FACILITY MANAGEMENT SYSTEM

1. Part 1 – General Requirements

1.1 System Summary

A. The central Operator Workstation shall be able to display information on all systems under a single software operating environment.

1.2 Related Work Specified in Other Sections

A. Where work specified under other Sections of these Specifications connects to equipment or systems which is a part of this Section, provide proper connection(s) to such equipment including trade coordination. The following sections may have direct links to the installation of the FMS system:

B. Section 00000 - General Conditions

C. Section 15000 - Mechanical Work

D. Division 16 - Electrical Work

E. Additional related work as specified in Part 3 or as shown on the design drawings.

1.3 Definitions

A. Algorithm: A software procedure for solving a recurrent mathematical or logical problem.

B. Analog: A continuously varying signal or value (temperature, current, velocity, etc.).

C. Binary: A two-state system where an “ON” condition is represented by a high signal level and an “OFF” condition is represented by a low signal level.

D. Facility Management System (FMS): The entire system of hardware and software specifically designed to centrally manage building HVAC and related utilities. The FMS includes the DDC subsystem, open system ports, and open protocol bus or integrators and network routers for connection to information networks.

E. FMS Contractor: The Facility Management System Contractor responsible for the installation of the Facility Management System specified herein.

F. Control Process: The software required to perform a complete control loop from input signal to interlock logic, process calculation to final output signal control.

G. Control Wiring: Includes conduit, wire and wiring devices to install a complete Control System including motor control circuits, interlocks, thermostats, PE and EP switches and like devices. Includes all wiring from a DDC cabinet to all sensors and points defined in the Points List summary or specified herein and required to execute the sequence of operation. Includes necessary power wiring to all FMS devices, digital controllers including terminal units and actuators.

H. Deadband: A temperature range over which no heating or cooling energy is supplied, such as 72-78 degrees F, i.e. as opposed to single point changeover or overlap, or a range from setpoint over which no control action is taken.

I. Direct Digital Control System: The portion of the FMS which provides closed loop control of all HVAC equipment.

J. Distributed Control: A system whereby all control processing is decentralized and independent of a central computer. The control system is built up of stand-alone controllers. A single controller failure shall not impact more than one system.

K. Integration: The ability of control system components from different manufacturers to connect together and provide coordinated control via real-time data exchange through a common communications data exchange protocol. Integration shall extend to the operator's workstation software, which shall support user interaction with all control system components. Methods of integration include industry standard protocols such as: BACnet, LonMark/LonTalk, OLE for Process Control (OPC) or integrator interfaces between cooperating manufacturer's systems.

L. Network: A system of distributed control units that are linked together on a communication highway. A network allows sharing of point information between all control units. Additionally, a network provides central monitoring and control of the entire system from any distributed control unit location. First tier networks shall provide "Peer-to-Peer" communications. Second tier networks shall provide either "Peer-to-Peer", Master-Slave or Supervised Token Passing communications.

M. Open Protocol Bus (OPB): A pre-programmed communications integrator that allows devices from one manufacturer to communicate and interact with those of another.

N. Open System Port (OSP): A user programmable communications port that provides the ability to develop custom communications processes to integrate other operating systems with the FMS System.

O. Operator-Machine Interface: A method by which an operator communicates with a FMS System. Operator-machine interfacing allows an operator to command, monitor, and program the system.

P. Peripheral: Input/Output equipment used to communicate with the computer and make copies of system outputs, peripherals include CRT, printer, tape deck, diskette, etc.

Q. Pick Point: A pick point is a graphical display element that allows the operator to “click” the item and automatically display the associated screen or service. Any screen may have pick points to or be linked from any other screen. Pick points shall be configured on each display screen to provide a logical user navigation system using a ladder tree hierarchy.

R. PID Control Loop: A mathematical calculation used to evaluate a control input and determine the control output value required to maintain the input value at setpoint. The PID (Proportional, Integral, Derivative) control loop shall have operator adjustable maximum rate of change, P and D gains and loop response time delay. The loop shall be self-integrating so that no integral constant is required and the loop shall not be subject to “Integral Windup”.

S. The term “provide” means “provide complete in place”, that is, furnished and installed and ready for operation and use.

1.4 Quality Assurance

A. General

1. The facility management system shall be an extension of the existing Johnson Controls Metasys system. The system shall be able to read/write and fully communicate with all existing Metasys points. The Facility Management System (FMS) herein specified shall be fully integrated and installed as a complete package by the Facility Management System Contractor. The System shall include all wiring, piping, installation supervision, calibration, adjustments, and checkout necessary for a complete and fully operational system. Distributors or wholesalers are not acceptable.

2. The Facility Management System Contractor shall be a factory owned branch office that is regularly engaged in the engineering, programming, installation and service of Facility Management Systems of similar size and complexity.

3. The FMS Contractor shall have a local branch facility within a 100-mile radius of the job site. Emergency service shall be available on a 24-hour, 7-day-a-week basis.

4. The FMS Contractor shall be responsible for all work fitting into place in a satisfactory and neat workmanlike manner acceptable to the Owner/Architect/Engineer.

5. The FMS Contractor will coordinate with other Trade Contractors regarding the location and size of pipes, equipment, fixtures, conduit, ducts, openings, switches, outlets, and so forth, in order to eliminate any delays in the progress of the job.

B. Experience Record

1. The FMS Contractor shall have a minimum of ten years experience with the complete, turnkey installation of Facility Management Systems of similar size and technical complexity. The FMS Contractor shall provide a list of five comparable projects that have Facility Management Systems with the features as specified for this project. These projects must be on-line and functional.

2. The FMS Contractor shall employ specialists in the field of Facility Management Systems including: Programming, Engineering, Field Supervision, and Installation. Specialists shall have a minimum of five years of experience with Facility Management Systems.

C. Products

1. The Facility Management System architecture shall consist of the products of a manufacturer regularly engaged in the production of Facility Management Systems, and shall be the manufacturer's latest standard of design. Controllers and DDC (Direct Digital Control) system components shall be current production products.

2. All other equipment shall be the products of the FMS manufacturers or of an approved manufacturer regularly engaged in production of specialized Facility Management System materials or equipment. Only factory direct branches are acceptable.

3. Following is a list of the only acceptable FMS Contractors/Installers:

   a. Johnson Controls, Inc. – Metasys (Contact: Jeff Lee 908-557-4597)

D. ISO-9001

1. The manufacturer of the Facility Management System shall provide documentation supporting compliance with ISO-9001

(Model of Quality Assurance in Design/Development, Production, Installation, and Servicing). Product Literature provided by the FMS manufacturer shall contain the ISO-9001 Certification Mark from the applicable registrar. Manufacturers delivering products that do not comply with the ISO-9001 certification requirement shall provide the following information to assure that quality systems are in place which are equivalent to the ISO-9001 standard:

a. Marketing Specification Standards
b. Design File Standards
c. Manufacturing Test Standards
d. Calibration Standards
e. Quality System Standards
f. Quality System Procedures
g. Documented management commitment that all employees participate in quality programs
h. Training Procedures
i. Methods by which corrective actions are taken for problems identified within the factory process.

E. Quality Assurance Program

1. The FMS Contractor shall implement a Quality Assurance Program. At minimum, this program shall consist of the following requirements:
   a. The FMS Contractor shall assign a single individual to serve as the Quality Assurance Manager, who is to be responsible for the management of the program.
   b. The Quality Assurance Manager shall provide or maintain:
      ◊ Documentation of training for employees—including office, field, and subcontractors—on the Quality Assurance Program.
      ◊ Written verification that each worker on the project has read the Specification sections outlining the project requirements for his or her area of specialty. The initial project team shall be documented in the first project submittal.
      ◊ A detailed audit trail for all Quality Assurance issues, including: problem ID number, date of original problem report, name of individual initiating report, and individual assigned responsibility for resolving the problem.
   c. Each individual team member shall be responsible for identifying and reporting Quality Assurance problems and for assisting, as requested by the Quality Assurance Manager, in the resolution thereof.

F. Governing Code Compliance

1. The FMS Contractor shall comply with all current governing codes ordinances and regulations, including UL, NFPA, the local Building Code, NEC, and so forth.

G. FCC Regulation

1. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Section 15, Governing Radio Frequency Electromagnetic Interference, and be so labeled.

1.5 Work Included

A. Installation of Facility Management System (FMS)

1. The FMS Contractor shall furnish and install a complete Facility Management System (FMS) for all mechanical systems and other facility systems as included in the project documents. The FMS will provide the functional features as defined in Part 1-General Requirements, Part 2-Products, and Part 3-Execution of these Specifications. The FMS Contractor shall provide a complete and operational system to perform all sequences of operations stated within Part 3 or shown on the control drawings.

2. In addition, the following apply:

a. The work under this Section shall include all materials and labor to perform all work required for the installation of the FMS as specified.

b. The drawings and Specifications are complementary to one another—meaning that what is called for on one is to be considered called for in both. Where conflicts exist between the Specifications and/or drawings, the more stringent requirement shall apply.

c. The FMS Contractor shall be responsible for field verification of site conditions and for gathering all necessary field data for all items to be provided under this contract prior to submitting his or her bid.

d. Where work specified under other Sections of this Specification connects to equipment or systems that are listed and described in this Section, the FMS Contractor shall provide proper connection(s) to such equipment, including trade coordination.

1.6 Coordination

A. Divisions

1. The FMS Contractor shall cooperate with other divisions performing work on this project as necessary to achieve a complete and neat installation. The Contractor shall also consult the drawings and specifications of all trades to determine the nature and extent of others' work.

B. Contractors, Sub-contractors, Employees

1. It will be the duty of this Contractor to work in cooperation with other contractors, and with other sub-contractors and employees, rendering assistance and arranging his or her work so that the entire project will be delivered in the best possible condition and in the shortest time.

1.7 Submittals

A. Shop Drawings, Product Data, and Samples

1. The FMS Contractor shall submit installation drawings and control strategies for review.

2. Each submittal shall have a cover sheet with the following information provided: submittal ID number; date; project name, address, and title; FMS Contractor name, address and phone number; FMS Contractor project manager, quality control manager, and project engineer names and phone numbers.

3. Each submittal shall include the following information.
   a. FMS riser diagram showing all DDC controllers, operator workstations, network repeaters, and network wiring.
   b. One-line schematics and system flow diagrams showing the location of all control devices.
   c. Points list for each DDC controller, including: Tag, Point Type, System Name, Object Name, Expanded ID, Display Units, Controller Type, Address, Cable Destination, Module Type, Terminal ID, Panel, Slot Number, Reference Drawing, and Cable Number.
   d. Vendor's own written description for each sequence of operations, to include the following:
      ◊ Sequences shall reference input/output and software parameters by name and description.
      ◊ The sequences of operations provided in the submittal by the FMS Contractor shall represent the detailed analysis needed to create actual programming code from the design documents.
      ◊ Points shall be referenced by name, including all software points such as programmable setpoints, range limits, time delays, and so forth.

- ◊ The sequence of operations shall cover normal operation and operation under the various alarm conditions applicable to that system.

e. Detailed Bill of Material list for each panel, identifying: quantity, part number, description, and associated options.

f. Control Damper Schedules. This spreadsheet type schedule shall include a separate line for each damper and a column for each of the damper attributes, including: Code Number, Fail Position, Damper Type, Damper Operator, Blade Type, Bearing Type, Seals, Duct Size, Damper Size, Mounting, and Actuator Type.

g. Control Valve Schedules. This spreadsheet type schedule shall include a separate line for each valve and a column for each of the valve attributes, including: Code Number, Configuration, Fail Position, Pipe Size, Valve Size, Body Configuration, Close off Pressure, Capacity, Valve CV, Calc CV, Design Pressure, Actual Pressure, and Actuator Type.

h. Cataloged cut sheets of all equipment used. This includes, but is not limited to, the following: DDC panels, peripherals, sensors, actuators, dampers, control air system components, and so forth.

4. FMS Contractor shall not order material or begin fabrication or field installation until receiving authorization to proceed in the form of an approved submittal. FMS Contractor shall be solely responsible for the removal and replacement of any item not approved by submittal at no cost to the Owner.

1.8 O&M Manuals

1. Submit three sets of each manual.
   a. Include the following documentation in the Hardware Manual:
      - ◊ General description and cut sheets for all components.
      - ◊ Detailed wiring and installation illustrations and complete calibration procedures for each field and panel device.
      - ◊ Complete trouble-shooting procedures and guidelines.
      - ◊ Complete operating instructions for all systems.
      - ◊ Maintenance Instructions: Document all maintenance and repair/replacement procedures.
   b. Provide three copies of all manufacturers manuals covering the installed system. This shall include, as a minimum:
      - ◊ System Engineering Manual
      - ◊ System Installation Manual
      - ◊ Programming Manual

- ◊ Engineering and Troubleshooting Bulletins
- ◊ Operator Workstation Software Manual
- ◊ All other pertinent manuals published by the control system manufacturer.

2. All manuals shall be provided in hard copy format or on a single Compact Disk (CD) as part of an on-line documentation system through the operator workstation.

3. Record Drawings

1.9 Warranty

A. Material and Labor:

1. The Control System shall be free from defects in material and workmanship under normal use and service. If within one year from the date of completion any of the equipment herein described is defective in operation, workmanship or materials, it will be replaced, repaired or adjusted at the option of the FMS Contractor free of charge.

2. Part 2 – Products

2.1 System Architecture

A. First Tier Network

1. The first tier network shall be based on a PC industry standard of Ethernet TCP/IP. PC Workstation LAN controller cards shall be standard “off the shelf” products available through normal PC vendor channels.

2. The FMS shall network multiple operator workstations, network controllers, system controllers, application-specific controllers and third-party networks integrators. The first tier network shall provide communications between operator workstations and first tier DDC (Direct Digital Control) controllers.

3. The first tier network shall operate at a minimum communication speed of 2.5 M baud, with full peer-to-peer network communication.

4. Network Controllers shall reside on the first tier.

5. The first tier network will be compatible with other facility-wide networks. The first tier shall be connected to a facility network by way of standard networking practices.

B. Second Tier Network

1. Second tier networks shall provide communication between Network Controllers and individual DDC/ASC controllers and shall operate at a minimum communication speed of 9600 baud.

2. DDC System Controllers shall reside on the second tier.

C. Integration

1. Direct Protocol (Integrator Panel)

a. The FMS system shall include appropriate hardware equipment and software to allow bi-directional data communications between the FMS system and 3rd party manufacturers' control panels. The 3rd party manufacturer shall provide their "Metasys compatible" or "N2 compatible" communication hardware and software. The FMS shall receive, react to, and return information from multiple building systems, including but not limited to the chillers, boilers, variable frequency drives, power monitoring system, fire alarm, access control and lighting systems.

b. All data required by the application shall be mapped into the Network Controller's database, and shall be transparent to the operator.

c. Point inputs and outputs from the third-party controllers shall have real-time interoperability with FMS software features such as: Control Software, Energy Management, Custom Process Programming, Alarm Management, Historical Data and Trend Analysis, Totalization, and Dial-Up and Local Area Network Communications.

d. The Facility Management System shall provide any combination of third-party controllers on a single network. A minimum of 100 third-party controllers shall be supported on a single network. Integration shall be via RS-232 or RS-485 technologies.

e. The system operator shall have the ability to verify, and diagnose communication messages and point information between third-party controllers and the FMS.

2.2 Operator Interface – Platforms

A. M-5

1. The FMS Contractor shall provide and install a personal computer workstation for command entry, information management, network alarm management, and database management functions. All real-time control functions, including scheduling, history collection and alarming, shall be resident in

the FMS controllers to facilitate greater fault tolerance and reliability.

2. Workstation System Architecture – The architecture of the workstation shall be implemented to conform to industry standard APIs (application specific interfaces), so that it can accommodate applications provided by the FMS Contractor and by other third party applications suppliers, including but not limited to Microsoft Office Applications. Specifically it must be implemented to conform to the following interface standards.
    a. All historical information contained in Time Series Databases and all configuration data contained in relational databases must be accessed via ODBC (utilizing ANSI SQL database query specifications).
    b. All real-time, online building data must be accessible by all applications (including, but not limited to, graphics, reports, etc.) via OPC (OLE for Process Control).
    c. All real-time event data (including alarms, change of state events, warning events, etc.) shall be accessible by all applications via OPC (OLE for Process Control).
    d. The FMS Contractor shall provide all necessary OPC servers for communicating to the DDC controllers that are provided as part of this contract. In addition, the system shall accommodate installation and registration of OPC servers provided in the future by other equipment suppliers.
    e. Workstation Operator Applications architecture – Major operator viewing applications shall be implemented utilizing the current Microsoft Model of an Active-X control, to be contained in one or more Active-X compliant containers. Specifically, the graphics application shall be provided as an Active-X control (for example it shall be possible to embed a graphic in a web page and view it in Internet Explorer). Conversely, it shall be possible to embed other Active X controls—such as trends and other third party available controls—in the real-time graphic application.
3. PC Hardware – The personal computers shall be configured as follows:
    a. Memory – 256 MB (Minimum)
    b. CPU– Pentium IV or greater; 1.5 GHz or Faster Clock Speed
    c. Hard Drive – 40.0 GB or greater hard drive
    d. Floppy Drive – 3 1/2” Diskette Drive
    e. CD ROM Drive – 32X performance
    f. Ports – (2) Serial and (1) parallel Ports, ESP/
    g. Keyboard – 101 Keyboard and 2 Button Mouse
    h. CRT configuration as follows:

- ◊ 17” SVGA Monitor 1280 x 1024 NI resolution minimum; .26 or better dot pitch and 72 Hz. minimum vertical refresh rate or max resolution; 65k colors.

i. LAN communications – Ethernet communications board; 3Comm or equal.

4. Operating System Software
   a. Windows NT 4.0. Complete operator workstation software package, including any hardware or software keys. Include the original installation disks and licenses for all included software, device drivers, and peripherals.
   b. Provide software registration cards to the Owner for all included software.
5. Peripheral Hardware
   a. Alarm printers:
      - ◊ Printer Make – Epson or equal
      - ◊ Printing Method – 24-Pin Impact Dot Matrix
      - ◊ Print Speed – 270 Characters Per Second, Per Line
      - ◊ Buffer – 64 K Input Print Buffer

B. Workstation Application Components

1. Operator Interface
   a. An integrated software package shall be used as the operator interface program.
   b. All Inputs, Outputs, Setpoints, and all other parameters as defined within Part 3, shown on the design drawings, or required as part of the system software, shall be displayed for operator viewing and modification from the operator interface software.
   c. The operator workstation software shall provide context-sensitive help menus and instructions for each operation and/or application currently being performed.
   d. All controller software operating parameters shall be displayed for the operator to view/modify from the operator workstation. These include: setpoints, alarm limits, time delays, PID tuning constants, run-times, point statistics, schedules, and so forth.
   e. The operation of the control system shall be independent of the operator workstation, which shall be used for operator communications only. Systems that rely on the operator workstation to provide supervisory control over controller execution of the sequences of operations or system communications shall not be acceptable.
2. Alarms

a. Each workstation shall receive and process alarms sent to it by the control system. The alarm management portion of the operator workstation software shall, at the minimum, provide the following functions:
   - ◊ Log date and time of alarm occurrence.
   - ◊ Generate a “Pop-Up” window informing an operator that an alarm has been received.
   - ◊ Allow an operator, with the appropriate security level, to acknowledge, delete, or disable an alarm.
   - ◊ Provide an audit trail for alarms by recording operator acknowledgment, deletion, or disabling of an alarm. The audit trail shall include the name of the operator, the alarm, the action taken on the alarm, and a time/date stamp.
   - ◊ Record all alarms received at an operator’s workstation to that workstation’s hard drive.
   - ◊ Allow the operators to view/manage the alarm data archived to hard disk. Selection of a single menu item or tool bar button shall allow the user to acknowledge, disable, delete, or print the selected alarm.

b. Alarms shall be generated by the operator workstation for any controller that is “Off-Line” and is not communicating, or that does not have an active control program loaded.

c. Changes made to alarm setpoints from the Operator Workstation shall directly modify the controller alarm management database.

d. Selection of a single menu item or tool bar button shall print any displayed alarm report on the system printer for use as a building management and diagnostics tool.

3. Reports

a. Reports shall be generated and directed to one of the following: workstation displays, printers, or disk. As a minimum , the system shall provide the following reports:
   - ◊ All points in the network.
   - ◊ All points in a specific controller.
   - ◊ A listing of a user-defined group of points in the network. There shall be no limit to the number of user-defined groups
   - ◊ All points currently in alarm.
   - ◊ All points in hardware override.
   - ◊ All disabled points.
   - ◊ All weekly schedules.
   - ◊ All or selected point attributes, including, but not limited to:
     Values

Setpoints
Alarm Limits
Statistics
Run Times

- ◊ All programmed holidays and associated schedules.
- ◊ All disabled alarms.
- ◊ All active, unacknowledged alarms.
- ◊ All active, acknowledged alarms.
- ◊ Any and all other controller operating parameters.

b. Reports shall be provided for specific point types, for each logical point group, for user-defined groups, or for the entire facility without restriction due to the hardware configuration of the control system or communications network.

c. The system shall allow for the creation of custom report point groups that shall be capable of including points from multiple controllers. Systems limiting point report displays to only a single controller's point database shall not be accepted.

d. The number of custom reports or display groups shall be limited by the amount of available system memory.

e. Selection of a single menu item, tool bar item, or tool bar button shall print any displayed report on the system printer for use as a building management and diagnostics tool.

4. Schedules

a. A spreadsheet-type schedule input form for time-of-day scheduling and override scheduling of building operations shall be provided. At a minimum, the following spreadsheet types shall be provided:

- ◊ Weekly schedules, by system.
- ◊ Temporary override schedules, by system.
- ◊ Special "Only Active If Today Is A Holiday" schedules, by system.
- ◊ Monthly calendars.
- ◊ Holiday scheduling system, including the ability to define floating holidays.

b. Weekly schedules shall be provided for each piece of equipment with a specific time use schedule. Each schedule shall include columns for each day of the week, as well as holiday and special day columns for alternate scheduling on user-defined days. Equipment scheduling shall be accomplished by simply inserting use and non-use times into appropriate information blocks on the spreadsheet.

c. It shall be possible to define one or more master holiday schedules to allow the operator to define in one location the holidays for all associated schedules. Systems requiring the

operator to change holiday definitions on a schedule by schedule basis shall not be accepted.

d. Standard weekly schedules shall be inactive on a holiday. The system shall allow the user to include in a schedule group a schedule that will only be active if today is a holiday.
e. In addition, temporary override schedules may be inserted into schedule groups for modifying operating schedules. After overrides have been executed, the original schedule will automatically be restored.
f. Schedules shall be provided for each system or sub-system in the facility. Each schedule shall include all commandable points residing within the system. Each point may have a unique schedule of operation relative to the system use schedule, allowing for sequential starting and control of equipment within the system. Scheduling and rescheduling of points shall be accomplished easily via the system schedule spreadsheets.
g. Monthly calendars for a 12-month period shall be provided that allow for simplified scheduling of holidays and special days in advance. Holidays and special days shall be user-selected with the pointing device or keyboard, and shall automatically reschedule equipment operation as previously defined on the weekly schedules.
h. Changes to schedules made from the Operator Workstation shall directly modify the controller schedule database. Systems that require permanent schedule changes to be made with a program editor shall not be acceptable.
i. Formatted schedule displays shall be provided for each system. These shall include all schedule data and associated parameters.
j. Selection of a single menu item or tool bar button shall print any displayed schedule on the system printer for use as a building management and diagnostics tool.

5. Password
   a. Multiple-level password access protection shall be provided to allow the user/manager to limit workstation control, display, and database manipulation capabilities as he or she deems appropriate for each user, based on an assigned password.
   b. Each user shall have the following: a user name (12 characters minimum); a password (12 characters minimum), and an access level (from 1 - 5).
   c. The system shall allow each user to change his or her password at will.

d. When entering or editing passwords, the system shall not echo the actual characters for display on the monitor.
e. A minimum of five levels of access shall be supported as follows:
   - ◊ Level 1 = Data Access and Display
   - ◊ Level 2 = Level 1 and Operator Overrides
   - ◊ Level 3 = Level 2 and Database Modification
   - ◊ Level 4 = Level 3 and Database Generation
   - ◊ Level 5 = All privileges, including Password Add/Modify
f. A minimum of 100 unique passwords, including user initials, shall be supported.
g. Operators shall be able to perform only those commands available for their respective passwords. Display of menu selections shall be limited to only those items defined for the access level of the password used to log-on.
h. The system shall automatically generate a report of log-on/log-off and system activity for each user. Any action that results in a change in the operation or configuration of the control system shall be recorded, including: modification of point values, schedules or history collection parameters, and all changes to the alarm management system, including the acknowledgment and deletion of alarms.
i. User-definable, automatic log-off timers of from 1 to 60 minutes shall be provided to prevent operators from inadvertently leaving the operator workstation logged on.

6. Screen Manager - The FMS workstation shall be provided with a screen management application that allows the user to activate, close, and simultaneously manipulate a minimum of 16 windows across a minimum of 3 physical screens.

The terminology defined in the table below is for use in the functional description that follows.

Term	Definition
Console	The group of 1 to 3 physical screens that is driven by the one workstation, and manipulated by the single keyboard, and single mouse.
Template	A predefined definition that defines the number of windows that shall be opened, the screen on which the window is located, its geometry, and its properties.
Layout	A screen template in which all of the applications to be launched and application properties (such as which graphic to load) are fully defined.

a. Configuration – The following configuration functions shall be provided:

- ◊ The user shall be able to predefine and name any number of screen layouts. Each screen layout can contain up to a maximum of 16 windows. Each window can launch any supported FMS application.

b. Following are typical examples of templates and layouts that shall be capable of being constructed as described above.
   - ◊ One Click Operation – The operator shall be able to launch any predefined layout by selecting the layout by name.
   - ◊ Operator-created layout – The operator shall be able to create his or her own layout by selecting the appropriate blank template and dragging applications into it. The operator can then save the layout for subsequent use.
   - ◊ History – The system shall automatically maintain a list of the last 8 layouts activated, and the operator shall be able to return to them by scrolling through a list of "last launched" layouts.

c. Within applications the user shall easily be able to navigate to new information (for example, launch a new graphic within a graphic).

7. M-Graphics
   a. The graphics application program shall be supplied as an Active-X control and as an Active-X document server. The document server shall be able to contain other Active-X controls.
   b. The graphics applications shall include a create/edit function and a runtime function. An unlimited number of graphics documents (graphic definition files) shall be able to be generated and executed.
   c. The graphics shall be able to display and provide animation based on real-time data that is acquired, derived, or entered. The data values shall be provided by support of the following variable types:
      - ◊ OPC item – A real-time value acquired from any field controller or device as supported by the installed OPC-compliant communication servers.
      - ◊ Local variable – A variable defined as part of the graphic object, and either calculated during graphic runtime execution or entered by the operator.
      - ◊ A real-time calculation – A calculation whose expression is defined as part of the graphic object. Each expression shall be able to contain constants, local variables, OPC items, or simulation variables.

d. Graphics runtime functions – Up to a maximum of 16 graphic applications shall be able to execute at any one time on a single workstation. Each graphic application shall be capable of the following functions:
   - ◊ All graphics shall be fully scalable to any display geometry.
   - ◊ On a per graphic basis, the user shall be able to configure the graphic to force a maintained aspect ration, or float the aspect ratio.
   - ◊ All Microsoft TrueType fonts shall be supported.
   - ◊ On a per graphic basis, the user shall be able to enable or disable font scaling.
   - ◊ Background color shall be on a per graphic basis, selectable to any available color (64,000 minimum color capability).
   - ◊ Enabling/disabling the shadow color of all objects on the graphic shall be available.
   - ◊ The ability to highlight valid entry object on a graphic shall be available.
   - ◊ The ability to configure the color of all animations and values displays to indicate if the data is no longer valid because of system failure shall be available.
   - ◊ The user shall be able to configure the fastest speed at which data will be updated on the specific graphic.

e. Window setting – The user shall have the ability to determine how the window containing the specific individual graphic application will appear and operate when the graphic is displayed in the runtime mode (for example, scrollbars, buttons, menus).

f. Basic graphical objects – All graphics shall be able to be constructed from the following basic graphical objects:
   - ◊ Single or multi-segment lines of any thickness – Line styles at a minimum shall include: solid, dotted, and dashed.
   - ◊ Rectangles – User may fill with any color or no fill, and may configure the thickness of the outline.
   - ◊ Polygons – User may fill with any color or no fill, and may configure the thickness of the outline.
   - ◊ Arcs.
   - ◊ Circles and Ellipses – User may fill with any color or no fill, and may configure the thickness of the outline.
   - ◊ Text boxes – User may configure text boxes with any W98 TrueType font, any foreground color, any background color, and with 8 or more thickness levels.

g. Animation – Any Basic object , any group of basic objects, or any symbol or group of symbols, shall be capable of being animated with one or multiple of the following animation algorithms:
   - ◊ Fill Color – up to 32 different color states.
   - ◊ Outline Color – up to 32 different color states.
   - ◊ Shadow Color – up to 32 different color states.
   - ◊ Analog Color – Animated on a continuous movement across the color spectrum (64,000 colors).
   - ◊ Size – Any object's size shall be able to be animated based on the value of any of the variable types. The size of the object shall dynamically change based on the current percentage of scale of the variables range. The range shall be adjustable. The size of the object shall be able to be animated based on any combination of the axes of the object (up, down, left, or right).
   - ◊ Location – Any object can be animated to move dynamically over the available window geometry, based on the current percentage of scale of the variables range. The range shall be adjustable. The path the object follows as it moves can be any straight line, or can follow a configured path of any number of line segments.
   - ◊ Rotation – Any object shall be able to be animated to rotate up 360 degrees based on the current percentage of scale of the variables range. The range shall be adjustable. The angle and pivot of the rotation shall be configurable for each rotation.
   - ◊ Visibility – It shall be possible to make any object dynamically appear or disappear based on the true / false result of any boolean equations. These equations can contain any combination of the three variable types.

h. Operation from graphics – It shall be possible to change values (setpoints) and states in system controlled equipment by any of the following methods of operator interaction:
   - ◊ Pick points –Any object shall be configurable as a pick point. In such cases specific actions can be associated with selecting the object with either the left, middle, or right mouse button:
     Load a specific graphic.
     Drag/Drop to load a graphic in a selected window.
     Link forward or backward to another graphic.
     Change or toggle the value of an object.

Launch an executable application.

- ◊ In addition to pick points certain methods of changing setpoints shall be available and other analog values shall be configurable implicitly as part of a graphic:
  Slider action – Any object can be defined to be a slider and configured to change a setpoint or other variables as the user slides an object over a configured geometry.
  Dial action – Any object can be configured so that it can change a configured analog value over a range as the object is rotated. This is most often used to represent dials.
  Data Entry – A variable is displayed on a graphic. By selecting the variable, the data entry function for the value is enabled and the operator is able to enter a new value for the variable.

i. Graphic editing tool – A graphic editing tool shall be provided that allows for the creation and editing of graphic files. The graphic editor shall be capable of performing all drawing functions, defining all calculations to be executed as part of the graphic, defining all animations, and defining all runtime binding. It is not acceptable for separate programs to be required to do these various functions.

- ◊ The graphic editing tool shall in general provide for the creation and positioning of objects by dragging from tool bars and positioning where required. It shall provide the ability to create, at a minimum, all of the object types, all of the animation algorithms, and all of the action types referenced in this section.
- ◊ In addition, the graphic editing tool shall be able to add additional content to any graphic by:
  Importing – The tool shall be able to import any Windows metafile (.wmf) or any bitmap file (.bmp). In addition to importing, the graphic editor shall be able decompose any imported metafile into its components so that specific components can be edited or animated.
  Embedding – Any Active-X controls (.ocx) shall be able to be embedded in any graphic.

j. Basic drawing functions – In addition to the ability to create / edit any of the objects listed above, the following basic drawing manipulation functions shall be provided as a minimum:

- ◊ Group
- ◊ Ungroup
- ◊ Move object to back

- ◊ Move object to front
- ◊ Free rotate object
- ◊ Align objects
- ◊ Space object
- ◊ Copy
- ◊ Paste
- ◊ Duplicate

k. Symbol library – The FMS system shall be provided with a very complete symbol library containing all of the basic symbols used to represent HVAC, FIRE, and SECURITY components of a typical FMS system.

- ◊ Symbols shall be able to be added to any graphic display being constructed by simply dragging the symbol from the library to the graphic under construction.

l. Creating symbols – The user shall be able to add any number of new symbols to the symbol library. Symbol generation shall include all of the abilities described for the graphic editor.

- ◊ Any drawing—including all objects contained therein, and all animation definitions, and all action definitions—shall be able to be grouped and saved into the symbol library for re-use in graphic displays. Symbols shall be able to include implicit bindings or aliased bindings, as described in the following section.

m. It shall be easy to maintain and expand the graphics displays initially provided with the system. The following tools shall be provided as a means to decrease the engineering labor required to engineer and maintain the graphics subsystem.

- ◊ Aliasing – Many graphic displays representing part of a building and various building components are exact duplicates, with the exception that the various variables are bound to different field values. Consequently, it shall be possible to bind the value of a graphic display to aliases, as opposed to the physical field tags. The same graphic display can then be used an unlimited number of times by simply providing a look-up table for the aliases that correspond to each individual use of the graphic.
- ◊ Graphic Find/Replace Functions – The graphic displays shall include binding definitions to a large number of field points. It must be easy to find and replace all occurrences of a point definition to accommodate any future changes the owner or his agents may wish to make to the system configuration.

Consequently a tool shall be provided that automatically searches all objects and all definitions contained within a graphic display or an entire directory of graphic displays, and either lists the occurrences or automatically replaces the string with a specified string.

8. Historical trending and data collection
   a. Each Network Controller shall store trend and point history data for all analog and digital inputs and outputs, as follows:
      ◊ Any point, physical or calculated, may be designated for trending. Three methods of collection shall be allowed:
      Defined time interval.
      Upon a change of value.
      Whenever a value is out of range.
      ◊ Each network controller shall have a dedicated RAM-based buffer for trend data, and shall store 96 samples for each physical point and software variable, including an individual sample time/date stamp. Points may be assigned to multiple history trends with different collection parameters.
   b. Trend and change of value data shall be stored within the controller and then uploaded to the trend database(s). Uploads shall occur based upon one of the following: user-defined interval, manual command, or when the trend buffers are full.
   c. The system shall provide a configurable data storage subsystem for the collection of historical data. Data can be stored in either Microsoft Access or SQL database format.
   d. To enable users to easily access stored data, the system shall provide the capability to store historical data in more than one file system (i.e., removable media, separate hard drives, or a remote network file system).
   e. Provide the capability to perform statistical functions on the historical database without having to design special queries. On a specified data interval, provide functions for calculating:
      ◊ Average.
      ◊ Arithmetic mean.
      ◊ Maximum/minimum values.
      ◊ Range – difference between minimum and maximum values.
      ◊ Standard deviation.
      ◊ Sum of all values.

- ◊ Variance.

9. Trend data viewing and analysis
   a. Provide a trend viewing utility that shall have access to all database points.
   b. Provide database access through an Open Database Connectivity (ODBC) interface – a standard Application Programming Interface (API) for accessing data from relational databases. Client applications can reside within a Windows 95, Windows 98, or Windows NT environment.
   c. It shall be possible to retrieve any historical database point for use in displays and reports by specifying the point name.
   d. The trend viewing utility shall have the capability to view up to 32 data sources at one time in a tabular or graphical format.
   e. Graphic displays shall be able to be single or stacked graphs with on-line selectable display characteristics, such as ranging, color, and plot style.
   f. It shall be possible to display trend data in histogram (X-Y plots) format as well as area and bar graphs.
   g. Display magnitude and units shall both be selectable by the operator at any time without reconfiguring the processing or collection of data. This is a zoom capability.
   h. Display magnitude shall automatically be scaled to show full graphic resolution of the data being displayed. This function shall also be operator selectable.
   i. The display range shall consist of magnitude and units fields. The units are seconds, minutes, hours, days, and months.
   j. Provide a wild card capability when specifying a display range for data retrieval within the historical database. Wild carding will allow the user to easily specify relative time based date ranges for the retrieval of data. The following wild cards will be used:
      - ◊ NOW - This keyword specifies the current date/time. The value is set at the exact time the database request is made.
      - ◊ TODAY - This keyword specifies the current date.
      - ◊ D - This keyword indicates a specific number of days. Example: TODAY-8D
      - ◊ H - This keyword indicates a specific number of hours. Example: NOW-3H
      - ◊ M - This keyword indicates a specific number of minutes. Example: NOW-5H30M
      - ◊ 12/12/97 12:00:00 PM - This keyword indicates a specific date/time.

- ◊ 12/12/97 23:00:00 - This keyword indicates a specific date/time.

k. A time offset capability shall be available to assist in a user's analysis. The offset visually shifts the data being displayed to allow a user to concurrently view information without having to scroll the display.

l. The system shall be capable of printing a hard copy record of the trends as they are displayed on the workstation.

2.3 Network Controllers

A. Network Controller

1. The Network Controller shall be a fully user-programmable, supervisory controller. The Network Controller shall monitor the network of distributed application-specific controllers, provide global strategy and direction, and communicate on a peer-to-peer basis with other Network Controllers.

2. First Tier Network – The Network Controller (NC) shall reside on the first tier network. Each NC shall support a sub-network of a minimum of 100 controllers on the second tier network.

3. Open Systems Port – Each controller shall have the ability to connect to third-party control systems by way of an Open Systems Port, as specified or as shown on the design drawings. All programming required to implement the OSP shall reside solely within the controller and the associated device.

4. Processor – Controllers shall be microprocessor-based with a minimum word size of 16 bits and a maximum program scan rate of 1 second. They shall be multi-tasking, multi-user, and real-time digital control processors. Controller size and capability shall be sufficient to fully meet the requirements of this Specification.

5. Memory – Each controller shall have sufficient memory to support its own operating system, databases, and control programs, and to provide supervisory control for all second tier controllers.

6. Hardware Real Time Clock – The controller shall have an integrated, hardware-based, real-time clock.

7. Communications Ports – The NC shall provide at least two RS-232 serial data communication ports for operation of operator I/O devices, such as industry-standard printers, operator terminals, modems, and portable operator's terminals. Controllers shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers, or terminals.

8. Diagnostics – Controller shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The network controller shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failures to establish communication.

9. Power Failure – In the event of the loss of normal power, there shall be an orderly shutdown of all controllers to prevent the loss of database or operating system software. Nonvolatile memory shall be incorporated for all critical controller configuration data, and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.
   a. During a loss of normal power, the control sequences shall go to the normal system shutdown conditions.
   b. Upon restoration of normal power and after a minimum off-time delay, the controller shall automatically resume full operation without manual intervention through a normal soft-start sequence.
   c. Should a controller memory be lost for any reason, the operator workstation shall automatically reload the program without any intervention by the system operators.

10. Certification – All controllers shall be listed by Underwriters Laboratories (UL).

2.4 Application Specific Controllers

A. Expanded Digital Controller (DX-9100)

1. Each DX-9100 shall operate as a standalone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each DX-9100 shall be a microprocessor-based, multi-tasking, real-time digital control processor.

2. DX-9100 controllers shall support, but not be limited to, the following configurations of systems to address current requirements described in the “Execution” portion of this Specification, and to address future expansion.
   a. Air Handling Units.
   b. Single boiler or chiller plants with pump logic.
   c. Cooling towers.
   d. Zone pressurization of labs.
   e. Generic system interlocking through hardware.

3. Point types – Each DX-9100 shall support the following types of point inputs and outputs:

a. Analog inputs shall monitor the following analog signals:
   - ◊ 4-20 mA Sensors
   - ◊ 0-10 VDC Sensors
   - ◊ 1000ohm RTDs

b. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input "bouncing."

c. Counter inputs shall monitor dry contact pulses with an input resolution of one HZ minimum.

d. Analog outputs shall provide the following control outputs:
   - ◊ 4.20 mA – Sink or Source
   - ◊ 0-10 VDC

e. Binary outputs shall provide SPDT output contacts rated for 2 amps at 24 VAC.

f. TriState outputs shall be paired binary outputs for use as Power Close/Power Open control output contacts rated for 2 amps at 24 VAC.

g. Pneumatic outputs shall provide a 3-15 PSI pneumatic output.

4. DX-9100 controllers shall have a built-in status, and adjust panel interface to allow for the local adjustment of all setpoints, temporary override of any input or output points, and status of any points in alarm.

5. Powerfail Protection – All system setpoints, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the DX-9100.

6. The capability to extend the input and output capacity of the DX-9100 via Point Expansion Modules shall be provided.

   a. The Point Expansion Modules shall communicate to the DX-9100 controller over a local RS-485 expansion bus.

   b. The Point Expansion Modules shall have available a range of configurations of 4, 8, 12, or 16 data points:
      - ◊ Analog Inputs – 0-10V, 4-20mA, 1000 ohm RTD
      - ◊ Analog Outputs – 0-10V, 4-20mA
      - ◊ Digital Inputs w/ digital counter
      - ◊ Digital Outputs – triacs or relay contacts

   c. Expansion module data points shall be available for inclusion in all DX-9100 control strategies.

B. Unitary Controllers (UNT)

1. Each Unitary Controller shall operate as a standalone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each Unitary

Controller shall be a microprocessor-based, multi-tasking, real-time digital control processor.

2. Unitary Controllers shall support, but not be limited to, the following types of systems to address specific applications described in the “Execution” portion of this Specification, and to address future expansion:
   a. Unit Vents (ASHRAE Cycle, I, II, III, or W).
   b. Heat Pumps (Air-to-Air, Water-to-Air).
   c. Packaged Rooftops.
   d. Fan Coils (Two-Pipe, Four-Pipe).
3. Point types – Each Unitary Controller shall support the following types of point inputs and outputs:
   a. Analog inputs shall monitor the following analog signals:
      ◊ 0-10 VDC Sensors
      ◊ 1000ohm RTDs
   b. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input “bouncing.”
   c. Counter inputs shall monitor dry contact pulses with an input resolution of one HZ minimum.
   d. Analog outputs shall provide the following control outputs:
      ◊ 0-10 VDC
   e. Binary outputs shall provide SPDT output contacts rated for 2 amps at 24 VAC.
   f. TriState outputs shall be paired binary outputs for use as Power Close/Power Open control output contacts rated for 2 amps at 24 VAC.
   g. Pneumatic outputs shall provide a 3-15 PSI pneumatic output.
4. Unitary Controllers shall have a library of control routines and program logic to perform the sequence of operations specified in the “Execution” portion of this Specification.
5. Unitary Controllers shall directly support the temporary use of a portable service terminal that can be connected to the UNT via zone temperature or directly at the controller.
6. Powerfail Protection – All system setpoints, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the UNT.

C. VAV Terminal Unit Controller (VMA)

1. The VMA shall provide both standalone and networked direct digital control of pressure-independent, variable air volume terminal units.

2. The VMA shall be a configurable digital controller with integral differential pressure transducer and damper actuator. All components shall be connected and mounted as a single assembly that can be removed as one piece.

3. The integral damper actuator shall be a fast response stepper motor capable of stroking 90 degrees in 30 seconds for quick damper positioning to speed commissioning and troubleshooting tasks.

4. The VMA shall be a configurable digital controller with an integral differential pressure transducer. It shall be compatible with 3 wire (incremental) and proportional damper actuators.

5. The VMA shall determine airflow by dynamic pressure measurement using an integral dead-ended differential pressure transducer. The transducer shall be maintenance-free and shall not require air filters.

6. Each VMA shall have the ability to automatically calibrate the flow sensor to eliminate pressure transducer offset error due to ambient temperature / humidity effects.

7. The VMA shall utilize a proportional plus integration (PI) algorithm for the space temperature control loops.

8. Each VMA shall continuously, adaptively tune the control algorithms to improve control and controller reliability through reduced actuator duty cycle. In addition, this tuning reduces commissioning costs, and eliminates the maintenance costs of manually re-tuning loops to compensate for seasonal or other load changes.

9. The VMA shall provide the ability to download and upload VMA configuration files, both locally and via the communications network. Controllers shall be able to be loaded individually or as a group using a zone schedule generated spreadsheet of controller parameters.

10. VMA control setpoint changes initiated over the network shall be written to VMA non-volatile memory to prevent loss of setpoint changes and to provide consistent operation in the event of communication failure.

11. The VMA firmware shall be flash-upgradeable remotely via the communications bus to minimize costs of feature enhancements.

12. The VMA shall provide fail-soft operation if the airflow signal becomes unreliable, by automatically reverting to a pressure-dependent control mode.

13. The VMA shall interface with balancer tools that allow automatic recalculation of box flow pickup gain (“K” factor), and the ability to directly command the airflow control loop to the box minimum and maximum airflow setpoints.

14. The VMA shall be capable of direct electronic connection to the Alnor DB150 Balometer balancing hood. Connection shall be through a port located on the room sensor, or directly at the controller. As an alternative, software balancing tools shall be provided that will run in a hand-held Palm Pilot type PC (such as the 3COM Palm Pilot or IBM Workpad). The balancing tools shall allow adjustment of airflow setpoints and parameters, and provide permanent upload of the values entered to the VMA. The Palm Pilot shall connect to the terminal unit through the room sensor port.

15. The VMA performance shall be self-documenting via on-board diagnostics. These diagnostics shall consist of control loop performance measurements executing at each control loop’s sample interval, which may be used to continuously monitor and document system performance. The VMA shall calculate exponentially weighted moving averages (EWMA) for each of the following. These metrics shall be available to the end user for efficient management of the VAV terminals.
    - ◊ Absolute temperature loop error.
    - ◊ Signed temperature loop error.
    - ◊ Absolute airflow loop error.
    - ◊ Signed airflow loop error.
    - ◊ Average damper actuator duty cycle.

16. The VMA shall detect system error conditions to assist in managing the VAV zones. The error conditions shall consist of:
    - ◊ Unreliable space temperature sensor.
    - ◊ Unreliable differential pressure sensor.
    - ◊ Starved box.
    - ◊ Insufficient cooling.
    - ◊ Insufficient heating.

17. The VMA shall provide a compliant interface for ASHRAE Standard 62-1989 (indoor air quality), and shall be capable of resetting the box minimum airflow based on the percent of outdoor air in the primary air stream.

18. The VMA shall comply with ASHRAE Standard 90.1 (energy efficiency) by preventing simultaneous heating and cooling, and where the control strategy requires reset of airflow while in reheat, by modulating the box reheat device fully open prior to increasing the airflow in the heating sequence.

19. The VMA shall be compatible with the U.S. EPA Energy Star Buildings recommendations for fan energy reduction via demand-based static pressure reset down to 2/3 of duct static pressure set point, “VSD 2/3 Reset.”

20. Inputs:
    a. Analog inputs shall monitor the following analog signals, without the addition of equipment outside the terminal controller cabinet:
        ◊ 0-10 VDC Sensors
        ◊ 1000ohm RTDs
        ◊ NTC Thermistors
    b. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input “bouncing.”
    c. For noise immunity, the inputs shall be internally isolated from power, communications, and output circuits.

21. Outputs
    a. Analog outputs shall provide the following control outputs:
        ◊ 0-10 VDC
    b. Binary outputs shall provide a SPST Triac output rated for 500mA at 24 VAC.
    c. For noise immunity, the outputs shall be internally isolated from power, communications, and other output circuits.

2.5 HVAC Input Devices

A. General Requirements

1. Installation, testing, and calibration of all sensors, transmitters, and other input devices shall be provided to meet the system requirements.

B. Temperature Sensors

1. General Requirements:
    a. Sensors and transmitters shall be provided, as outlined in the input/output summary and sequence of operations.
    b. The temperature sensor shall be of the resistance type, and shall be either two-wire 1000 ohm nickel RTD, or two-wire 1000 ohm platinum RTD.

c. The following point types (and the accuracy of each) are required, and their associated accuracy values include errors associated with the sensor, lead wire, and A to D conversion:

Point Type	Accuracy
Chilled Water	± .5°F.
Room Temp	± .5°F.
Duct Temperature	± .5°F.
All Others	± .75°F.

2. Room Temperature Sensors
   a. Room sensors shall be constructed for either surface or wallbox mounting.
   b. The temperature sensor shall be of the resistance type, and shall be either two-wire 1000 ohm nickel RTD, or two-wire 1000 ohm platinum RTD.
   c. Room sensors shall have an integral pushbutton to allow restoration of occupied mode.
   d. Room sensors shall be available with integral setpoint adjustment slider.
   e. Room sensors shall have integral jack for field connection of portable operator device.
   f. Room sensors shall be available with either terminal block wiring connections or with modular 8-pin jack for utilization of pre-configured wiring cables.
3. Thermowells
   a. When thermowells are required, the sensor and well shall be supplied as a complete assembly, including well head and Greenfield fitting.
   b. Thermowells shall be pressure rated and constructed in accordance with the system working pressure.
   c. Thermowells and sensors shall be mounted in a threadolet or 1/2” NFT saddle and allow easy access to the sensor for repair or replacement.
   d. Thermowells shall be constructed of brass.
4. Outside Air Sensors
   a. Outside air sensors shall be designed to withstand the environmental conditions to which they will be exposed. They shall also be provided with a solar shield.
   b. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate that surrounds the sensor element.
   c. Temperature transmitters shall be of NEMA 3R construction and rated for ambient temperatures.

5. Duct Mount Sensors
    a. Duct mount sensors shall mount in an electrical box through a hole in the duct, and be positioned so as to be easily accessible for repair or replacement.
    b. Duct sensors shall be insertion type and constructed as a complete assembly, including lock nut and mounting plate.
    c. For outdoor air duct applications, a weatherproof mounting box with weatherproof cover and gasket shall be used.
6. Averaging Sensors
    a. For ductwork greater in any dimension that 48 inches and/or where air temperature stratification exists, an averaging sensor with multiple sensing points shall be used.
    b. For plenum applications, such as mixed air temperature measurements, a string of sensors mounted across the plenum shall be used to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12-foot long segment.
    c. Capillary supports at the sides of the duct shall be provided to support the sensing string.

C. Humidity Sensors

1. The sensor shall be a solid state type, relative humidity sensor of the Bulk Polymer Design. The sensor element shall resist service contamination.
2. The humidity transmitter shall be equipped with non-interactive span and zero adjustments, a 2-wire isolated loop powered, 4-20 mA, 0-100% linear proportional output.
3. The humidity transmitter shall meet the following overall accuracy, including lead loss and Analog to Digital conversion. [more information]
4. Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA 3R enclosure with sealtite fittings and stainless steel bushings.
5. A single point humidity calibrator shall be provided, if required, for field calibration. Transmitters shall be shipped factory pre-calibrated.
6. Duct type sensing probes shall be constructed of 304 stainless steel, and shall be equipped with a neoprene grommet, bushings, and a mounting bracket.
7. Acceptable Manufacturers: Johnson Controls, General Eastern, Veris Industries, Mamac.

D. Differential Pressure Transmitters

1. General Air and Water Pressure Transmitter Requirements:
   a. Pressure transmitters shall be constructed to withstand 100% pressure over-range without damage, and to hold calibrated accuracy when subject to a momentary 40% over-range input.
   b. Pressure transmitters shall transmit a 0 to 5 VDC, 0 to 10 VDC, or 4 to 20 mA output signal.
   c. Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device, and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing Contractor and Owner permanent, easy-to-use connection.
   d. A minimum of a NEMA 1 housing shall be provided for the transmitter. Transmitters shall be located in accessible local control panels wherever possible.
2. Low Differential Water Pressure Applications (0” - 20” w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of flow meter differential pressure or water pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      ◊ .01-20” w.c. input differential pressure range.
      ◊ 4-20 mA output.
      ◊ Maintain accuracy up to 20 to 1 ratio turndown.
      ◊ Reference Accuracy: +0.2% of full span.
   c. Acceptable Manufacturers: Setra and Mamac.
3. Medium to High Differential Water Pressure Applications (Over 21” w.c.)
   a. The differential pressure transmitter shall meet the low pressure transmitter specifications with the following exceptions:
      ◊ Differential pressure range 10” w.c. to 300 PSI.
      ◊ Reference Accuracy: $\pm$1% of full span (includes non-linearity, hysteresis, and repeatability).
   b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.

c. Acceptable Manufacturers: Setra and Mamac.

4. Building Differential Air Pressure Applications (-1" to +1" w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      ◊ -1.00 to +1.00 w.c. input differential pressure ranges. (Select range appropriate for system application)
      ◊ 4-20 mA output.
      ◊ Maintain accuracy up to 20 to 1 ratio turndown.
      ◊ Reference Accuracy: +0.2% of full span.
   c. Acceptable Manufacturers: Johnson Controls and Setra.
5. Low Differential Air Pressure Applications (0" to 5" w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      ◊ (0.00 - 1.00" to 5.00") w.c. input differential pressure ranges. (Select range appropriate for system application.)
      ◊ 4-20 mA output.
      ◊ Maintain accuracy up to 20 to 1 ratio turndown.
      ◊ Reference Accuracy: +0.2% of full span.
   c. Acceptable Manufacturers: Johnson Controls and Setra.
6. Medium Differential Air Pressure Applications (5" to 21" w.c.)
   a. The pressure transmitter shall be similar to the Low Air Pressure Transmitter, except that the performance specifications are not as severe. Differential pressure transmitters shall be provided that meet the following performance requirements:
      ◊ Zero & span: (c/o F.S./Deg. F): .04% including linearity, hysteresis and repeatability.
      ◊ Accuracy: 1% F.S. (best straight line) Static Pressure Effect: 0.5% F.S. (to 100 PSIG.
      ◊ Thermal Effects: <+.033 F.S./Deg. F. over 40°F. to 100°F. (calibrated at 70°F.).

b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.
c. Acceptable manufacturers: Johnson Controls and Setra.
d. Static Pressure Traverse Probe
   - ◊ Duct static probes shall be provided where required to monitor duct static pressure.
   - ◊ Acceptable manufacturers: Dwyer A301

E. Power Monitoring Devices

1. Current Measurement (Amps)
   a. Current measurement shall be by a combination current transformer and a current transducer. The current transformer shall be sized to reduce the full amperage of the monitored circuit to a maximum 5 Amp signal, which will be converted to a 4-20 mA DDC compatible signal for use by the Facility Management System.
   b. Current Transformer – A split core current transformer shall be provided to monitor motor amps.
      - ◊ Operating frequency – 50 - 400 Hz.
      - ◊ Insulation – 0.6 Kv class 10Kv BIL.
      - ◊ UL recognized.
      - ◊ Five amp secondary.
      - ◊ Select current ration as appropriate for application.
      - ◊ Acceptable manufacturers: Veris Industries, Neilsen-Kuljian
   c. Current Transducer – A current to voltage or current to mA transducer shall be provided. The current transducer shall include:
      - ◊ 6X input over amp rating for AC inrushes of up to 120 amps.
      - ◊ Manufactured to UL 1244.
      - ◊ Accuracy: +.5%, Ripple +1%.
      - ◊ Minimum load resistance 30kOhm.
      - ◊ Input 0-20 Amps.
      - ◊ Output 4-20 mA.
      - ◊ Transducer shall be powered by a 24VDC regulated power supply (24 VDC +5%).
      - ◊ Acceptable manufacturers: Veris Industries, Neilsen-Kuljian

F. Status and Safety Switches

1. General Requirements
   a. Switches shall be provided to monitor equipment status, safety conditions, and generate alarms at the FMS when a failure or abnormal condition occurs. Safety switches shall be provided with two sets of contacts and shall be interlock wired to shut down respective equipment.
2. Current Sensing Switches
   a. The current sensing switch shall be self-powered with solid state circuitry and a dry contact output. It shall consist of a current transformer, a solid state current sensing circuit, adjustable trip point, solid state switch, SPDT relay, and an LED indicating the on or off status. A conductor of the load shall be passed through the window of the device. It shall accept over-current up to twice its trip point range.
   b. Current sensing switches shall be used for run status for fans, pumps, and other miscellaneous motor loads.
   c. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.
   d. Acceptable manufacturers: Veris Industries, Neilsen-Kuljian
3. Air Filter Status Switches
   a. Differential pressure switches used to monitor air filter status shall be of the automatic reset type with SPDT contacts rated for 2 amps at 120VAC.
   b. A complete installation kit shall be provided, including: static pressure tops, tubing, fittings, and air filters.
   c. Provide appropriate scale range and differential adjustment for intended service.
   d. Acceptable manufacturers: Johnson Controls, Cleveland Controls
4. Air Flow Switches
   a. Differential pressure flow switches shall be bellows actuated mercury switches or snap acting micro-switches with appropriate scale range and differential adjustment for intended service.
   b. Acceptable manufacturers: Johnson Controls, Cleveland Controls
5. Air Pressure Safety Switches
   a. Air pressure safety switches shall be of the manual reset type with SPDT contacts rated for 2 amps at 120VAC.

b. Pressure range shall be adjustable with appropriate scale range and differential adjustment for intended service.
c. Acceptable manufacturers: Johnson Controls, Cleveland Controls, Dwyer

6. Water Flow Switches
   a. Water flow switches shall be equal to the Johnson Controls P74.

7. Low Temperature Limit Switches
   a. The low temperature limit switch shall be of the manual reset type with Double Pole/Single Throw snap acting contacts rated for 16 amps at 120VAC.
   b. The sensing element shall be a minimum of 15 feet in length and shall react to the coldest 18-inch section. Element shall be mounted horizontally across duct in accordance with manufacturers recommended installation procedures.
   c. For large duct areas where the sensing element does not provide full coverage of the air stream, additional switches shall be provided as required to provide full protection of the air stream.
   d. The low temperature limit switch shall be equal to Johnson Controls A70.

2.6 HVAC Output Devices

A. Actuators

1. General Requirements
   a. Damper and valve actuators shall be electronic.

2. Electronic Damper Actuators
   a. Electronic damper actuators shall be direct shaft mount.
   b. Modulating and two-position actuators shall be provided as required by the sequence of operations. Damper sections shall be sized based on actuator manufacturer's recommendations for face velocity, differential pressure and damper type. The actuator mounting arrangement and spring return feature shall permit normally open or normally closed positions of the dampers, as required. Actuators being utilized for applications requiring failsafe operation shall be furnished with mechanical spring return. All actuators shall have external adjustable stops to limit the travel in either direction, and a gear release to allow manual positioning.
   c. Modulating actuators shall accept 24 VAC or VDC power supply, consume no more than 15 VA, and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA, and the

actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal and may be used to parallel other actuators and provide true position indication.

d. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Isolation, smoke, exhaust fan, and other dampers, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop associated fan.

e. Acceptable manufacturers: Johnson Controls, Belimo

3. Electronic Valve Actuators

a. Electronic valve actuators shall be manufactured by the valve manufacturer.

b. Each actuator shall have current limiting circuitry incorporated in its design to prevent damage to the actuator.

c. Modulating and two-position actuators shall be provided as required by the sequence of operations. Actuators shall provide the minimum torque required for proper valve close-off against the system pressure for the required application. The valve actuator shall be sized based on valve manufacturer's recommendations for flow and pressure differential. Actuators shall fail in the last position unless utilized in an application requiring failsafe operation. If failsafe operation is required, actuators shall be provided with mechanical spring return to permit normally open or normally closed positions of the valves, as required. All direct shaft mount rotational actuators shall have external adjustable stops to limit the travel in either direction.

d. Modulating Actuators shall accept 24 VAC or VDC and 120 VAC power supply and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal, and may be used to parallel other actuators and provide true position indication.

e. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Butterfly isolation and other valves, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop the associated pump or chiller.

B. Control Dampers

1. The FMS Contractor shall furnish all automatic dampers. All automatic dampers shall be sized for the application by the FMS Contractor or as specifically indicated on the Drawings.

2. All dampers used for throttling airflow shall be of the opposed blade type arranged for normally open or normally closed operation, as required. The damper is to be sized so that, when wide open, the pressure drop is a sufficient amount of its close-off pressure drop to shift the characteristic curve to near linear.

3. All dampers used for two-position, open/close control shall be parallel blade type arranged for normally open or closed operation, as required.

4. Damper frames and blades shall be constructed of either galvanized steel or aluminum. Maximum blade length in any section shall be 48". Damper blades shall not exceed six (6) inches in width. Damper frames shall be 16-gauge minimum hat channel type with corner bracing. Additional stiffening or bracing shall be provided for any section exceeding 48" in height. All damper bearings shall be made of acetal, stainless steel or oil-impregnated bronze. Dampers shall be tight closing, low leakage type, with synthetic elastomer seals on the blade edges and flexible stainless steel side seals. Dampers of 48"x48" size shall not leak in excess of 20 cfm per square foot when closed against 4" w.g. static pressure when tested in accordance with AMCA Std. 500.

5. Blades shall be either double-piece galvanized steel (mechanically joined) or 1/16" extruded aluminum in an airfoil blade. Acceptable manufacturers are Johnson Controls D-1300, Ruskin CD50, and Vent Products 5650.

6. One piece rolled blade dampers with exposed or concealed linkage may be used with face velocities of 1500 FPM or below.

7. Acceptable manufacturers are: Johnson Controls D-1100, Ruskin CD36, and Vent Products 5800.

C. Control Relays

1. Control Pilot Relays
   a. Control pilot relays shall be of a modular plug-in design with retaining springs or clips.
   b. Mounting bases shall be snap-mount.
   c. DPDT, 3PDT, or 4PDT relays shall be provided, as appropriate for application.
   d. Contacts shall be rated for 10 amps at 120VAC.

e. Relays shall have an integral indicator light and check button.
f. Acceptable manufacturers: Johnson Controls, Lectro, Functional Devices, Omron, Idec

D. Control Valves

1. All automatic control valves shall be fully proportioning and provide near linear heat transfer control. The valves shall be quiet in operation and fail-safe open, closed, or in their last position. All valves shall operate in sequence with another valve when required by the sequence of operations. All control valves shall be sized by the control manufacturer, and shall be guaranteed to meet the heating and cooling loads, as specified. All control valves shall be suitable for the system flow conditions and close against the differential pressures involved. Body pressure rating and connection type (sweat, screwed, or flanged) shall conform to the pipe schedule elsewhere in this Specification.

2. Chilled water control valves shall be modulating plug, ball, and/or butterfly, as required by the specific application. Modulating water valves shall be sized per manufacturer's recommendations for the given application. In general, valves shall be sized for a pressure drop of no more than a 5 PSI.

3. Modulating plug water valves of the single-seat type with equal percentage flow characteristics shall be used for all hot and chilled water applications, except those described hereinafter. The valve discs shall be composition type. Valve stems shall be stainless steel.

4. Ball valves shall be acceptable for water terminal reheat coils, radiant panels, unit heaters, package air conditioning units, and fan coil units.

5. Butterfly valves shall be acceptable for modulating large flow applications greater than modulating plug valves, and for all two-position, open/close applications. In-line and/or three-way butterfly valves shall be heavy-duty pattern with a body rating comparable to the pipe rating, replaceable lining suitable for temperature of system, and a stainless steel vane. Valves for modulating service shall be sized and travel limited to 50 degrees of full open. Valves for isolation service shall be the same as the pipe. Valves in the closed position shall be bubble-tight.

2.7 HVAC Miscellaneous Devices

A. Local Control Panels

1. All control panels shall be factory constructed, incorporating the FMS manufacturer's standard designs and layouts. All control panels shall be UL inspected and listed as an assembly and carry a UL 508 label listing compliance. Control panels shall be fully enclosed, with sub-panel, hinged door, and key-locking latch.

2. In general, the control panels shall consist of the DDC controller(s) and I/O devices—such as relays, transducers, and so forth—that are not required to be located external to the control panel due to function.

3. All I/O connections on the DDC controller shall be extended to a numbered, color-coded, and labeled terminal strip for ease of maintenance and expansion. Wiring to I/O devices shall be made from this terminal strip.

4. All other wiring in the panel, internal and external, shall be made to additional line or low voltage color-coded and labeled terminal strips. Low and line voltage wiring shall be segregated. All terminal strips and wiring shall be UL listed, 300-volt service and provide adequate clearance for field wiring.

5. All wiring for every control panel shall follow a common color-coded format. All terminal strip color coding and numbering shall follow a common format. All wiring shall be neatly installed in plastic trays or tie-wrapped.

6. A convenience 120 VAC duplex receptacle shall be provided in each enclosure, fused on/off power switch, and required transformers.

B. Power Supplies

1. DC power supplies shall be sized for the connected device load. Total rated load shall not exceed 75% of the rated capacity of the power supply.

2. Input: 120 VAC +10%, 60Hz.

3. Output: 24 VDC.

4. Line Regulation: +0.05% for 10% line change.

5. Load Regulation: +0.05% for 50% load change.

6. Ripple and Noise: 1 mV rms, 5 mV peak to peak.

7. An appropriately sized fuse and fuse block shall be provided and located next to the power supply.

8. A power disconnect switch shall be provided next to the power supply.

C. Thermostats

1. Electric room thermostats of the heavy-duty type shall be provided for unit heaters, cabinet unit heaters, and ventilation fans, where required. All these items shall be provided with concealed adjustment. Finish of covers for all room-type instruments shall match and, unless otherwise indicated or specified, covers shall be manufacturer's standard finish.

3. Part 3 – Performance / Execution

3.1 Installation Practices

A. Control System Wiring

1. All conduit, wiring, accessories and wiring connections required for the installation of the Facility Management System, as herein specified, shall be provided by the FMS Contractor unless specifically shown on the Electrical Drawings under Division 16 Electrical. All wiring shall comply with the requirements of applicable portions of Division 16 and all local and national electric codes, unless specified otherwise in this section.

2. All system input wiring shall be twisted shielded pair, minimum 18 gauge wire. All system analog output wiring shall be twisted shielded pair/3-wire as required, minimum 18 gauge wire. Preconfigured cables between Terminal Unit Controllers and Thermostats are acceptable, minimum 24 gauge.

3. All internal panel device wiring for binary outputs and pilot relay shall be minimum 18 gauge wire.

4. All Class 2 (24VAC or less) wiring shall be installed plenum rated cable (where concealed) or in EMT conduit (where exposed).
   a. Class 2 wiring not installed in conduit shall be supported every 5' from the building structure utilizing metal hangers designed for this application. Wiring shall be installed parallel to the building structural lines. All wiring shall be installed in accordance with local code requirements.

Exposed wiring shall only be allowed in concealed accessible locations.

5. Low voltage control wiring and 24VAC can be run in the same conduit. Power wiring 120VAC and greater must be in a separate conduit.

6. All wiring in mechanical rooms shall be in EMT conduit. Minimum control wiring conduit size 3/4".

7. All wiring in interstitial spaces shall be in plenum rated cable.

B. DDC System Multi-conductor Instrumentation and Communication Cabling

1. Analog Input, Analog Output, Binary Input, Binary Output, 24 VAC and General Purpose Cabling
   a. Cable shall consist of copper conductors not less No. 18 AWG-stranded.
   b. Shall be 2 or 3 conductor twisted cable with a drain wire
   c. Cable shall have a 100% overall shield.
   d. Cable shall be a plenum-rated.
   e. Cable shall meet or exceed NEC voltage rating of 300V.
   f. Cable shall be NEC type CMP.
   g. Cable shall meet or exceed UL temperature rating of +60 degrees C.

2. Primary and Secondary Communications Network Cabling
   a. Cable shall be of type recommend by the DDC System Manufacturer.
   b. Cable shall be shielded.
   c. Cable shall be a plenum-rated.
   d. Cable shall meet or exceed NEC voltage rating of 150V.
   e. Cable shall meet or exceed UL temperature rating of +60 degrees C.
   f. Cable shall be labeled at a minimum of every 18" with the DDC System manufacturer's name, system name and the communications network name.
   g. Each of the cable types shall be of a different color coding for easy identification and trouble shooting and shall be of a different color than the cable specified in Item A above.

3. Room Sensor Cabling
   a. Cable shall consist of copper conductors not less No. 24 AWG.
   b. Shall be multi-paired (at least two pairs) twisted cable.
   c. Cable shall have a 100% overall shield.
   d. Cable shall be a plenum-rated.
   e. Cable shall meet or exceed NEC voltage rating of 300V.

f. Cable shall be NEC type Article 800-CMP.
g. Cable shall meet or exceed UL temperature rating of +75 degrees C.

C. Digital Controller Systems

1. Each system will be provided with its own dedicated direct digital controller or application specific controller. Mechanical systems such as AHUs, VAVs or Packaged system shall not be controlled from more than 1 application specific controller.

2. Systems that use second tier controllers as point expansion for system controllers shall only be allowed under when the I/O points are directly controlled by the CPU of the local application specific controller.

D. Input Devices

1. All Input devices shall be installed per the manufacturers recommendation. The mechanical contractor shall install all in-line devices such as temperature wells, pressure taps, duct smoke detectors, air flow stations, etc.
   a. Low Differential Air Pressure Applications (Under 5” w.c.) Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing contractor and Owner permanent easy-to-use connection. Provide a minimum of a NEMA 1 housing for the transmitter.
   b. Medium Differential Air Pressure Applications (5” to 21” w.c.) Mount stand-alone pressure transmitters in a bypass valve assembly panel The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with hi and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.
   c. Medium to High Differential Water Pressure Applications (Over 21” w.c.): Mount stand-alone pressure transmitters in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with hi and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.
   d. Building Differential Air Pressure Applications (-1” to +1” w.c.): Transmitters exterior sensing tip shall be installed with a shielded static air probe to reduce pressure fluctuations caused by wind. The interior tip shall be

inconspicuous and located within a central corridor shown on the drawings.

e. Air Flow Measuring Stations: Where the stations are installed in insulated ducts, the airflow passage of the station shall be the same size as the inside airflow dimension of the duct. Station flanges shall be two inch to three inch to facilitate matching connecting ductwork. Stations shall be installed in strict accordance with the manufacturer's published requirements, and with ASME Guidelines affecting non-standard approach conditions.

f. Water Flow Monitoring Stations: Water Flow Monitoring Stations shall be installed in strict accordance with the manufacturer's published requirements, and with ASME Guidelines affecting non-standard approach conditions.

g. Outside Air Humidity Sensors: Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA 3R enclosure with sealtite fittings and stainless steel bushings.

h. Outside Air Sensors: Outside air sensors shall be mounted on the North wall to minimize solar radiant heat impact or located in a continuous intake flow adequate to monitor outside air temperatures accurately. Sensors exposed to solar radiation must be installed with solar shields. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate surrounding the sensor element.

i. Duct Temperature Sensors: Duct mount sensors shall mount in an electrical box through a hole in the duct and be positioned so as to be easily accessible for repair or replacement. The sensors shall be insertion type and constructed as a complete assembly including lock nut and mounting plate. For ductwork greater in any dimension that 48 inches and/or air temperature stratification exists such as a mixed air plenum, utilize an averaging sensor with multiple sensing points. The sensor shall be mounted to suitable supports using factory approved element holders. For large plenum applications such as mixed air temperature measurements, utilize a string of sensors mounted across the plenum to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12 foot long segment.

j. Space Temperature Sensors: Shall be mounted at 60" above the finished floor. Temperature sensors installed in public areas shall be provided with lockable covers to prevent tampering.

k. Low Temperature Limit Switches: Mount element horizontally across duct in a serpentine pattern insuring

each square foot of coil is protected by 1 foot of sensor. For large duct areas where the sensing element does not provide full coverage of the air stream, provide additional switches as required to provide full protection of the air stream.

l. Differential Pressure Status Switches: Provide complete installation kit including; static pressure tops, tubing, fittings and air filters. Provide appropriate scale range and differential adjustment for intended service.

E. Output Devices

1. All output devices shall be installed per the manufacturers recommendation. The mechanical contractor shall install all in-line devices such as control valves, dampers, etc.

2. Actuators: All control actuators shall be sized capable of closing against the maximum system shut-off pressure. The actuator shall modulate in a smooth fashion through the entire stroke. When any pneumatic actuator is sequenced with another device, pilot positioners shall be installed to allow for proper sequencing.

3. Control Dampers: Shall be opposed blade for modulating control of air flows. Parallel blade dampers shall be installed for two position applications.

4. Control Valves: Shall be sized for proper flow control with equal percentage valve plugs. The maximum pressure drop for water applications shall be 5 PSI. The maximum pressure drop for steam applications shall be 7 PSI (or critical pressure drop if steam supply pressure exceeds 15 psig).

3.2 Training

1. The controls contractor shall provide the following training services**:**

2. One day of on-site orientation by a field engineer who is fully knowledgeable of the specific installation details of the project. This orientation shall, at a minimum, consist of a review of the project as-built drawings, the control system software layout and naming conventions, and a walk through of the facility to identify panel and device locations.

3. Operator Training: Two days of on-site operator training shall include the detailed review of the control installation drawings, points list, and equipment list. The instructor shall then walk through the building identifying the location of the control devices installed. For each type of systems, the instructor shall

demonstrate how the system accomplishes the sequence of operation.

4. From the workstation, the operator shall demonstrate the software features of the system. As a minimum, the operator demonstrate and explain logging on, setting passwords, setting up a schedule, trend, point history, alarm, and archiving the database.

3.3 Commissioning

Commissioning the Facility Management System is a mandatory documented performance requirement of the selected FMS Contractor for all control systems detailed in this Specification and sequence of operations. Commissioning shall include verification of proper installation practices by the FMS Contractor and subcontractors under the FMS Contractor, point verification and calibration, system/sequence of operation verification with respect to specified operation, and network/workstation verification. Documentation shall be presented upon completion of each commissioning step and final completion to ensure proper operation of the Facility Management System.

A. Acceptance Check List

1. An acceptance checklist shall be completed that documents compliance with each item of this Specification.

B. Testing Procedure

1. Upon completion of the installation, the FMS Contractor shall start-up the system and perform all necessary testing and run diagnostic tests to ensure proper operation. The FMS Contractor shall be responsible for generating all software and entering all database information necessary to perform the sequences of control herein specified.

C. Testing Documentation

1. Prior to acceptance testing, FMS Contractor shall create, on an individual system basis, trend logs of input and output points, or have an automatic Point History feature for documentation purposes.

D. Field Points Testing

1. This step shall verify that all of the installed points receive or transmit the correct information prior to loading/activating the system software.

2. ON/OFF commands from the workstation shall be performed in order to verify each binary output point.

3. All binary input points are to be tested using the HAND/OFF/AUTOMATIC selector switch on the associated motor control center or by manually jumpering across the field device contacts.

4. All analog output points shall be tested using a command from the workstation to modulate the output device from minimum calibrated signal to maximum calibrated output.

5. All analog input points are to be tested by comparing the reading obtained through the workstations or portable terminal to the value of an independent testing meter.

E. Noncompliant Items

1. The Contractor shall remove and replace, at its expense, all items that are not in compliance with the Specification requirements.