SECTION 23 09 00

INSTRUMENTATION AND CONTROLS FOR HVAC

PART 1 - GENERAL

1.1 RELATED REQUIREMENTS

A. Comply with Division 1 - General Requirements and referenced documents.

B. Comply with Section 23 05 00, General Provisions, and all other Division 23 Sections, as applicable.

C. Refer to other divisions for coordination of work with other trades.

1.2 SYSTEM DESCRIPTION

A. The scope shall include the furnishing and installing of Energy Management System devices with new direct digital controllers, all local and remote control panels, temperature control field devices, appurtenances, etc., to accomplish specific control sequences specified herein, to provide fire and freeze protection; sensing and indicating devices; pressure and temperature indicating instruments; supporting structures, and other required components for a complete and operating system.

B. The scope shall include all new electric connections to new thermostats, sensors, dampers and actuators, and relays, and all other new components of the system requiring electric connections.

C. The scope shall further include all temperature control and interlocking wiring and wiring devices, including raceways, as indicated herein.

D. Provide all software programs as required to effect the sequences of control, monitoring, reporting, etc., as indicated herein.

E. The new system installed shall be fully automatic, subject to various types of remote surveillance, routine remote adjustments, remote status, remote alarms, remote data collection for trending/historical files, and other operations as indicated herein, from a new local remote microprocessor-based Local Area Network (LAN), with the local system capable of stand-alone operation. The system shall be capable of being monitored and controlled remotely on site by and IBM compatible Workstation (not provided under this contract) and off site by an existing Central Processing Unit (CPU) at the Facilities Central Maintenance Office via the web.

F. Bidders are specifically advised that full and effective two-way communication between the new system installed under this contract and the Owner's existing CPU

must be achieved in an approved manner, including whatever may be required in the form of interface hardware and software without effecting or interrupting other system software. Simultaneous on-line communication of this system and others with the Central EMS is mandatory.

G. This system of equipment and software shall be provided and installed by the single factory and authorized sales, installation and service agent of Reliable Controls (Enviromatic Systems).

1.3 QUALITY ASSURANCE

A. The equipment provided under this Section of the Specifications shall be installed, calibrated, adjusted, and put in completely satisfactory operation by a Control Systems installer experienced in this type of work.

B. The successful Control Systems installer shall meet the following requirements:

1. All spare parts must be locally stocked and readily available within a 24 hour period.
2. Service personnel shall be available, on call, on a 24 hour a day, year round basis, or service personnel will respond by visitation to the site within four (4) hours of a service call considered serious in nature or classified by the Owner as an emergency.
3. Be able to provide evidence of having successfully installed similar sized and types of systems for a minimum of ten (10) years.

C. All control devices shall be as specified in the technical portion of this section of the specifications. The system shall be installed by workmen skilled, experienced, and specifically trained in the application, installation, calibration, adjusting, and testing of instrumentation of the type specified.

D. A service representative of the installer shall check the instrumentation for proper installation, calibrate all instruments and make all adjustments necessary to insure proper operation of the system in full cooperation with the Testing, Adjusting, and Balancing (TAB) Firm. Refer to Section 23 05 93. All instruments required for checking, calibrating, and proving the system shall be provided under this Section of the Specifications. The service representative shall spend sufficient time with all of the Owner's Representatives after the system is installed and properly functioning to instruct the Owner's Representative (Operations and Maintenance Personnel) in the operation of the system for a minimum of sixteen (16) hours for the basic Controls System and eight (8) hours for the EMS. At final completion of the installation provide personnel and instruments of satisfactory quality available to check the calibration of all instruments, and to demonstrate system operation as described in "Sequences of Operation".

E. All basic control devices, parts, and other materials, shall be standard catalog products of a single reputable manufacturer and shall essentially duplicate equipment which has been in satisfactory service for at least one (1) year. All materials and parts shall be items in current production by the manufacturers. First of a kind new technology devices will not be considered. Accessory equipment that is required to make a complete and functioning system that is not of the same manufacturer furnishing the basic control equipment shall carry the guarantee of the basic control equipment manufacturer and repair and replacement parts shall be available through normal local trade channels.

F. All software updates and enhancements which evolve during the first year warranty period following system acceptance, "Substantial Completion", shall be furnished to the Owner without additional cost. This shall include the local stand-alone direct digital controllers and the building network manager computer(s).

G. All controllers shall be Native “ASHRAE BACNET” and shall communicate to an “ASHRAE BACNET” Building Level “Front End” controller at the building network level.

1.4 SYSTEM START-UP AND COMMISSIONING

A. After completion of the installation, Contractor shall place the system in operation and shall perform all necessary testing and debugging operations of the basic systems and EMS.

B. An acceptance test shall be performed in the presence of the Testing, Adjusting, and Balancing (TAB) Company, to verify correct sequences of operation, calibration, and operation of the Controls and Energy Management System, when installed, with every part of the system functioning satisfactorily and having been fully commissioned, and with no outstanding items requiring completion or correction, the system will be accepted by the Engineer and Owner for "Substantial Completion", and will then be placed under Warranty.

C. The Automatic Temperature Control and Energy Management System Installer shall thoroughly check all controls, sensors, operators, sequences, etc., before notifying the TAB Agency that the Automatic Temperature Controls and Energy Management System are operational. The Automatic Temperature Control and Energy Management System Installer shall provide technical support (technicians and necessary hardware and software) to the TAB Agency to allow for a complete check-out of these systems.

1.5 SUBMITTALS

A. Submittals shall be complete and be in full accordance with Section 23 0500, General Provisions.

B. Submittals shall include complete, continuous line, point to point wiring diagrams including tie-in points to equipment with written sequences of control adjacent to pertinent control diagrams. Specification sheets shall be submitted on each piece or type of equipment in a separate brochure and show sufficient detail to indicate compliance with these specifications. Drawings and Specification sheets shall show setpoints, throttling ranges, actions, proportional bands, and integration constants, where applicable. Complete brochures shall include the wiring diagrams as well as operating and maintenance instructions on the equipment.

C. Complete and approved shop drawings shall be obtained prior to commencing installation work, unless otherwise approved by the Owner or Owner's Representative.

D. Tag numbers, as shown or specified, shall appear for each item on the wiring diagrams and data sheets. Data sheets shall properly reflect in every detail the specific item submitted.

E. After completion of the work, Contractor shall prepare and furnish maintenance brochures for the Owner. The maintenance brochures shall include operating instructions, specifications, and instruction sheets for all instruments and a complete set of "As-Built" control drawings. After approval of submittal, completion of all installation work, software checkout, and system commissioning in conjunction with the Testing, Adjustment and Balance (TAB) Firm, furnish to the Owner the following:

1. Three (3) sets of Blue or Black line prints of "As-Built" drawings, half size (11" X 17"), inserted in a three ring binder.
2. Three (3) copies of the final approved Shop Drawings in suitably sized three ring binders.
3. Provide a complete replacement spare parts list to the Owner, three (3) copies.
4. Two (2) USB drives with PDF files of all items furnished under items 1, 2 and 3 above, along with all operations and maintenance manuals.

1.6 PRODUCT HANDLING

A. Cover and protect material in transit and at site. Material not properly protected and stored, and which is damaged or defaced during construction shall be rejected.

B. Cover control panels, open ends of control piping and open ends of control valves stored on site until just prior to installation of wiring and valves respectively.

C. Storage and protection of materials shall be in accordance with Division 1.

PART 2 - PRODUCTS

2.1 TEMPERATURE SENSORS

A. Temperature sensors shall be nickel wire thermistor, 10,000 ohm resistance, with 1000 ohms resistance at 70 Deg.F., and a 3 ohms/per degree F temperature coefficient.

B. Ambient temperature limits shall be minimum of 0-125 Deg.F. with a +/- 0.50% accuracy of nominal resistance at 70 Deg.F.

C. Mixed air temperature sensors shall be the averaging capillary type to sense duct temperature across the full duct width. Minimum sensor length shall be 15 feet and include adequate supports for element within the duct or at the face of the coil, maintain minimum one inch (1") separation from coil.

D. Furnish sensors with maximum 6 to 9 inch insulated pigtail leads.

E. All sensor actions shall be the same for the entire building.

F. Mount all room wall sensors at 48" inches above finished floor to comply with A.D.A., unless indicated or approved otherwise by the Engineer or Owner's Representative.

G. Wall space temperature sensors shall include the following accessories, features and functions:

1. Impact Resistant Lexan type cover material.
2. Local override pushbutton to energize controlled equipment for after-hours operation.
3. Local operator interface communication service jack compatible with mobile trouble shooting terminal unit. Alternately, provide spare service jack on terminal equipment controller on controlled terminal equipment.
4. Temperature increase/decrease adjustment capability.
5. Space temperature indication in Deg. F.

H. Sensors shall be as manufactured by General Eastern or Reliable.

2.2 RELATIVE HUMIDITY SENSORS

A. Provide a 100% solid state copolymer wafer, of bonded layer hygrometric materials, humidity sensor and transducer. Sensor shall require no periodic maintenance or recurring calibration. Sensor shall be linear and temperature compensated.

B. Sensor shall have +/-2% Relative Humidity (RH) accuracy over a 100% RH range and +/-1% over the 30-80% RH range.

C. Sensor shall produce outputs of 4-20 ma or 1-11 vdc.

D. Sensor shall be in an impact resistant cover with ventilating openings in occupied spaces. Provide duct or remote mount probes as required for the application.

E. Wall mounted sensors shall be mounted 48 inches above finished floor to comply with A.D.A., unless indicated or otherwise approved by the Architect or Owner's Representative.

F. Acceptable Manufacturers:

1. Vaisala (±2% to 3% acceptable).
2. General Eastern (±2 to 3% acceptable).
3. Reliable Controls (±2% only).

2.3 CARBON DIOXIDE SENSORS

A. Furnish and install "CarboCap" technology (Vaisala) or Single Beam, dual wavelength, Infrared type technology (Tel-Aire) carbon dioxide sensors where indicated and as specified elsewhere herein.

B. Sensors shall accurately sense carbon dioxide levels from 250-2000 Parts Per Million (PPM) with an accuracy of ± 60 ppm (± 2% of range (2000 PPM) and ± 2% of reading (use 1000 PPM)), repeatability of ± 2% of full scale, maximum drift of ± 5% of full scale in five (5) years, ± 1% of full scale in six (6) months, and linearity of less than ± 3% of full scale.

C. Sensors shall be suitable for operation in environments of 60 Deg.F. to 104 Deg.F. and 15-95% relative humidity, non-condensing, and air velocity ranges of 200 to 2750 feet per minute when located in ductwork. Wall mount sensors shall be able to sense accurately with air velocities as low as 20 feet per minute.

D. Sensors shall be calibrated at the factory at 1,000 PPM, ± 50 PPM; at 72 Deg.F, ± 4 Deg.F.; and at 50% relative humidity, ± 5%.

E. Power requirements shall be 24 colts AC with a power consumption not to exceed 5 watts.

F. Wall mount sensors shall be mounted at 48-54 inches above the finished floor.

G. Sensors shall be as manufactured by:

1. Vaisala, Model GMD/W20 or equals by;
2. Tel-Aire (Model 8101/8102), or
3. Alternate models by Veris Industries.

2.4 COMBINATION SENSORS

A. Where space temperature, relative humidity and/or carbon dioxide sensors are all designated to be located in the same location for control or monitoring purposes combination sensors are desired such that one wall mounted device and single back box is required.

B. Where combination sensors are required the specified levels of accuracy will be required. The use of combination sensors does not relieve these requirements.

2.5 CARBON MONOXIDE SENSOR AND ALARM (CLASSROOM/AREAS)

A. A carbon monoxide detector shall be installed in each classroom as shown on the Drawings.

B. The carbon monoxide detector shall be similar to Gentex Carbon Monoxide Alarm Model CO1209 Series.

C. The carbon monoxide detector shall have the following features and functions.

1. The carbon monoxide alarm shall utilize an electrochemical sensing element with an expected 5-year life.
2. The carbon monoxide alarm shall be calibrated in accordance with ANSI/UL 2034 requirements to alarm at 70 PPM CO for 1-4 hours, 150 PPM CO for 10-50 minutes, and 400 PPM for 4-15 minutes.
3. The alarm shall have a 9V alkaline battery as back-up in the evet that building power is lost. Battery impedance shall be verified by the circuit of the CO alarm. The CO alarm shall provide an indicator when the battery is low in power or high impedance or is missing.
4. The CO alarm will provide an audible indicator of 3 quick chirps every 30 seconds at the end of life of CO sensor.
5. The CO alarm shall be a solid state piezo alarm rated at 85dBA at 10ft.
6. An easily accessible test button shall be provided to indicate functionality of the sensor.
7. The device shall have tandem interconnect capability for up to 18 CO alarms and tandem interconnect with other CO alarms, smoke alarms, or combinations thereof.
8. The device shall have auxiliary relay contacts for initiating remote functions and annunciation.
    a. The device shall be installed such that it sends a signal to the EMS for alarming purposes.
    b. The device shall be installed such that it is employed in the sequence of operation for roof top air conditioning units.
9. The device shall be UL 2034 listed.

2.6 SMOKE DETECTORS

A. One (1) smoke detector shall be furnished under Division 28 (Fire Alarm Contractor) and installed by the Mechanical Contractor for each new air handling equipment item handling over 2,000 CFM of airflow or where units are serving two (2) or more spaces; to be mounted in the return air stream, which shall stop the fan motors upon detection of smoke.

B. Coordinate with Electrical and Fire Alarm Contractor requirements to insure sampling tubes are provided suitable to the width of duct in which installed.

C. Detectors shall be supplied with 24 volts, power supply under Division 26/28. Control circuit interlock wiring shall be installed by fire alarm contractor under Division 26/28. Controls Contractor to provide wiring to unit. Fire alarm Contractor to provide wiring to smoke detector or panel. Fire Alarm Contractor to install shut-down relay and supply and terminate wiring from coil to Fire Alarm panel/smoke detector. Controls Contractor to supply and terminate wiring to shut-down contact relays in unit.

D. Acceptable duct detectors, where not specified elsewhere, shall be THORN-DH-22, BRK-DH2851AC, or Gamewell MS-69433, suitable for single station operation.

2.7 ROOM SENSOR AND THERMOSTAT PROTECTIVE COVERS

A. Provide opaque Lexan thermostat guards with mounting brackets and tamper proof screws for each new wall mounted thermostat and sensor installed, unless indicated otherwise. Administrative office areas and classrooms shall not require guards. Generally, guards shall be provided in Institutional Public Use Areas, such as Cafetorium and Public Use Corridors.

B. Painted cast iron guards, shall be used in high abuse areas such as gymnasiums, shops, locker rooms, etc., without exception.

C. Guards shall be sized to accommodate the thermostat or sensor to be enclosed, and include ventilation openings, ring base, and key lock.

D. Guards shall be as manufactured by:

1. Mason.
2. Honeywell.
3. Best Engineered Control Products.

2.8 AUTOMATIC DAMPERS

A. Provide all control dampers, under this Section of the Specifications, of the types and sizes indicated on the Drawings, including but not limited to outside air intakes, return, relief, and other motorized air control dampers where shown, or where not an integral part of the equipment furnished and specified in other sections of these specifications. All dampers shall be special low leakage extended performance type.

B. Damper frames shall be not less than 16 gauge galvanized steel formed for extra strength with mounting holes for flange and enclosed duct mounting.

C. Dampers shall be available in two-inch size increments from 8" horizontal and vertical to 48". Requirements for dampers over 48" in size shall be met by using standard

modules with interconnecting hardware to limit damper blade length to a maximum of 48". Provide separate actuator for damper modules exceeding 32.0 square feet and as required for smaller sizes due to torque requirements.

D. All damper blades shall be not less than 16 gauge galvanized steel roll formed for high velocity performance. Blades on all dampers must be not over 6" wide.

E. Blade bearings shall be nylon or oilite with 1/2" zinc plated steel shafts.

F. All blade linkage hardware shall be of corrosion-resistant finish and readily accessible for maintenance after installation.

G. Provide continuous replaceable neoprene or butyl rubber edging seals for all outdoor and relief air dampers where blade edges meet when dampers are closed. Spring loaded stainless steel side jamb seals shall be provided for all dampers.

H. Dampers and seals shall be suitable for temperature ranges of -20 degrees F to 200 degrees F at specified leakage ratings.

I. Dampers used for proportional control shall have opposed blades.

J. Leakage rates for all controlled dampers shall not exceed 5 CFM of air flow per square foot of face area based on a 16 square foot damper, at 1.0" W.C. differential, rated in accordance with AMCA 500. Furnish test data with Submittals.

K. Acceptable manufacturers (No other manufacturers will be allowed):

1. Johnson Controls, Inc.
2. Honeywell, Inc.
3. American Warming and Ventilating, Inc.
4. Ruskin.

2.9 ELECTRIC DAMPER ACTUATORS

A. All control dampers shall receive electric actuators.

B. Electronic direct-coupled actuation devices shall be provided.

C. Electric Actuators shall be direct-coupled over the shaft, enabling it to be mounted directly to the damper shaft without the need for connecting linkage. The fastening clamp assembly shall be of a "V" bolt design with associated "V" shaped toothed cradle attaching to the shaft for maximum strength and to eliminate slippage.

D. Spring return actuators shall have a "V" clamp assembly of sufficient size to be directly mounted to an integral jack shaft of up to 1.05 inches when the damper is constructed in this manner. Single bolt or set screw type fasteners are not acceptable.

E. Actuators shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the entire rotation of the actuator. Mechanical end

switches or magnetic clutch to deactivate the actuator at the end of rotation are not acceptable.

F. For power-failure/safety applications, an internal mechanical spring return mechanism shall be built into the actuator housing. Non-mechanical forms of fail-safe operation are not acceptable. This applies to all dampers directly connected to outside and relief air systems. All spring return actuators shall be capable of both clockwise or counterclockwise spring return operation by simply changing the mounting orientation.

G. Proportional actuators shall accept a 0 to 10 VDC or 0 to 20 mA control input and provide a 2 to 10 VDC or 4 to 20 mA operating range. An actuator capable of accepting a pulse width modulating control signal and providing full proportional operation of the damper is acceptable. Floating point type control is acceptable on fan coil units, unit heaters and variable air volume terminals. All actuators shall provide a 2 to 10 VDC position feedback signal.

H. All 24 VAC/VDC actuators shall operate on Class 2 wiring and shall not require more than 10 VA for AC or more than 8 watts for DC applications. Actuators operating on 120 VAC power shall not require more than 10 VA.

I. All non-spring return actuators shall have an external manual gear release to allow manual positioning of the damper or valve when the actuator is not powered. Spring return actuators with more than 60 in-lb torque capacity shall have a manual crank for this purpose.

J. All modulating actuators shall have an external, built-in switch to allow the reversing of direction of rotation.

K. Actuators shall be provided with a conduit fitting and a minimum three-foot electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.

L. Actuators shall be Underwriters Laboratories Standard 873 listed.

M. Actuators shall be designed for a minimum of 60,000 full stroke cycles at the actuator's rated torque and shall have a minimum 2-year manufacturer's warranty, starting from the date of substantial completion.

N. All actuators connected to all sequenced dampers shall have independent control and adjustment from one another to emulate a pilot positioner.

O. Acceptable Manufacturer's:

1. Belimo.
2. Johnson Controls, Inc.
3. Siemens.
4. Invensys.

5. Honeywell, Inc.

2.10 CURRENT SENSING STATUS RELAY

A. Prove current sensing status relays for motor operation status monitoring as specified elsewhere herein.

B. Sensors shall be 100% solid state, no mechanical parts, and have no calibration drift.

C. Sensors shall have an adjustable trip level, be isolated, have single set point adjustment, require no external power (power induced from conductor), and have integrated adjustable wall or floor mounting bracket.

D. Sensors shall be suitable for motor loads from 0 to 100 HP, with a supply current of 1 ampere up to 135 amperes, 600 VAC RMS, set point adjustable to +/-1% range from 0-95% non-condensing relative humidity.

E. Sensors shall be as manufactured by Veris Industries.

2.11 AIR FLOW DIFFERENTIAL PRESSURE SWITCHES

A. Air flow differential pressure switches shall be provided to detect clogged air filters duct pressure, and building space pressure unless specified in other sections of these specifications.

B. Switches shall be capable operating in ambient temperatures from 0 Deg. F. to 165 Deg. F.

C. Setpoints shall be field adjustable from 0.05 to 5.0 inches water column to suit the application. Provide concealed scale plate with adjusting screw for setpoint adjustment. Scale shall be selected such that the normal operating range is at the midpoint of the scale; i.e. an operating range of 0.30 to 0.70 needs a scale of 1.0.

D. Materials of Construction:

1. Buna_N Diaphragm.
2. Molded polycarbonate enclosure.
3. Zinc plated cold rolled steel; 0.040 inches thick for diaphragm housing and 0.032 inches thick for cover material.

E. Provide appropriate mounting brackets and any remote mounting probe kits as necessary for each particular mounting condition.

F. Acceptable Manufacturers:

1. Johnson Controls, Inc.
2. Honeywell, Inc.
3. Invensys.
4. Siemens.

5. Robertshaw.
6. Dwyer.

2.12 LOCAL CONTROL PANELS

A. New local equipment control panels shall be installed in each equipment room, or other locations as indicated or as required, for new electric equipment and control devices. They shall be totally enclosed, wired to labeled terminals to house all associated controllers, thermometers, relays, switches, etc. serving that equipment. Provide one cabinet for each air handling unit or group of units in the same room.

B. Panels shall be mounted at a convenient height for access. Acceptable locations include mechanical equipment rooms, storage closets, electrical rooms, or other spaces as indicated on the Drawings. Above ceiling locations are not acceptable.

C. Thermometers, pilot light switches, and gauges shall be flush mounted on panel surface.

D. Cabinet frames shall be extruded aluminum sections with riveted corners supported by internal angle brackets. Door shall have continuous hinged door, with latch and key lock.

E. Sub-Panel and face panel shall be removable for ease of installation and replacement. Face panel shall be of a finished color with a finished frame.

F. Knockouts for 1/2" x 3/4" EMT connection and 1-1/2" x 1-1/2" trough shall be provided at top and bottom of panel.

G. Identify each panel, switch, and device by an engraved, bolt-on, black phenolic nameplate with white lettering securely attached. Identify all control devices inside panels similarly. Embossed plastic tape will not be acceptable on panel front faces but will be allowed on panel interiors.

H. Switches and pilot lights shall be mounted on the panel face with all other devices mounted inside the panel. Devices inside panels shall be wired to numbered dual terminal strips.

I. Start-Stop Pushbuttons and Pilot Lights, where called for, shall be of the low voltage and neon type. Pushbuttons shall be heavy duty type. Pilot lights shall be interlocked with starter auxiliary contacts except fans and pumps which shall have differential pressure sensors to indicate run status.

J. Each new control panel installed shall have a minimum of 25% consolidated spare/extra space available inside the panel for mounting of control devices for future system modifications or changes. This space shall be indicated on the panel shop drawing.

K. All wiring inside panels shall be concealed in a wiring harness.

L. Permanently affix inside each panel a final "as-built" control drawing of the piping and wiring of the panel.

M. All panels shall be factory assembled, piped and wired.

2.13 ENERGY MANAGEMENT SYSTEM

A. Network Level Controllers shall have a 16 bit based microprocessor with EPROM operating system. DDC programs and data files shall be in non-volatile EEPROM or flash memory to allow simple and reliable additions and changes. Each controller shall have an on-board 30 day battery backed realtime clock. Controllers shall be provided as required with capacity to accommodate input/output (I/O) points required for the application plus any spare points as specified. Each panel shall be provided with a socket for a Portable Operators Terminal (POT), and a port for network communications at no less than 78,000 baud. Controllers shall have outputs which shall be binary for On-Off control, with true variable voltage (0-10v), for driving analog or pneumatic transducer devices. Analog outputs shall have a minimum incremental resolution of one percent of the operating range of the controlled device. Controllers shall have LEDs for continuous indication of all bus communications, power, and operational status. All panel electronics and associated equipment shall be installed in suitable enclosures.

B. Terminal Equipment Controllers (TEC's) shall be UL916 standalone EEPROM based and configured to perform the sequences specified, and with I/O selected for the application. TEC enclosures shall be compact plastic conforming to UL94-5V or plated steel. Each TEC shall be provided with LED type annunciation to continually display its operational mode; power, normal, or in an alarm state. TEC networks operating on a 9000 baud rate shall be grouped with no more than 20 TEC's per primary bus connected device. For TEC networks operating over 50,000 baud, up to 100 TECs may be so grouped.

C. General:

1. Software development and programming shall be as directed by the Owner and as described herein. Contractor shall install all program operating time schedules as furnished by the Owner. During construction, the Contractor may operate equipment in what is considered a Construction Schedule. The control systems installer, at Substantial Completion, shall remove such schedules and replace these with individual, independent, operating schedules for each system and individual piece of equipment, specifically air handling equipment.
2. Program trend logging of all analog and binary points of control at intervals as directed by the Owner, initially use five (5) minutes.

3. Overall systems control shall be performed by a field programmable direct digital controller, microprocessor based, which incorporates Direct Digital Control, all necessary energy management functions and provides for digital display and convenient local adjustments of desired variations at each individual controller cabinet. This shall include scheduled programming and system interlocks.
4. DDC Control Units and all hardware shall be capable of continued operation at room temperatures of 40 Deg.F. to 120 Deg.F. and humidity from 10% up to a non-condensing point of 90%. All inputs shall be capable of withstanding continuous shorting to 120 VAC.
5. Provide any external electrical power supply protection devices to protect controllers from external voltage surges to include high voltage and lightning disturbances/protection.
6. Provide function switches in a local control panel if not integral with the DDC Controller with "on-off" control and a "manual-auto" switch for each new DDC output (contact type) with switch status information being available to the central systems historical data files for new rooftop units over 2000 CFM in capacity, exhaust fans over 2000 CFM in capacity, and make-up air fans. Switches shall be local and easily accessible and adjacent, or within sight of, controlled equipment. If switches are not an integral part of the Energy Management System or locally accessible for use, then furnish similar set of switches on the Local Control Panel, dip switches less than 1/4" wide and 1/4" tall shall not be acceptable for this function.
7. The new EMS system installed shall be automatic, subject to various types of remote site surveillance, routine adjustment, and operation as indicated herein, from a microprocessor-based Local Area Network (LAN), capable of stand-alone operation. In addition, basic control and LAN interface shall be provided in a Central Control Panel located where shown on the drawings. The entire system of control and automation at this building shall thus become an integral part of the Owner's existing Energy Management System (EMS) front end.
8. Bidders are specifically advised that full and effective two-way communication between the new system installed under this contract and one (1) of the Owner's three (3) existing CPU’s must be achieved in an approved manner, including whatever may be required in the form of interface hardware and/or software without effecting or interrupting concurrent communications with other connected buildings. No additional CPU's are allowed at the Central Digital Monitoring location.
9. Existing color graphic mouse commands shall be retained in a similar fashion.
10. Provide Control Graphics/Equipment Schematics for each piece of controlled equipment with on-line display of system control parameters. Program all graphics at system front end to include on-line alarm reporting resulting in print outs occurring each time an alarm message is reported on site.
11. Provide a hard wire connection between the Building LAN serving all new Controllers to the Central Facilities Management System. Verify dependable utilization of this system and transfer of local system data and functions to the existing control system CPU. General data reporting and alarms transmission shall be verified.

12. An operator shall be able to define the minimum time delay between the stopping of a piece of equipment and its subsequent restart. This time delay shall be in effect for motors in the software control mode and for EMS controlled motors in the "manual" control mode. Provide equipment fail restart software that will restart equipment shut down as the result of a fire alarm system, power outage or other building wide shut-down, following the return to normal conditions. This shall consist of designated groups of RTU's and other EMS controlled equipment being restarted at staggered time intervals to prevent excessive demand on the power supply.

D. Control:

1. Control algorithms shall be available and resident in the digital system controller to permit Proportional, Integral, and Derivative control modes in any combination to meet the needs of the application. Other control modes such as incremental, floating, or two-position must be available to adapt to job needs.
2. All control shall be performed in a digital manner using the digital signal from the microprocessor based controller converted through electronic circuitry for modulation of electric actuators or through transducers to produce the pneumatic signal for operation of pneumatic actuators.
3. Provide sensitivity, proportional, and integral adjustments for all DDC output control points.

E. Energy Management: The digital system controller shall perform all the energy management functions necessary to reduce energy consumption. The programs shall include, not necessarily utilized, but not be limited to:

1. Optimal start-stop using an adaptive algorithm to prevent the need for manual adjustment of parameters.
2. Optimization programs controlling equipment using outdoor dry bulb and dew point temperatures. The outdoor wet bulb temperature shall be calculated by the following equation:

$$WB = (DB-DP)K+DP \text{ where } K = 0.560-0.0068\ (DP-30)$$

3. Client Tailored Programs: The library of routines available in firmware must be capable of generating additional programs as may be required for specific client requirements. The Owner shall be capable of revising programs without the aide of the installer.

F. Local Display and Adjustment:

1. The DDC shall be provided with a Central Master Panel for digital parameter display, programmed to display analog variables, binary conditions, off normal scans and other analog or binary information required for analysis and adjustment of the system being controlled. The DDC shall further contain display features to indicate automatic operation, manual or override operation, alarm indication, and other auxiliary displays associated with special purpose auxiliary function keys. Additionally, provide one portable operators terminal to make adjustments at any controller where connected to the network.

2. The associated keyboard shall contain all alphanumerical keys to call-up the desired points and type of value to be displayed and have several special dedicated keys for such functions as manual-auto, test and function and value enter, as an aid to the operator. A minimum of two keys shall be programmable for auxiliary functions that may be used frequently.
3. Adjustments of control variables shall be conveniently available at each local DDC panel or device through a resident or portable keyboard and display. The adjustments shall include, but not be limited to, proportional gain, integral rate, the velocity and acceleration constants associated with incremental control and on/off values of two-position control.

G. Field Programmable:

1. The Local DDC Controllers shall contain all necessary mathematic, logic, utility functions; and all standard energy calculations and control functions in ROM to be available in any combination for field programming the unit. These routines shall include, but not be limited to:
   a. Math Routines:

      Basic Arithmetic
      Binary Logic
      Relational Logic
      Fixed Formulas for Psychometric Calculations
   b. Utility Routines for:

      Process entry and exit
      Keyboard functions
      Variable adjustments and output
      Alarm Indication
      Restart
   c. Control Routines For:

      Signal compensation
      Loop control
      Energy conservation
      Timed programming
2. Final field programs shall be stored in battery backed up RAM.

H. Expandability: The DDC shall be expandable by adding additional field interface units that operate through the central processor of the DDC. The processor in the DDC shall be able to manage remote field interface units thereby expanding its control loop and energy management point capacity. Remote units shall be able to stand alone and have two-way communication in a LAN configuration. Systems furnished shall be fully manufacture-supported and under current production.

I. Calibration Compensation: To maintain long term analog accuracy to the controller sensing circuits, the DDC shall sense the voltage being supplied to the resistance

sensing element and through firmware compensate for power supply changes due to long term drift or drift due to ambient temperature changes at the power supply.

J. Battery Backup: The DDC system shall be supplied with a minimum of 48 hours of nickel-cadmium battery backup, during power outages, for the RAM, with an automatic battery charger to maintain charge while power is on, to prevent internal component damage or failure. DDC modules shall have automatic restart capabilities with sequencing after a power failure without program interruption.

K. Associated Hardware:

1. All actuators for dampers shall be supplied under this section of the specifications.
2. Where electric actuators are used they shall be compatible with the (pulse width modulated) output of the Digital System Controller.

L. Diagnostics: The Digital System Controller shall contain in its program a self test procedure for checking the digital controllers, and by means of a non-destructive memory, check the computer.

M. Default Operating Procedure and Alarms:

1. All variables shall be identified as being reliable or unreliable. When a calculation is required to use a value (sensed or calculated), which is identified as being unreliable, the unreliable data value will flash. The calculation will use a default value programmed into the unit.
2. All alarms (a fan that did not start, etc.) and all deviation alarms (temperature, off, normal, etc.) will locally display an alarm as well as report to the remote CPU the type of alarm, designate equipment or system effected, date and time of alarm. A hard copy printout of alarms shall be generated at the remote CPU location. A scan can then identify all alarm conditions and their identifier.

N. Cabinet:

1. The DDC modules, central and remote units, shall be enclosed in a metal frame cabinet. The cabinet shall be constructed such that it can be mounted and electrical terminations can be made during the construction phase of the project. The DDC electronics are to be removed and added at a later date, only prior to start-up.
2. Cabinet shall be installed on the wall in the Mechanical Rooms or elsewhere as indicated.
3. DDC cabinets in Mechanical Rooms shall be provided with a key lock. All cabinets on each installation shall utilize one master key. Sheet metal set screw locking covers are not acceptable.
4. All control wiring and system communications shall be electrically terminated inside DDC cabinets.

O. U. L. Approval: The DDC system panels shall be an approved U.L. System, with U. L. listing as a Signaling System.

P. General software features of system, with sufficient internal memory, shall include the following as a minimum (although not all are necessarily used):

1. Start-Stop Functions.
2. Optimized Start-Stop Control (warm-up and cool-down).
3. Time Programmed Commands.
    a. Normal occupancy.
    b. Holiday.
    c. Occupancy overrides.
    d. Schedules shall be programmable up to one year in advance with system wide or global scheduling and local, point by point scheduling.
4. Duty Cycle Control (not used).
5. Night Setback/Setup.
6. Electric Demand Limiting (not used).
7. Override Feature.
8. Run Time Totalization with data in non-volatile module memory. Provisions shall be made for on-line programming and override.
9. Staggered start of Groups of Equipment following power outages or Mass Building Equipment Shutdown.

Q. Individual On/Off Points of System Control and run Status shall be provided for each of the following:

1. Each Rooftop A/C Unit; Refer to plans for quantities, sizes and related requirements.
2. Exhaust Fans:
    a. New kitchen grease hood exhaust fan – status only.
    b. Existing Dishwasher Hood Exhaust fan – status only.
    c. EMS controlled Toilet Exhaust Fans, refer to plans for quantities.
    d. Electrical Rooms, refer to plans for quantities.
3. Make-Up Air Fan for grease hood – status only.
4. Exterior Lighting Controls: Re-use all existing currently controlled exterior lighting controls contactors and schedules.

R. Run Status (On/Off) of all individual equipment indicated above shall also be capable of being accessed for on-line programming. Verify by using current sensing relays on all fan motors.

S. Failure Alarm Status for the following items shall be provided through the EMS:

1. Combined Safety and Failure Alarm: One (1) for each EMS controlled exhaust fan, make-up air fan, or Rooftop AC Unit.
2. High/Low Temperature Sensor Alarm for each Temperature Sensor installed; initially set at 3 Deg. F. above or below setpoint.

3. High Relative Humidity (RH) Sensor Alarm for each RH Sensor installed, initially set at 65% R.H.
4. High Carbon Dioxide Level Alarm for each carbon dioxide sensor installed, on a rise above 1300 Parts Per Million, PPM, adjustable.
5. Emergency Overflow Condensate Moisture Detection/High Water Level Alarm (**all rooftop units**): De-energize unit served and sends alarm to EMS.
6. High Carbon Monoxide Level Alarm for Classroom Areas, on a rise above 70 Parts Per Million, PPM, adjustable. Provide for individual alarm indication of Carbon Monoxide Sensor for each Classroom Unit, separate from general safety alarm circuit alarm.

T. Provide cumulative run time logging and indication for equipment noted in Paragraph "R", above.

U. Provide analog indication for the following:

1. For each Rooftop A/C Unit receiving new controls:
    a. Space temperature, Deg. F.
    b. Supply air temperature, Deg. F.
    c. Space Relative Humidity, % R.H., new units only (except as noted below where units share common sensor).
2. Re-use existing indication of outside air temperature in Deg.F. for each building.
3. Re-use existing indication of outside air relative humidity in % R.H. for each building.
4. Space Temperature, Degrees F.:
    a. Main Electrical Room.
    b. MDF Room.
    c. All IDF Rooms, refer to plans for quantity
    d. All Electrical Rooms, refer to plans for quantity.
    e. Main Fire Riser Room.
5. Space Carbon Dioxide Level, PPM, (refer to plans for quantities and locations):
    a. Gymnasium.
    b. Cafetorium.
    c. Library.

V. Building Computer Software Management features:

1. Provide minimum of 15 User Selectable Passwords with a minimum of three levels of access. Highest level provides system access, secondary level provides access for command to field devices only, lowest level provides monitoring capabilities only with no field control allowed. Password access will be logged with time/date stamp and associated user ID.
2. Provide a minimum of 16 Point Group Summaries with each point inclusion selectable by system operator. Summaries will have a minimum of six character

identifiers for each group. A separately selectable All Points Summary shall be available to the operator for a view of the complete system. Alarm Summaries, listing all points in an alarm status shall be provided, and shall be Owner definable.

3. Trend logs and summaries:
   a. The Network Manager, and existing Central Computer, shall be provided with, as a part of this contract, the ability to periodically trend any hardware, software, or simulated point within any of the attached DDC panels, for this project, at an Owner selectable interval of a minimum of once per second, up to at least once per 1000 minutes.
   b. The trending programming for selected points and all feature attributes of these points shall be accomplished online at the CPU with no disruption of dynamic communication with the remote DDC panels. The operator shall be able to add, delete, and modify points and attributes at any time while online. Online programmable attributes shall include:
      - Point addition, deletion, and modification
      - Sampling intervals and ranges
      - Historical samples to be stored per individual point
      - Dynamic data values
      - Engineering units of each point
4. Online editing capabilities shall be provided for, but not limited to the following:
   a. Add/Delete Points
   b. Modify Engineering Units
   c. Modify/Create Point Groups
   d. Adjust Set Points
   e. Adjust Individual Start/Stop Time
   f. Trend Selected Points
   g. Observe Any System Point, Hardware, or Software
      This editing capability shall be for both CPU resident programs and remote DDC panel programs.
5. English language shall be used for all inputs, outputs, and display. Code or computer language will not be acceptable.
6. Remote DDC Field Communication: Communication between the Network Manager and the remote DDC panels shall be achieved via digital transmission utilizing a distributed polling technique for recognition of all field points both software and hardware points status issuing of commands, programming of DDC units, etc. Additionally provide software for the existing Central Computer to allow the same interaction/communication features as noted for the Computer Warkstation Building. Data transmission via hardwire interlock shall be compatible with electric category type 3002 as described in Bell System technical publications for data transmission using 4600 Baud Rate.
7. CRT Format:

a. The existing CPU located at the Facilities Central Maintenance Office CRT format shall include and display in an individually dedicated and protected area of the viewing screen the following Dynamic information:

1) The current time, date, and day of week (including Holidays).
2) Sequential as occurred alarms.
3) Visual indication of "alarm", "on" or "off" normal conditions which are active; all alarms to print out as they occur at the system front end.
4) Current operator identification.
5) Operator work area to display various forms of point information issue commands, and data base information relevant to current activities.

b. Operator will have full access to the system for issuing commands, etc. while this display is active.

8. Provide a graphic software package and programming to result in a schematic illustration for each controlled piece or group of pieces, of equipment to illustrate all related controlled variables, set points and operating parameters. Additionally provide a building floor plan with room numbers and locations of all space sensors and controlled equipment. The user shall be able to click on any feature to pull up related system graphics.
9. Provide a portable operators terminal or fully operable and programmed laptop computer terminal for use by the Owners designated service technician to view, monitor and trouble shoot the control system via service jacks at all controllers and temperature sensors.

W. For all above ceiling or roof mounted equipment with controllers not mounted on or in the units, the EMS controllers should be mounted directly above the ceiling where the space temperature system is located.

2.14 WEB BROWSER INTERFACE

A. Provide Internet/Intranet Connectivity utilizing a Web Browser as follows:

1. Shall be a "Server" based product that provides browser access to Ethernet enabled automation controllers. Access is accomplished by utilizing a standard web browser. No other "client" side software shall be necessary to view and utilize the system. The "Server" hosting the Web Application can be located anywhere on the Internet. The software functions by taking real-time data from the active automation systems and combining that information with the appropriate graphic file in an HTML format to be viewed by the web browser. The number of simultaneous users connected to the web application shall only be limited by the capability of the server hosting the application. The application should be able to service multiple sites.
2. The graphics utilized for this system shall not require external applications to convert the images for use between the web server-based application and the

traditional graphical user interface. Graphics shall be interchangeable between applications.

3. Web Browser Server shall receive server-based software which shall support Microsoft's .NET standards for the exchange and interoperability of information and data.
4. **Server-based software upgrades shall be free to the owner for the first five (5) years the server is owned by the building Owner.**

B. The Host Server (existing) shall be reused and shall meet the minimum requirements noted for data servers.

C. The Web Browser Interface shall include the following user configuration requirements:

1. Usernames and passwords can be setup via the Web Browser Interface. Physical access to the server is not required but will be password protected.
    a. Individual user names/passwords are to be utilized.
    b. Usernames/passwords can be specifically unique to allow the user to be automatically redirected to a specific site, and or graphic display when logging into the system.
2. Passwords can be configured to allow the user to modify setpoints or not.
3. All user configuration functions shall be provided through an intuitive graphical user interface.
4. Web Browser Interface shall not require any external applications, "Client Side" software or "Plug-Ins" to connect, view, or control any aspect of the building automation system.
5. Access to the installed automation system shall be performed through Microsoft Internet Explorer.

D. Site Graphics shall meet the following requirements:

1. Graphics displayed through the Web Browser Interface must be the same graphic images provided through the Graphical User Interface described above. No external applications are to be required to interchange graphic images between the web server application and the graphical user interface.
2. Trend data must be able to be displayed graphically and in "spread sheet" format without the addition of any additional client side software, plug-Ins, or additional applications.
3. Digital Start/Stop Logging shall be able to be displayed and printed from the browser interface without the addition of any additional "client side" software, plug-Ins, or additional applications.
4. The display and printing of alarm data shall be performed without the addition of any "client side" software, plug-Ins, or additional applications.
5. Points that are manually overridden shall be displayed on the graphic screen by an icon adjacent to the overridden point to provide a quick visual indication of any points on the screen that are overridden.

6. The viewing and modification of weekly schedules shall be performed in a graphically intuitive manner that is consistent with the non-Web Enabled application. This shall be performed without the addition of any "client side" software, plug-Ins, or additional applications.
7. The viewing and modification of annual holiday schedules shall be performed in a graphically intuitive manner that is consistent with the non-Web Enabled application. This shall be performed without the addition of any "client side" software, plug-Ins, or additional applications.
8. "Right clicking" on the point and modifying the value shall perform the editing of point values.
9. Points can be placed in "manual" or "automatic" mode from the Web Browser, providing password restrictions for the user allow such functionality."

2.15 ELECTRICAL WIRING

A. All wire, wiring, and conduit required for the operation of the control system shall be the responsibility of this section of the specifications and shall be installed as described and in full accordance with the requirements of Division 26 of these Specifications. Conduit down in walls to space sensors and back to accessible ceiling space to be provided by Division 26. Automatic Controls Contractor to coordinate installation of conduit of space sensors with Division 26 and provide if not provided by Division 26.

B. The control manufacturer shall be responsible for supplying complete and approved wiring diagrams and installation supervision of the wiring of the control system and shall perform all necessary set-up and calibration labor.

C. Starters, furnished in other sections of these specifications, shall be installed under Division 26, but all wiring from auxiliary contacts or relays shall be under this section of the specifications.

D. All wiring, including Class 2 signal wiring, shall be installed as a Class 1 electrical system as defined by the National Electrical Code (NEC).

E. All control conduits with #8 conductor or smaller (cross-sectional area) shall have one (1) spare conductor each run in conduits carrying 5 or more conductors. Spare conductor shall be same size as the majority of conductors sized in the conduit. Conduits with 9 or more conductors shall have two spare conductors. Terminate spare conductors at control panels in an acceptable manner and tag wires as "spare".

F. The electrician shall be licensed by the City and local authorities having jurisdiction over the area in which the work is to be performed.

G. All class 1 control wiring conduit shall be run with not more than 30% fill based on inside conduit diameters and cross-sectional area. This provision is for future modifications or additions to the control system.

H. All conduit carrying shielded twisted pair cabling, communication, or signal, Class 2 wiring, shall be sized for a maximum of 40% fill based on inside conduit diameter and cross-sectional area. This provision is for future modifications or additions to the control system.

I. All wiring shall be run in conduit. All Class 1 power wiring shall be run in conduit. All Class 2 signal wiring, low voltage control type, shall be run in conduit. No exposed wiring of any kind will be allowed. Class 2 signal wiring may be installed without conduit but only when installed above fully accessible lay-in ceilings and if run-in plenum rated cable supported independently from structure and run parallel and perpendicular to the structure.

J. All conduit shall be 3/4 inch size minimum, except raceways terminating at control devices manufactured with 1/2" knock-outs, i.e., conduit from junction box to smoke or fire detectors (local single device wiring only).

K. Electrical Systems Installer on project may perform temperature control conduit and wiring installation on project only that this portion of work shall be bid directly to the Temperature Control Systems Installer, and all work in relation to temperature control wiring shall be done subordinate to this Section of the Specifications. Wiring terminations shall be under this Section of the Specifications.

L. Under this Section of Specifications, coordinate the furnishing and installation (by the job site electrician), at an early stage of construction (when walls are being constructed) galvanized steel back boxes for all wall mount space sensors, suitably secured with 3/4" EMT routed to four inches (4") above an accessible ceiling. This will also require the installation of pull wire for installation of sensors and related wiring at a later stage of construction under this Section of Specifications.

M. Work Not Included Under this Section of Specifications: The Electrical Systems Installer shall provide:

1. Branch circuit and motor feeder circuit conductors, raceway, connections, and overcurrent protection for each motor or item of equipment furnished by the Owner or other Contractors.
2. Installation of motor controllers furnished by the Owner or other Contractors, along with branch circuit and motor feeder circuit conductors, raceway, and connections in accordance with the manufacturer's approved wiring diagrams.
3. Disconnect switches, where indicated on the drawings or required by codes, except as provided as an integral part of manufactured equipment.
4. Power supply conductors, raceway, connections, and over-current protection for input power to HVAC Temperature Controls, HVAC Automation, and HVAC Energy Management Systems in accordance with approved rough-in and connection diagrams furnished by the system suppliers only when shown on Division 26 Drawings.

5. The above represents an outline of the work for the purpose of describing one division of the work which is acceptable to insure that all work is contained within the General Contract. The Contractor is fully responsible for the installation of complete, operating systems in accordance with the functional intent of the specifications.
6. Nothing herein shall be construed to confine the Contractor from assigning the work to any single member or group of systems installers deemed best suited for executing the work to effect completion of the contract. Refer to specific bidding instructions of the General Contract for the actual division of the work.
7. Installation of all control conduit in walls to accessible above ceiling space.

N. Work Included Under this Section of the Specifications: The Mechanical Systems Installer shall provide:

1. Motors and equipment, erected in place and ready for final connection of power supply wiring, along with manufacturer's approved wiring diagrams.
2. Motor controllers, in suitable enclosures and of the type and size in accordance with the manufacturer's recommendations and NEMA requirements, along with properly sized overload elements or devices which are normally provided as part of manufactured equipment.
3. Disconnecting switches or devices which are normally provided as a part of manufactured equipment.
4. Rough-in and connection diagrams for input power supply and connections for the HVAC Temperature Control, HVAC Automation, and HVAC Energy Management Systems.
5. The above represents an outline of the work for the purpose of describing one division of the work which is acceptable to insure that all work is contained within the General Contract. The Contractor is fully responsible for the installation of complete, operating systems in accordance with the functional intent of the specifications.

O. Contractor, under this Section of the Specifications, shall insure the furnishing and installation of:

1. All new branch circuit wiring, conduits, protective devices and accessories for power wiring to serve new control panels, control transformers, electric control dampers and valve actuators, combination fire-smoke dampers and any other control system power requirements where not shown to be performed by others. Field verify spare electrical circuits available where applicable. Do not tap into existing branch circuits without approval by the Owners Representative. Run all new circuits back to electrical feeder panels.
2. Conductors and raceways for the HVAC temperature control, HVAC automation, and HVAC Energy Management System in accordance with approved rough-in and connection diagrams furnished by the system suppliers.
3. Termination of all conductors, raceways, devices, and connections for low voltage systems for the HVAC Temperature Control, HVAC Automation, and HVAC Energy Management Systems in accordance with the provisions of Division 26,

and approved systems shop drawings to provide complete operating systems in accordance with the functional requirements of the specifications.

P. Wire all safety devices in series to include freezestats, firestats, smoke detectors, and static pressure high limit controls; any single device when tripped, shall de-energize air handling equipment.

Q. Wiring Requirements shall also include the following:

1. The conduit/wiring system required for the basic electric controls and Energy Management System shall be a complete and operating system. Conduit sharing with other unrelated electrical systems is not permitted.
2. All wiring shall be labeled at both ends and at any spliced joint in between. Wire and tubing shall be tagged using 3M, Scotch Code Write On Wire Marker Tape Identification System; product number SWD-R-11954 with 3/4" x 5/16" write-on area or SLW 12177 with 1" x 3/4" write-on area and with 3M Scotch Code SMP Marking Pen. In addition to tagging at field device end and at spliced joints, a tag shall be placed 6" after entering each DDC panel. Identification and tag information shall be included in engineering/wiring submittal which must be submitted for Owner approval prior to beginning work. Tag information shall coincide with equipment/point information as written in the specification Input/Output summary.
3. Digital Input (D.I.) wiring (Class 2) may be run in a common conduit with Digital Output (D.O.) Wiring (Class 1) where local codes permit.
4. Analog Input (A.I.), Analog Output (A.O.), Digital Input (D.I.), and Network Communications Trunk (N.C.T.) wiring may be run in a common conduit.
5. Digital Output (D.O.) wiring run in a common conduit with Analog Input (A.I.), Analog Output (A.O.), or Network Communication Trunk (N.C.T.) is not permitted under any circumstances.
6. AC line power to DDC panel shall be #12 THHN.
7. Digital Output (D.O.) wiring shall be #14 THHN.
8. Digital Input (D.I.), Analog Input 4-20 mA (A.I.) and Analog Output (A.O.) wiring shall be #18 TSP (twisted shielded stranded pair with drain wire).
9. Analog Input or voltage types (A.I.) wiring shall be #18 TSP (twisted shielded stranded pair with drain wire).

2.16 GENERAL

A. System shall be installed complete with DDC panels, remote panels, thermostats, sensors, control dampers, all actuators, switches, relays, alarms, etc., in accordance with the extent of the sequences of operation. Provide all auxiliary equipment required. All controls shall be installed under this section of work, with the exception of automatic dampers and taps for flow switches and pressure sensing devices which shall be installed under Section 23 30 00.

B. Control Systems manufacturer shall submit a complete and final check list verifying final calibration and set points for each system prior to final construction review.

C. Complete control drawings shall be submitted for approval before field installation is started. The submittals shall give a complete description of all control devices and show schematic piping and wiring, as well as a written sequence for each operation.

D. All control dampers shall be furnished by Control manufacturer and shall be set in place, under other sections of the specifications, and be adjusted for proper operation, including the installation of necessary linkages with actuators under this section of specifications. Contractor shall also furnish, under other sections of the specifications, install any necessary blank-off plates required to fill duct when damper size is smaller than the duct. All outside and relief air damper frames and blank-off plates shall be caulked air tight with non-hardening silicone caulking to the ductwork or frame opening.

E. Work under this section shall regulate and adjust the control system, including all thermostats, relays, motors, and other equipment provided under this contract. They shall be placed in complete operating condition subject to the approval of the TAB firm. Contractor shall cooperate fully with the balancing agency in the testing, check-out and adjustment of the various systems. Contractor, under other sections of these specifications, shall install all and automatic dampers.

F. Control system herein specified shall be free from defects in workmanship and material under normal use and service. If, within twelve (12) months from the date of "Substantial Completion", any of the equipment herein described is proven to be defective in workmanship or material (except electrical wiring done by others), it shall be adjusted, repaired, or replaced free of charge.

PART 3 - EXECUTION

3.1 SEQUENCE OF OPERATION - ROOFTOP UNITS WITH HOT GAS RE-HEAT (SINGLE ZONE TYPE) - (3 TONS AND LARGER)

A. The direct digital control system shall monitor and control each rooftop A/C unit. An electronic room temperature sensor shall, through a local terminal unit DDC Controller, one per unit, control its DX Cooling (minimum 2-stage for units 7 tons and greater (required on units over 7 tons in size)), hot gas reheat coils, 1 or 2-stage gas heaters (for units 3 tons in size and larger) and economizer, outside, return and relief/exhaust air dampers to provide the following sequences:

1. The DDC controller shall be of the automatic change-over type to provide for a heating and a cooling set point to be software interlocked to prevent the cooling set point from being set below the heating set point and vice-versa. Provide for a minimum 2 Deg.F. dead band between set points, adjustable up to 5 Deg.F.
2. Include optimized start and stop features for unit control where the space temperature is compared to the ambient outdoor air temperature to calculate the

minimum run time necessary to attain the normal mode set point by the occupied time scheduled.

3. Any time the rooftop A/C unit is in operation in the "Occupied" mode, the outdoor air damper shall open to its minimum position except during morning warm-up (optimized start), night set-back, morning cool-down (optimized start) and night set-up. For units specified to have carbon dioxide sensors, the outside air dampers shall remain closed in the occupied space, except when the unit is operated in the normal occupied mode in which case the outside air dampers shall open to the minimum-minimum position scheduled. Once the carbon dioxide set point of 1,100 PPM, adjustable, is reached; the outside air damper shall modulate further open to maintain this set point but in no instance shall it open beyond the minimum-maximum position scheduled.
4. Upon a need for mechanical cooling, the DX cooling system shall be energized in such a manner as to maintain a stable space temperature set point of 72 Deg.F (adj.). On a rise above set point the 1st stage of cooling, first compressor, shall be energized. For 2 stage units the second compressor (or stage) will only be energized upon a further rise above set point and when the first compressor (or stage) has been on longer than 5 minutes, adjustable. On a decrease in demand for cooling the second stage compressor (or stage) shall be cycled off. On a further decrease in space temperature, the first stage compressor shall be cycled off. For units with greater than 2 stages of cooling a similar sequence shall occur for each stage up to full capacity of the unit. Each stage of cooling shall have a minimum off time of approximately 5 minutes (Variable as determined through PID loop control).
5. The space relative humidity (R.H.) sensor shall, through its DDC controller output signal, cause the unit to go into the dehumidification mode only when there is not a sensible cooling demand; and, upon a rise in space R.H. above set point, 60% R.H., adjustable. All units shall have a hot gas reheat coil, energized via a hot gas solenoid valve, which shall be used to reheat the supply air to a nearly neutral temperature only when in the dehumidification mode. Provide R.H. sensors for all units. Should the space temperature drop to below the heating set point, the dehumidification mode shall be de-energized and the gas heat shall be allowed to cycle on as needed to satisfy the heating set point once the compressor is cycled off.
6. The heating temperature set point shall be 70 Deg. F., adjustable. On a drop in space temperature below heating set point, the furnace section shall be energized, in stages, as required, to maintain set point. The cooling system and hot gas reheat shall be de-energized while heating with natural gas. A supply air high limit control feature shall be provided to prevent the supply air temperature from raising above 90 Deg.F. by overriding and de-energizing the heat as required. The heat, when a demand for heat remains, shall shut-off for a minimum of three (3) minutes, adjustable, and be energized when the supply air temperature drops (fan runs continuously) below 80 Deg.F., adjustable. For 2-stage or greater heating units, the furnace heating sections will stage on as required to meet demand in a stable fashion.

7. When the outdoor air temperature is below 60 Deg. F., adjustable, the economizer dampers shall modulate, in sequence, as required, to satisfy the space temperature sensor's cooling set point. If the economizer cannot satisfy the space temperature set point (100% open) then energize the cooling system of compressor(s), as required. No enthalpy or return air comparison economizers allowed. Should the space relative humidity rise to 60% RH, adjustable, while in the economizer mode inversely reset the outside air dry bulb set point downward until the relative humidity drops to below 60% R.H. (use a 4% R.H. differential). Carbon dioxide sensor control shall be disabled when the unit is in the economizer mode.
8. An evaporator fan differential pressure switch will be interlocked through the DDC system in such a manner that anytime the unit fan is de-energized the gas fired heat and cooling compressors will also be de-energized unless operated for a heat purge sequence upon furnace shutdown after which time the furnace will shut down.
9. Space temperature sensors will also be used to operate the units in the unoccupied modes of operation.
10. During the optimized start morning "warm-up" mode (winter), the air unit fan motor will be cycled on and the unit furnace will be energized, as required, to bring space temperature to the normal heating set point. During this mode the minimum outdoor air damper will be closed. When the space reaches warm-up set point, one (1) Deg.F. below the heating set point, the unit will then be allowed to operate in the "occupied" mode at which time the outdoor air damper will be allowed to open to minimum position, or be controlled by a carbon dioxide sensor as indicated elsewhere herein, and the system will be controlled as described above. Warm-up shall occur not more than once each day. The discharge air temperature high limit control sequence shall remain in control during the morning warm-up mode.
11. During the optimized start morning cool-down (summer) mode, the air unit fan motor will be cycled on and the unit cooling system will operate at the capacity as required to bring the space temperature to the normal cooling set point. During this mode, the outdoor air damper will be closed. When the space reaches cool-down set point, one (1) Deg.F. higher than the cooling set point, the unit will operate in the occupied mode at which time the outdoor air damper will be allowed to open to its minimum position, or be controlled by a carbon dioxide sensor, as indicated elsewhere herein, and the space temperature sensor will control as described above. Cool-down shall occur not more than once each day.
12. During the night set-forward and night set-back modes the equipment will be cycled as required to maintain those set points; on at 80 Deg.F. and off at 76 Deg. F., adjustable, for set-forward and on at 55 Deg.F. and off at 60 Deg.F., adjustable, for night set-back. The outdoor air dampers shall be closed in both of these modes. The discharge air temperature high limit control sequence shall remain in control during the night set-back mode.

B. Rooftop A/C units shall be furnished with factory assembled modulating economizers with digital controller which shall be interfaced in such a manner as to:

1. Allow the mechanical cooling system to be locked out and economizers to be enabled and disabled as hereinafter described. However, should the economizer be

unable to maintain the cooling set point, the mechanical cooling system shall be energized as needed.

2. Digital controller shall be interfaced in such a manner that when the A/C unit is in the economizer mode of operation it shall be controlled so it opens the outdoor air, above minimum setting, where applicable, only on a cooling demand by the space temperature sensor.
3. Instrumentation and Control system provider shall furnish and install all necessary signal conditioners, relays, etc. to perform the economizer interface as described herein. Coordinate these requirements with each specified equipment manufacturer.
4. Provide for a discharge air temperature control, which shall prevent the discharge air temperature from dropping below 53 Deg. F., adjustable, when the unit is operated in the economizer mode. Override the economizer dampers as needed to achieve this low limit condition. Coordinate this provision with each specified equipment manufacturer.

C. Provide a wall mounted carbon dioxide sensor which shall modulate, via an analog signal to the rooftop unit, the return and outside air dampers, in sequence, to maintain a maximum level of 1000 Parts Per Million (PPM), adjustable for following units:

1. Gymnasium units – RTU- GYM-NE, GYM-NW, GYM-SE, and GYM-NW.
2. Cafetorium units - RTU-CAFÉ-SW, CAFÉ-SE, CAFÉ-NE, and CAFÉ-NW
3. Library – RTU-LIB-N, E and W.

Outside air dampers of multiple units shall modulate together when they are energized. The return damper shall modulate from its fully open position to the corresponding sequenced position with the outside air damper, which shall go from its fully closed position up to its maximum-minimum value scheduled. The return air damper shall have a software safety interlock that will not allow it to go past 50% closed during mechanical cooling. Carbon dioxide sensor control shall be locked out when the unit enables the economizer cycle.

D. Should the space temperature drop to 1 Deg.F., adjustable, below heating set point while the RTU is operating in the dehumidification mode, the unit shall go into alarm and revert to fan and compressor or furnace cycling (on-off) to meet space temperature (sensible load only) requirements until reset.

E. For multiple units serving a common space, units shall stage on to maintain space temperature for portion of space served.

F. Cafeteria roof top units, and Kitchen rooftop units shall be interlocked with existing grease hood and Dishwasher hood exhaust fans in the following manner:

1. If any fan is energized and Kitchen unit (RTU-KITCHEN) and Cafeteria units are not currently energized, Kitchen Unit shall be energized.
2. When any fan is energized, kitchen unit outside air dampers shall modulate to the minimum-maximum position. If EF-DW is energized then no additional units shall

be energized. If KEF-KITCHEN is energized, then additional Roof-Top Units shall be energized as noted below.

3. When KEF-KITCHEN is energized, the make-up air fan, SF-KIT shall be energized and continue to run until KEF-KITCHEN is de-energized.
4. When two fans are energized or KEF-KITCHEN is energized, the Four Cafeteria Units will be energized and their outside air dampers shall modulate to the minimum-maximum position. When this occurs, this shall override the carbon dioxide sequence control for that unit(s). This will not override the economizer control sequence.
5. When the Kitchen fans are de-energized, the Kitchen unit shall modulate the outside air damper to the minimum-minimum position and the Cafeteria units shall return to normal operation.

G. Provide a condensate overflow moisture sensor/float in upper portion of drain pan that shall alarm the EMS and have a unit interlock shutdown when actuated. All new units shall be provided with this.

H. Provide a carbon monoxide sensor in each classroom mounted to the ceiling which shall alarm the "EMS and have a unit interlock to shutdown when over 70 PPM of carbon monoxide is sensed.

I. Unit safety circuit shall consist of fire alarm system interlock for all units over 2,000 CFM, overflow alarm in condensate drain pan, and carbon dioxide alarm (for classroom units).

J. Two temperature sensors shall be provided for the following units:

UNIT DESIGNATION	PRIMARY SENSOR LOCATION	SECONDARY SENSOR LOCATION
RTU-C103	Principal C103	Reception C102
RTU-72D	Office 72A	Office 72F
RTU-69	Workroom 69	Lounge 68

The primary sensor shall control heating and cooling set point, unless the space temperature in secondary space is greater/less than 2.5 Deg.F., difference from set point. When this occurs, the secondary sensor shall control the heating set point until such time as it is within 1 Deg.F. of space set point. Once this temperature is reached, the primary space temperature sensor shall return to being the control sensor for the unit.

K. For units less than 3 tons in capacity, they shall cycle to maintain space temperature and are NOT equipped with humidity control. Units that do not have hot-gas re-heat coils, shall cycle to maintain space temperature such that when space temperature is reached the unit shall shut-off for a minimum of 5 minutes, adj., prior to re-energizing.

3.2 SEQUENCE OF OPERATION - EXHAUST AIR FANS

A. Where fans are designated to be thermostatically controlled, on a rise in space temperature above 78 Deg.F., the respective fan controlled shall be energized. When a fan is energized, the respective make-up air dampers, where indicated on the Drawings, shall be opened. On a fall in temperature to 75 Deg.F., the fan shall stop, and interlocked dampers shall be closed. Where fans are to be interlocked with heaters serving the same space, coordinate the furnishing of combination heating-cooling thermostats (individual thermostats for the fan and heater not allowed) such that heating and cooling cannot occur simultaneously.

B. Install fan speed control switches at a convenient location on direct drive fans on the load side of the disconnect. Refer to equipment schedules on the Drawings for direct drive fan designation. Fan speed controllers are furnished with the fans as specified under other Sections of these Specifications.

C. Other exhaust fans shall be interlocked, be provided with locally manually controlled motor rated toggle switches with pilot lights where manual switches are scheduled and where specified in other sections of these specifications.

D. EMS controlled fans shall run continuously during normal occupied mode and be de-energized during all other modes of operation.

E. Kitchen dishwasher machine exhaust fans shall be interlocked to immediately be energized when the dishwasher is started. Include the addition of a time delay relay in the control circuit such that the exhaust fan will continue to run for five (5) minutes, adjustable, after the dishwasher machine is de-energized (interlock through booster heater control panel).

F. Interlock kitchen grease hood exhaust and makeup air supply fans, with respective fire suppression system of hood served to shutdown fans during discharge of suppression agent as required by local Code. Generally the make-up air fans or make-up air unit are turned off and the exhaust continues to run. Provide fan interlocks to operate exhaust and make-up air fans or unit when switched "on" and "off" at the respective hood served. Switches are furnished with the hoods as specified in other Sections of these Specifications. Additionally, provide for the interlock with the grease exhaust hood manufacturer furnished exhaust air thermostat which shall energize the hood exhaust air system upon a rise in temperature above its set point.

G. Dry Storage exhaust fan shall be energized based on a rise in space temperature over 78 Deg F, adjustable, during cooling mode only. Dry storage fall shall also be energized based on a wall switch. The space temperature sensor and wall switch shall be wired in parallel such that either shall be able to energize the fan.

H. For the Kiln Room the exhaust fan system shall be interlocked to energize the RTU that serves this room should the space temperature rise to above 80 Deg.F., adjustable. Alarm the front-end monitoring system and "page" the designated maintenance personnel should this space temperature ever rise to above 90 Deg.F.

I. Provide firestats for each make-up fan, over 600 CFM and under 2000 CFM capacity, set at 125 Deg.F. (adjustable), automatic reset type, to de-energize fans on a rise above setpoint.

3.3 SEQUENCE OF OPERATION - NIGHT SET-BACK

A. A night set-back mode shall be provided to keep equipment from operating except as needed to heat the space to protect the building systems from freezing and potential water damage.

B. Designate a space temperature sensor, to be located on an interior partition within 8 feet of a Northern exposure, selection as recommended by the balancing agency, to be used for night set-back control. Sensor, adjustable, shall be set for 55 Deg.F. Provide one per AHU or system.

C. Below set-back set point, respective rooftop A/C or heat pump units shall receive a control signal and shall be started if not already energized.

D. Lockout cooling systems, ventilation cycles, morning warm-up and cool-down modes, night set-up mode, close all outside and relief air dampers and de-energize all EMS controlled toilet and locker exhaust fans located in the spaces served.

3.4 SEQUENCE OF OPERATION - MORNING WARM-UP MODE

A. A warm-up mode shall be provided to warm the building, or area served by a system, to within 1 Deg.F. of the normal occupied heating setpoint, adjustable of 71 Deg.F., through the building Energy Management System optimized start feature.

B. Warm-up shall function the same as night setback, except the set point shall be as noted above.

C. Lockout the warm-up mode after the cycle is completed until the following scheduled cycle, generally not to occur more than once per day.

D. Lockout cooling systems, ventilation cycles, night set-back, morning cool-down, night set-up, close all outside and relief air dampers and de-energize all EMS controlled toilet and locker exhaust fans.

3.5 ELECTRICAL INTERLOCKS

A. Certain electrical interlocks shall be as listed herein and in other sections of these specifications.

B. All electrical interlocks shall be made by means of auxiliary contacts on motor starters or shall be accomplished with separate relays unless indicated otherwise. No motor power lead shall be utilized in an interlock circuit, unless indicated otherwise. Each separate control power lead serving a starter shall be provided with a disconnecting switch suitably identified and housed, which may be a toggle switch or other suitable disconnecting device, of proper capacity and number of poles.

3.6 TEST, ADJUST, AND BALANCE SUPPLEMENTARY PROVISIONS

A. Under this section of the specifications, provide a temperature test port adjacent to all duct mounted EMS sensor locations. Additionally, furnish any other permanent test tees or wells for sensor calibration and for verification of all system monitoring data.

B. Under this section of the specifications, provide all pressure taps, sensors, wiring/cabling, etc., to be connected to the Energy Management System to include all points necessary for the sequence of operations specified hereinafter.

C. Assist the TAB Agency in all sensor calibration and during all functional performance testing of controls, basic and devices and EMS controlled equipment.

3.7 DDC CONTROL

A. Provide complete DDC Control for all equipment as indicated elsewhere herein.

B. Not more than one local unitary direct digital controller shall be utilized per AHU/piece of equipment. Each DDC controller used for Global System control and for air handling units shall have their own real time clock.

END OF SECTION