dampers shall be coordinated to give the required building pressure level. The cooling coil, dampers, and heating coil shall be acting in sequence following the control algorithm. When the heating coil is located in the outside air stream, it shall be protected to maintain a minimum temperature of 2 °C (35 °F).

10. Enthalpy economizer control: When the outdoor temperature is below the desired leaving air temperature of the cooling coil, the outdoor air and the return air dampers shall modulate to supply the desired air temperature and the cooling coil shall be deactivated. When the outdoor temperature is above the desired leaving air temperature of the cooling coil, the enthalpies of the outdoor air and the return air shall be calculated and compared. If the outdoor air enthalpy is less than the return air enthalpy and the outdoor temperature is between the desired leaving air and the return air temperature, the outdoor damper shall be fully open. Otherwise, the outdoor air damper shall be at the minimum air position. The measurement of temperature and humidity of the outdoor air may be done locally or through the network from a central location. The outdoor air, return air, and relief air dampers shall be coordinated to give the required building pressure level. The cooling coil, dampers, and heating coil shall be acting in sequence following the control algorithm.

INDICATE ON DRAWINGS OR IN SPECIFICATION WHERE MULTIPLE SENSORS ARE REQUIRED FOR MULTI-SPACE ZONES SERVED BY A SINGLE CONTROL VALVE.

11. Discriminator control: When one control system with multiple sensors serves an HVAC system with multiple zones, the control system shall provide the highest temperature, within an allowable limit, to satisfy the zone calling for the greatest cooling, and shall provide the lowest temperature, within an allowable limit, to satisfy the zone calling for the greatest heating.

INDICATE ON DRAWINGS OR IN SPECIFICATION WHERE STATIC PRESSURE CONTROL SENSOR (SENSORS FOR MULTIPLE SENSOR SYSTEMS) IS LOCATED. EDIT TO INDICATE SUPPLY FAN CONTROL TYPE AND NUMBER OF STATIC PRESSURE SENSORS. SEE REFERENCE SECTION AT THE END OF THIS SECTION.

12. Supply air fan control for VAV systems: The [variable speed drive] [inlet vanes] shall vary the capacity of the supply fan as required to maintain the static pressure setpoint of the pressure controller. [For systems having multiple static pressure sensors, the static pressure controller shall maintain a minimum setting at all duct sensor locations.] Provide a high limit pressure sensor at fan discharge to stop fan operation when the high limit setting is exceeded.

INDICATE ON THE DRAWINGS THE LOCATIONS OF AIR FLOW RATE MEASURING STATIONS AND THE DESIRED AIR QUANTITY DIFFERENCE BETWEEN SUPPLY AND RETURN AIR. SEE REFERENCE SECTION AT THE END OF THIS SECTION.

13. Building pressure control for VAV system: The total supply air and the total return air of the air handling system No. [ ] shall be measured by air flow rate measuring stations in ducts. The difference between the supply air and return air quantities shall be maintained as specified whenever the system is in operation. When the difference exceeds 5% of the specified difference, the variable speed drive or inlet vanes of the return air fan shall be modulated to provide the specified difference. See Paragraph 2.02 C. FLOW, PRESSURE, AND DIFFERENTIAL PRESSURE for requirements of maintaing 3.6 meters per second (700 feet per minute) minimum air velocity.

THIS SPECIFICATION COVERS COOLING-ONLY VAV UNITS AND UNITS WITH HOT WATER REHEAT COILS. EDIT TO SUIT THE SYSTEM SELECTED. FOR SYSTEMS HAVING UNITS OTHER THAN THESE TWO TYPES, EDIT ACCORDINGLY.

14. VAV terminal unit control

a. The terminal unit control shall maintain space temperature at the setpoint or within the deadband as specified. The unit control shall use a proportional-integration algorithm.

b. The air flow rate of the unit shall be measured and shall be maintained between the maximum and minimum flow rates, except when the damper is closed as specified.

c. There shall be separate cooling and heating set temperatures with a deadband in between. There shall be temperature setup for cooling and setback for heating during the unoccupied period. For the temperature setting, morning warm-up shall be considered as part of the occupied period.

d. When the space temperature is above the cooling set temperature, the air flow rate shall be modulated to give higher flow rate at higher cooling demand. When the space temperature is below the heating set temperature, the air flow rate shall be maintained at the minimum flow rate.

e. When the space temperature is in the deadband, the air flow shall be at the minimum rate during the occupied period. The damper shall be closed during unoccupied period.

f. Provisions shall be made to give occupants the capability of overriding the occupied/unoccupied schedule at the room sensors. The override shall be reverted to the automatic program after an 8-hour duration.

g. Software access to terminal units controllers shall be through the host computer and at the room temperature sensors. Access shall enable operators to reset setpoints, operating parameters, operating schedules, and proportional-integration constants.

FOR SYSTEMS HAVING COOLING-ONLY TERMINAL UNITS, NO OTHER PARAGRAPH OF SPECIFICATION IS NEEDED. FOR SYSTEMS HAVING REHEAT HOT WATER COILS, EDIT TO RETAIN THE FOLLOWING PARAGRAPH.

h. Sequence of operation for units with reheat hot water coils: The air damper and hot water valve shall operate in sequence. Upon decreasing cooling demand, the air flow rate shall decrease until the minimum flow rate limit is reached. Then the hot water heating valve shall open until the space temperature is satisfied. The reverse shall occur when the space cooling load is increasing. When heating is required during unoccupied period, the air damper shall be at minimum flow position. When heating is required during warmup period, the air damper shall be at maximum flow position.

15. Coil freeze protection: A sensor located after the heating coil shall maintain the set temperature of the heating coil at all times. A remote bulb type freeze protection sensor located in front of the cooling coil shall stop the supply air fan and close the outdoor dampers when the coil face reaches 2 °C (35 °F). The heating coil control valve shall be fail-safe at a full open position when any part of the heating control fails. A Level 2 alarm shall be generated when any of these conditions occur.

THE FOLLOWING PARAGRAPHS ARE FOR MULTIPLE CHILLERS AND MULTIPLE-CELL OR MULTIPLE COOLING TOWERS. EDIT IF SINGLE CHILLER AND SINGLE COOLING TOWER ARE SPECIFIED.

16. Chiller plant control

a. The condenser water pumps and chilled water pumps shall be started by the operator through the host computer keyboard or at the field panels. Upon verification of water flow through the condensers and evaporators, the chillers shall be started manually at the chiller control consoles.

b. The chiller temperature controllers shall be adjustable at the field panels. Each chilled water pump and condenser water pump shall have differential pressure sensors to monitor pump status. A Level 2

alarm shall be generated within 10 seconds, if no flow is indicated after a pump-start command is given.

EDIT THE FOLLOWING IF THE COOLING TOWER HAS ONLY ONE CELL OR THE AIR FLOW RATE OF COOLING TOWER FAN IS NOT ADJUSTABLE.

c. The condenser water bypass valve, the air flow rate of cooling tower fans, and/or the number of cooling tower fans in operation shall be operating in sequence by maintaining [18] °C ([65] °F) minimum temperature in the condenser water main. When the chiller load is increasing, the following sequence shall take place: bypass valve to allow more water from towers to chillers, cooling tower fans to be turned on in turn at the lowest air flow rate, and air flow rates of the cells to be increased uniformly till full flow.

d. The software shall allow the operators to alter the lead-lag sequence of operating the chillers and tower cells.

e. The pressure differential between the chilled water supply and chilled water return shall be maintained by controlling the chilled water bypass valve at the chillers.

f. Level 2 alarms shall be generated when the following events occur:

Chillers are malfunctioning

Chilled water temperature is above setting

Condenser water supply temperature is above 30 °C (85 °F) or below [18] °C ([65] °F)

Differential pressure across chilled water and condenser water pumps drop to indicate malfunctioning of pumps

Level of cooling tower basin too high or too low

RETAIN THE FOLLOWING PARAGRAPH IF AUTOMATIC CONDENSER WATER TREATMENT SYSTEM IS SPECIFIED.

g. The automatic condenser water treatment pump shall operate only when the refrigeration machines are off

line and the condenser water pumps are in operation. The operation/control of the water treatment pump shall be part of the BAS system. The BAS subcontractor shall coordinate with the condenser water treatment subcontractor.

h. See Chiller Sections for requirements on capacity and safety controls.

EDIT THE FOLLOWING PARAGRAPHS TO AGREE WITH THE HEATING SYSTEM SELECTED (HOT WATER OR STEAM BOILERS).

17. Heating plant control

a. The hot water pumps shall be started by the operator through the host computer keyboard or at the field panels. Upon verification of water flow through the boilers, the boilers shall be started manually at the boiler control console.

b. The boiler temperature controller shall be adjustable at the field panel or from the host computer keyboard. The field panel and the host computer system shall monitor the [hot water entering and leaving] [the steam and entering water] temperature at the boiler, burner status, forced or induced draft fan status, the stack temperature, the stack CO_2 concentration, the fuel consumption rate, the heat output rate, and other pertinent data of each boiler. Also monitored shall be the [hot water supply and hot water return temperature] [steam pressure or temperature] [condensate temperature] at the plant main pipes, flow and energy rate of [hot water] [steam and condensate] for the entire plant.

c. See Boiler Section for requirements on capacity and safety controls.

18. Space heating water circuit control: Space heating served by Pump No. [ ] shall be controlled as follows:

a. Pump shall be activated automatically when outdoor temperature drops below the setpoint.

b. Water flow shall be verified by differential pressure sensors across the pump. Whenever the verification is negative while the outdoor temperature is below

setpoint, an alarm shall be generated. A command from the host computer keyboard or at the field panel shall start the standby pump.

c. A pressure reducing (choke) valve or variable speed pump shall maintain the differential pressure setting.

19. Steam to hot water convertor control

a. When the hot water circulation pump is not in operation, the convertor control system is deactivated and steam valves shall be closed.

b. Steam valves shall be operated in sequence [1/3 and 2/3 of full capacity] to maintain the leaving water temperature setpoint.

c. The operation of the water circulation pump and adjusting of leaving water temperature setpoint shall be made from the host computer system keyboard or at the field panel.

20. Finned tube radiation control

a. Space temperature sensor shall control the hot water valve.

b. When the outdoor temperature is above [18] °C ([65] °F), the hot water valve shall remain closed.

c. The space temperature and low limit temperature set points shall be adjustable from the host computer keyboard.

PROVIDE A LIGHTING CONTROL SCHEDULE SHOWING THE LIGHT ON/OFF TIME AND THE CORRESPONDING LIGHTING AREAS. IF OCCUPANCY SENSORS ARE SPECIFIED IN LIEU OF SCHEDULED ON/OFF CONTROL, DELETE THE FOLLOWING PARAGRAPH. SEE REFERENCE SECTION AT THE END OF THIS SECTION.

21. Lighting control: Lights shall be turned on and off in areas as scheduled. A local switch shall allow occupants to override the automatic on/off switching. However, the override shall be reverted to the automatic program after an 8-hour duration.

22. Fire safety and security

a. Activation of any fire safety sensor, including smoke detectors, pull stations, and sprinkler flow switches, shall generate a Level 3 alarm on the fire safety and the security system host computers. Video display of these systems shall show all pertinent information, including the floor plan where the alarm is occurring with the affected sensors flashing. Only operator's acknowledgement of alarms silences the audible alarm sound. An automatic call to the designated offices responsible for building fire and security shall be initiated. Fire alarm bells in the same fire zone shall sound the alarm continuously.

b. Activation of any security alarm, including entrance card units, emergency exits, and ground floor window intrusion sensors, shall generate a Level 3 alarm on the security system host computer. Video display of the security system shall indicate all pertinent information associated with the alarm, including the floor plan where the security sensors are involved with the sensors flashing. Only operator's acknowledgement of alarms silences the audible alarm sound. An automatic call to the offices responsible for building security shall be initiated.

c. Detection of malfunctions of fire safety or security sensors and circuits shall be reported as a Level 2 alarm on their respective host computer system and the HVAC host computer system. Display shall indicate all pertinent information associated with the trouble conditions and location. An audible sound shall be initiated. Only operator's acknowledgement of alarms silences the sound. Fire alarm bells shall not sound alarm.

d. A video display shall identify alarm locations and shall automatically display the floor plan where the latest alarms are occurring.

e. All fire safety and security zones in alarm status shall be shown flashing on their associated video display.

f. When a smoke detector in a smoke zone is activated, the air handling system associated with that zone shall be activated or deactivated so as to prevent the

circulation of smoke. Such actions shall override the regular mechanical system controls.

g. When a smoke detector in any elevator lobby is activated, it shall cause the elevator control to capture the elevators and send them to the ground floor.

h. The system shall provide instructions to fire fighters for displaying other floor plans when the fire safety system is under fire status. The display shall automatically return to the fire involved floor after one minute.

i. The fire safety system shall have the highest priority over the HVAC and security systems when a fire alarm is initiated. Commands of the other two systems if given during a fire alarm and are in conflict with the fire alarm system shall be ignored. All unacknowledge alarm message shall have higher priority over trouble messages.

j. The security system shall provide access control by employee identification, time schedule, and entrance location. Authorized personnel with a recognized password shall be able to override the programmed access. The time schedule of access control shall be programmable up to 6 periods per day. Authorized personnel with a special password shall be able to change a data file of the access control from the host computer keyboard.

k. A record of all security alarms and entrance card units shall be stored in permanent record and shall be printed when commanded. A menu of command options for entrance activities shall include but not be limited to time interval, employee identification catagory, and entrances requested.

E. DDC Field Panel Software

1. Software of field panels and unitary controllers shall allow HVAC equipment to operate independently through local loop control of DDC algorithms.

2. The system shall independently monitor and control all points under the field panels.

3. Field panels shall accept global controls from host computers.

4. Field panels shall accept downloading of programs from host computers.

5. Field panels and unitary controllers shall have PID algorithms. Proportional, integral, and derivative constants shall be resettable. The errors between the sensed and setpoint values shall be kept to a minimum while maintaining system stability. The actual operation of the control loops shall be determined by the nature of the equipment applications.

2.13 SYSTEM ACCURACY

A. System accuracies are system end-to-end accuracies which include sensors, transmitters, signal processing, and signal transmission.

B. The minimum system accuracies shall be provided:

1. Air and water temperature (not for energy calculation): +/- 0.6 °C (1 °F).

2. Temperature differential for energy computation: +/- 0.3 °C (0.5 °F).

3. Humidity of air: +/- 3% RH

4. Air flow rate: +/- 3% of calibrated span.

5. Fluid (water and steam) flow rate: +/- 1% of calibrated span.

6. Electric meters: +/- 0.25% of reading.

2.14 SYSTEM RESPONSE TIME

A. Alarm caused by sensor input change or contact change: 10 seconds.

B. Alarm caused by controller failure: 5 seconds.

C. Contact closure by operator's command from keyboard: 5 seconds.

THE FOLLOWING IS A SUGGESTED POINT SCHEDULE. ALL MONITORING AND CONTROL POINTS SHOULD BE LISTED IN THE SCHEDULE. REVISE AS NECESSARY. SEE REFERENCE SECTION AT END OF THIS SECTION.

2.15 POINT SCHEDULES: The essential elements of required points are as listed in the following point schedules:

SCHEDULE NO._____

Building Name_____

System Name_____ Date_____

POINT NAME	LOCA-TION	ANALOG POINT								BINARY POINT						CONTROL						LOG			ALARM					

PART 3 - EXECUTION

3.01 PRECONSTRUCTION QUALIFICATION

A. Before starting the work the project foreman shall meet with the Contracting Officer's representative and present an approved copy of qualification submittal. See QUALITY ASSURANCE and SUBMITTALS paragraphs of this specification.

B. Throughout the installation of BAS equipment, piping, wiring and other devices, testing, calibration, checkout, and final functioning testing, the project foreman shall be available on the construction site.

C. Should the construction project foreman be unavailable because of sickness or any other reason for more than 8 hours in any 40-hour construction week, the Contracting Officer's representative, at his sole discretion may temporarily suspend automatic control work until such time as the approved project foreman or an approved replacement is available on a full time basis without incurring delay on the part of the Government.

D. Should the Contractor elect to provide more than one project foreman, then each shall be approved.

3.02 INSTALLATION

A. Tubing and Wiring: Install pneumatic tubing, control wiring and conduit to connect the BAS components for an operational system.

1. Run pneumatic tubing and conduit in straight lines parallel to the lines of the building, and rack on factory furnished mounting blocks attached to the building structure. In finished spaces, tubing and conduit shall be concealed.

2. Wiring in mechanical equipment rooms shall be in approved raceways (cable tray, conduit, EMT). Open wiring strung above the ceiling shall be plenum rated cable, bundled together and protected from mechanical damage. Wiring shall not be supported from ductwork or piping.

3. Do not bury or conceal tubing and wiring beneath insulation. Provide stand-off supports.

4. Locate tubing and wiring clear of access doors, accessible ceilings, lighting fixtures, walkways, or any location subject to damage or abrasion.

5. Arrange wiring and conduit neatly with sufficient spaces when entering field panels. Provide grommets at panels and conduit to protect tubing and wiring. Tubing shall be racked, supported, and labeled to present a neat traceable system.

6. Provide manual valves at field panels and controlled devices to allow shutoff of main air.

7. Provide air gages at pressure devices so that input and output pressure of the devices may be determined. Gages shall have a minimum diameter of 50 mm (2 inches).

8. Install all wiring in accordance with the National Electrical Code, NFPA 70.

9. Communication and sensor wiring shall not be installed parallel to high voltage power lines or transformers within 3 meters (10 feet). Care shall be taken that other electromagnetic interferences shall be minimized. Signal wiring and a.c. power wiring shall be in separate raceways.

10. Sensor cables shall be minimum 22 gauge twisted and shielded.

11. Provide long radius at wire and conduit bends.

12. Label communication and sensor lines at ends.

13. Ground communication wire shielding at one point or as recommended by the equipment manufacturer.

14. Use shielded cable couplers at splices to maintain shielding integrity. Splicing shall be at accessible locations.

15. See ELECTRICAL Section for other requirements of supports and installation of wires, cables, and conduits.

B. Field Panels: Field panels shall be located as shown on the drawings. Provide screw type terminal strips in the field panels for the termination of all field wiring. Lay out terminal strips in an orderly fashion and label each termination. All wiring entering the panel shall be routed through the panel wireways in a neat and workmanlike manner, properly tied or laced and terminated. All control and system communication wiring shall be electrically terminated inside the field panel.

C. Instrumentation Display Panels

1. Mount all indicating instruments pertaining to the same field panel and HVAC system on the same display panel.

2. Mount system control diagrams of HVAC systems on the face of the instrumentation panels accompanying HVAC field panels.

3. Mount floor plans showing sensors and actuators locations on the face of instrumentation panels accompanying fire safety and security field panels.

D. Identification:

1. Identification labels shall be permanent, not subject to fading.

2. Label or code each field wire and pneumatic tube at each end.

3. Permanently mark terminal blocks at wire termination points.

4. Identify each controlled device with an engraved laminated phenolic nameplate, white on black, lettering not less than 4 mm (1/8 inch) in height, on 38 mm x 25 mm (1 1/2-inch x 1 inch) tag and brass interlocked chain secured to the controlled device. The name shall correspond with identification on the shop drawings.

5. Identify field panels, sensors, relays, and other field components with a similar name tag as specified above. Attach identification tags to field panels with stainless steel or brass screws or rivets. Do not use adhesives.

E. Field Sensors

1. Locate pressure and temperature sensing points sufficiently downstream from the controlled device to promote control stability.

2. Provide thermowells for all temperature sensors in pressure vessels and piping. For pipes up to 65 mm (2 1/2 inches) in diameter, strap-on sensors may be used.

3. Install thermowells at locations that the sensors sense the bulk temperature of the flowing fluid. Install wells in such positions that they will retain liquid heat transfer fluid in the well.

4. Where pipe diameters are smaller than the thermowell length,

provide wells at the piping elbow or tees to affect flow across the entire well area.

5. Should thermowells restrict cross sectional pipe area to less than 70 percent free area, provide pipe increases at the well not less than 150 percent of pipe diameter.

6. Mount strap-on sensors using helical screw stainless steel band clamps. If pipes are not required to be thermally insulated, strap-on sensors must be insulated thermally with 13-mm (1/2-inch) minimum thick, maximum k = 4.3×10^{-3} J/s cm °C at 25 °C (k = 0.3 Btu in/h ft^2 °F at 75 °F) insulation, 38 mm (1 1/2 inches) beyond the sensing tips on all sides.

7. Temperature sensors in ducts shall be secured to measure the average temperature of the flowing air without being unduly affected by thermal conduction from the support.

8. Thermal insulation on ducts shall not conceal locations of sensors.

9. Provide gaskets or sealant where sensor elements penetrate duct walls.

10. Sensor locations shall be readily accessible for easy maintenance and servicing.

F. Space Sensor

1. Space sensors shall be securely mounted.

2. Locate room sensors approximately 1,5 meters (5 feet) above the floor on an inside wall where they will respond to average conditions in the space.

3. Avoid installing sensors on outside walls. If unavoidable, mount sensors on insulating bases.

4. Avoid locations where exposed to direct sunlight.

G. Control Valves

1. Install control valves with stems upward as vertical as possible but in no case more than 45 degrees from vertical.

2. For soldered or welded valve connections, remove valve internal parts before soldering or welding.

3. Wire electric control valves in accordance with NEC recommendations. Provide not less than 0.6 meter (2 feet) of flexible water tight connectors with bushings at the valve actuator. Brace conduit to the building structure.

H. Damper Operators

1. Mount damper operators where accessible for maintenance.

2. If damper operators are located on insulated ducts or casing, mount operators on 14 gauge reinforced support plates arranged to allow insulation between the support plates and the face of the ducts or casing.

3. Brace damper operators securely so that there is no deflection or movement over the full range of the damper stroke. Pneumatic damper actuators must be allowed to pivot on their mounting pin.

I. Dampers: Mount dampers to casings and ductwork in conformance to SMACNA Standards. Provide welded or bolted galvanized steel structural supports for dampers larger than 1.9 square meters (20 square feet). Through-bolt damper frames to structural supports.

3.03 TEST DURING INSTALLATION

A. General:

1. All BAS components and wiring shall be tested during and after installation to verify that they are installed properly. These tests shall not substitute tests specified in FINAL FUNCTIONAL TEST AND VERIFICATION paragraphs.

2. The required final verification of software programs are specified in FINAL FUNCTIONAL TEST AND VERIFICATION paragraphs.

B. Pneumatic System Pressure Test: Perform a pressure test on the entire pneumatic system as follows:

1. Test high pressure air piping at 1,034 kPa (150 psig) air pressure. Maintain the pressure for 2 hours without loss of pressure. If loss of pressure is indicated, correct and retest until the system shows no loss of pressure for 2 hours.

2. Test low pressure air tubing at 207 kPa (30 psig) air pressure. Maintain this pressure for 2 hours without

pumping, during which time the pressure shall not drop more than 6.9 kPa (1 pound per square inch). Should pressure loss occur, determine the leak, repair with new equipment or piping and retest until the system shows no more than 6.9 kPa (1 pound per square inch) pressure drop in 2 hours.

3. Leaks at pipe and tube joints shall be corrected by remaking of joints.

C. Instrumentation and Control Components:

1. Each sensor must be calibrated in the laboratory or in the field with true input of the specified range for at least two points. Substitution of calibration certificates from instrument manufacturers or testing laboratories may be acceptable.

2. Transmitters or sensor-transmitter sets shall be calibrated. Calibrated signal generators may be used to input known signals to the transmitters for calibration.

3. Each wiring shall be tested to verify that the connections are not crossed.

4. Simulate minimum and maximum transmitter signal values to verify minimum and maximum controller output and stroke ranges of controlled devices.

5. Test all local control loops to verify that the loops are responding properly.

6. Control ramps, reset schedules, proportion, reset, and derivative relationships of all control loops shall be set and tested. Record all final data.

7. After verifying that the controller-controlled device loops are responding as designed, restore all disconnected wiring.

8. After mechanical equipment control becomes operational, perform an operational test of each control loop. Record input, output, and other control parameters for sensors, transmitters, and controlled devices.

9. Verify the proper operation of the host computer systems.

10. Upon satisfactory test, the final test results shall be included as part of the Operating and Maintenance Manual.

3.04 FINAL FUNCTIONAL TEST AND VERIFICATION

A. Test Plan:

1. Prepare a detailed final functional test and verification plan indicating in a step-by-step logical fashion the procedures by which the BAS will be tested, adjusted, verified, and accepted. Detailed software verification of all programs shall be included.

2. Not less than 6 weeks prior to these tests, provide four copies of the proposed plan to the Contracting Officer's representative for approval. Meet with the Contracting Officer's representative, discuss the test plan, and make necessary revisions.

3. The plan shall include, as a minimum, for each control system and sub-system the following:

   a. System name.

   b. List of devices with brief description of functional purpose of each.

   c. A detailed point list as installed.

   d. The expected signal values transmitted by the sensors.

   e. The expected signal values transmitted by the controller to the controlled device or actuator.

   f. The expected values of the control medium from limit-to-limit.

   g. A description of the instrumentation required to test the system, including proof of calibration.

   h. A description of the expected field adjustments for transmitter, controller, and control actuator should control parameters fall outside of expected values.

   i. A detailed step-by-step process in conducting test and verification.

   j. Log sheets on which expected and field read values will be recorded and final field read values indicating that the system is operating in accordance with Contract requirements.

B. Final Functional Tests

1. This phase of the work is to perform final functional tests to verify that the entire BAS is designed, installed, and adjusted to perform as required in the contract. This phase is an extension of the phase specified under the TESTS DURING INSTALLATION paragraphs. The work under this phase is to demonstrate to the Government for final acceptance, not for the BAS subcontractor to adjust and fine tune the system.

2. The entire final functional test and verification shall be witnessed by a Government team. The demonstration and testing shall be conducted by the BAS subcontractor. The BAS subcontractor shall coordinate with the representative of the Contracting Officer on the time schedule and logistics of the tests.

3. System and software verification:

a. Verify the operation of each host computer system by using computer system manufacturer's recommended test routines. Each components (video display unit, disk drives, printer, communication interface, etc.) shall be verified.

b. Verify all field panel application software individually. All possible branching of application software decisions shall be tested and verified. In order to create the input conditions to enable the verification, calibrated signal generators may be used. The actual responses of the system shall be measured and/or observed to confirm the correctness of the software.

c. Verify global application software of the host computer systems. Similar to field panel application software verification, all possible branching of application software decisions shall be tested and verified.

d. Verify all command software by sending commands from the host computer keyboards.

e. Verify the operator access software. Access passwords and codes, access levels, and access revision capability shall be verified.

f. Verify alarm generation and reporting by creating alarm conditions. All alarm conditions shall be verified. For the fire safety system, conditions shall also be created to disable the fire safety host computer system to verify the automatic substitution of other host computers for fire safety. Manipulate conditions to verify the capability of self testing of sensor and circuit malfunction of the fire safety system.

g. Verify downloading and uploading of programs and data between host computers and field panels.

h. Verify self-diagnostic capability of field panels.

i. Verify the operation of the clock routine in the field panels and resetting of field panel clocks by host computers.

C. System Accuracy Verification: As a final course of the functional testing process, system accuracies for each control loop, end-to-end (from sensing to controlled media), shall be verified. The system accuracies shall be not less than those listed in SYSTEM ACCURACY paragraphs of PART 2.

D. Failure to Perform: Should the BAS fail to perform in accordance with the requirements of the specification, the system shall be repaired, recalibrated, and debugged as necessary, and new tests performed.

1. Subsequent tests shall occur until the representative of the Contracting Officer deems that the BAS and all associated mechanical and electrical equipment are operating in accordance with contract requirements.

2. All testing, debugging, retesting, recalibration shall be at no additional expense to the Government

E. Test Report: Upon completion of the final functional test and verification, a report of the test results shall be submitted to the Contracting Officer. The report shall also be included in the Operating and Maintenance Manual.

3.05 DEMONSTRATION TO GOVERNMENT PERSONNEL

A. It is the intention of the Government that this contract includes training of the operating personnel of the Government or its O & M contractor. After completion of the final functional testing

process and acceptance by the Government, the first year maintenance period by the BAS subcontractor begins. The BAS subcontractor shall demonstrate system operation and maintenance to the designated Government operating personnel.

B. A formal demonstration shall be performed at the beginning of the first year period in the presence of a representative of the Contracting Officer and such operating personnel as he may designate.

C. The demonstration shall include the operation of the entire BAS, such as the start up, system operation, software program revision, debugging, and installation, and shutdown of the system.

D. The operation of each device and system shall be performed in accordance with the written instructions contained in the Operation and Maintenance Manual. Deviation from procedures in the Operating Manual shall be avoided.

3.06 TRAINING TO GOVERNMENT OPERATING PERSONNEL

A. Training Material: The training of Government operating personnel or the Government's O & M contractor personnel, utilizing written operating instructions prepared and approved under the SUBMITTALS paragraph of PART 1. The instruction material shall be appropriate and adequate. Ten extra copies of training material shall be delivered to the Government.

THE NUMBER OF DAYS NEEDED FOR THE FORMAL TRAINING DEPENDS ON THE COMPLEXITY OF THE BAS AND THE EXPOSURE OF BAS TO THE OPERATING PERSONNEL. A SUGGESTED TIME IS FOUR DAYS FOR THE INITIAL TRAINING AND 2 DAYS FOR THE 6 MONTH TRAINING.

B. Training Program

1. An initial [ ] day formal training for Government or its designated personnel shall be conducted approximately 30 days before the time of Government acceptance. Topics shall include system overview, host computer system operation, field panel operation, sensor calibration, software logic and revisions, maintenance and troubleshooting of system components. The training shall be conducted by an instructor and the project foreman at the project site.

2. During the start-up, check-out, performance test and final functional test and verification period, Government

operating personnel will observe the operation.

3. As part of the training program during the first year of operation, the BAS subcontractor shall provide on-the-job training to the Government operating personnel. The total training hours under this item shall be [ ] hours.

4. A [ ] day formal training session shall be conducted after 6 months of the initiation of the first year period. The topics shall be similar to the initial training with emphasis on operating and maintenance. The training shall be conducted by an instructor. The training material shall be updated from those of the initial training.

5. The initial formal training will be witnessed by a representative of the Contracting Officer who shall monitor the entire training program. A written report on the competency and effectiveness of instructors and the level of expertise of designated operators will be prepared. This report will be rendered to the Contracting Officer recommending additional training if such training is deemed necessary. The cost of additional training, if authorized by the Contracting Officer, will be borne by the Government.

END OF SECTION

REFERENCE SECTION

1. Scope: The scope of the building automation system (BAS) of this specification covers microprocessor based, distributed network control systems for HVAC, fire safety, and building security. This specification does not include a building telecommunication system, except that the BAS has the capability to connect to the building telecommunication system when the building management desires to do so in the future.

2. Architecture of System: There are many different arrangements of BAS architecture available on the market, basically depending upon the manufacturer's design philosophy and planned costs of the systems. Since this specification is performance oriented, it avoids going into the details of definitive architectural and component requirements. However, the specification states clearly the Government's requirements on BAS functions. The BAS must have stand-alone field panels and unitary controllers to control and monitor local control loops. The system must have host computers and peripherals to collect information throughout the BAS and to issue and monitor commands of global nature. The three essential elements of the system (HVAC, fire safety, and building security) must operate independently during normal mode. In case one host system fails, other systems must take over the failed system automatically. This is quite essential from the view point of life safety.

3. Drawing coordination: The designers should locate all host computers and field panels on the drawings. This is especially necessary for host computer systems (host computers and their associated peripheral equipment), since the host computer systems are usually located in separate offices and the coordination with the project architects for allocating these rooms is needed. In locating field panels, consideration should be given to the distance of field panels to their associated sensors and actuators, the maximum number of inputs and outputs of the panels, and the overall cost.

4. Operation, Service, and Maintenance: At the present, different operation and maintenance arrangements are being used in GSA managed Federal buildings. Some buildings are operated and maintained by Government personnel; some buildings are operated and maintained by GSA's Commercial Facility Management Contractors (CFM); and a small number of buildings has control contractors, in addition to Government or CFM personnel, to operate and maintain control systems. These control contractors are the same control subcontractors who built the control system. Satisfactory results have been experienced in the latter arrangement for buildings with complex control systems (e.g. DDC based BAS). In this arrangement, the Government or CFM personnel can learn fully the operation and maintenance procedures from the control

contractors. The specifiers should consult with PBS's safety and real property management in deciding the arrangement to be specified for the first year warrranty period and the optional operation and maintenance contracts.

5. Kind of Actuators to be Specified: Generally, the overall job cost is still very competitive when pneumatic powered actuators are used. The way this specification is written: it is best to let the contractors decide the kind of actuators to be used in a project in order to get the lowest cost. If for some reason the designer wants only one kind of actuators to be used in a project, the specifier should edit the specification to reflect that determination.

6. Software

   A. Application programs are very much dependent on the projects. Variables which may affect the programs are weather factors, HVAC system selection, control strategy combinations, and even the designer's preferences. The software listed in this guide specification are the most basic single strategy software. A certain software scheme may not be desirable when combined with other schemes. The project specifiers must evaluate the particular project circumstances and edit the requirements.

   B. Scheduled start/stop control: The start/stop is usually scheduled according to time of the day and day of the week. Generally, it should include lighting, certain pumps, exhaust fans, small refrigeration machines, etc. When large pieces of equipment are involved, the starting time should be sequenced with small time lags between them, in order to minimize the demand load during equipment starting time. Some of this equipment may be put under optimum start/stop control. A list of the equipment to be included in scheduled start/stop and the time of start and stop should be shown on the drawings.

   C. Load shedding: Equipment to be included in load shedding should be listed on the drawings. Equipment that can usually be selected are air handling units, office electrical equipment, general lighting in selected areas, etc. Do not list large refrigeration machines in the load shedding schedule. For the same kind of equipment, such as air handling units, prioritizing by areas they serve should be applied.

   D. Economizer control: Unless good maintenance of humidity sensing devices can be assured, enthalpy economizer control

should be avoided. When a dry bulb economizer control is used, a change-over temperature should be determined and specified in the construction documents. The change-over temperature is weather dependent: temperature, humidity, and the total time of a year being in these temperatures and humidities. The change-over temperature selected should achieve the lowest energy consumption for the system on a yearly bases.

E. Cooling tower control: Cooling tower capacity control is usually done by changing the tower fan speed, adjusting blade pitch, bypassing water from active cells, etc. The guide specification should be edited to suit the tower specified.

F. Open loop type controls: Specifying controls without feedback from the controlled media, such as resetting air handling unit deck temperature and heating hot water temperature by outdoor air temperature, does not achieve precisely the desired purposes and should be avoided.

7. Point Schedules: A typical point schedule is shown in paragraph 2.15. Because of their large sizes, many point schedules should be shown on the drawings. Detailed point schedules which include all monitoring and control points are very helpful in conveying the designer's intentions to the contractor and consequently, must be listed in the schedules. Point schedules should identify all points clearly. The schedules should contain all analog and binary input and output points such as temperature, differential temperature, pressure, differential pressure, flow rate, electrical energy consumption, equipment run time, equipment conditions (on/off, open/close, flow/no flow, etc.). Also included are command or control requirements (start/stop, open/close, reset, change-over, etc.) and control strategy requirements (demand limit, control point adjustment, economizer cycle, etc.). Alarm requirements should identify the point of critical alarms, other alarms, and a reminder for operation personnel (such as for maintenance). Requirements of trend logs and displays of various points are also necessary. An illustrative point schedule of an air handling system may be found in GSA/PBS Direct Digital Control Based Building Automation System Design Criteria.

8. Final Functional Testing and Verification (also known as commissioning): This is an important procedure in quality control of any construction project. This is particularly true for BAS. Both hardware installation (such as crossed wire connections) and software logic need to be thoroughly checked and corrected. There is no magic way of doing this, although efforts are being made in developing emulator testing equipment. At the present, the only practical way is to check every possible "cause-effect" of the entire system. This specification

requires the contractor to submit a final functional test plan to test all systems and sub-systems from end to end to verify the results. Since the work is very complex and tedious, good record keeping should be emphasized.

9. Building Automation System (BAS): A general discussion and specific design criteria of DDC based BAS may be found in GSA/PBS Direct Digital Control Based Building Automation System Design Criteria.

10. Variable Air Volume System (VAV): Detailed discussions of VAV system design may be found in GSA/PBS Variable Air Volume Design Guide.

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This publication is intended for building system designers' use in specifying direct digital control (DDC) based building automation systems (BAS) for construction of Federal buildings. This guide specification conforms with the format of guide specifications used by the General Services Administration (GSA) and its professional services contractors.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

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