SECTION 15104 – HVAC CONTROL SYSTEMS

PART 1 – GENERAL

1.1 SCOPE:

A. Control of heating, ventilating, and air conditioning systems is primarily achieved by the application of microprocessor based digital controls. Factory furnished controls are to be provided on select manufactured systems, electric controls may be used for select applications. Pneumatic controls are not used.

B. Interoperability (BACnet, LonWorks, ModBus) between the Energy Management System (EMS) and HVAC equipment manufacturers' microprocessor controls is currently not an accepted practice; however, all EMS systems installed shall be capable of BACnet operations.

C. All controls shall be installed by MCPS approved Energy Management System (EMS) contractors. The controls installations are to be bid along with the general contract for construction as a sub-contract of the mechanical work

1.2 DESIGN RESPONSIBILITIES: Project Mechanical Engineer and the Energy Management System consultant shall work together to assure that the HVAC systems are controlled in accordance with Engineer's design intent and that the EMS is per MCPS standards. Refer to Section 15002 regarding communication procedures. The delineation between responsibilities of the design engineer and EMS consultant are as follows:

A. Project Mechanical Engineer: Project mechanical engineer is responsible for HVAC system design including equipment/systems sequences of operations. The A/E is also responsible for forwarding any design updates, Addenda, RFI's, etc. to the EMS Consultant.

B. EMS Consultant is responsible for writing the control specification, Section 15900, and for providing control drawings. All of the EMS Consultant's work is subject to the approval of the Project Mechanical Engineer and MCPS. The EMS Consultant will:

1. Create Control Zones for the building mechanical systems.
2. Incorporate the Engineer's flow diagrams and control sequences into control drawings.
3. Provide control drawings for inclusion in the contract documents including:
    a. Building control zone maps
    b. Equipment/systems flow diagrams (originally provided by the Engineer) with control devices added.
    c. Sequences of Operation
    d. Points Lists
4. Review and comment on each review submission with regard to HVAC systems and controls.
5. Review the controls contractor construction submittals. This includes verification that control submittal is in compliance with equipment manufacturer submittals.
6. Verify controls systems installation and performance is in compliance with contract.

C. EMS Consultant is responsible for full coordination with the A/E that is to include requesting the required CAD backgrounds, MEP updates, etc. The documents required for review (as indicated in Section 15002) shall be forwarded to the Architect for incorporation into the full review submission when requested.

1.3 ENERGY MANAGEMENT FUNCTIONS: The EMS performs Start/stop control of mechanical systems/equipment by zones (similar to time clock functions). EMS start/stop commands are generated via schedules, optimization, warm-up/cool-down, set-back/set-up, and demand limiting routines.

A. Heat pumps are started/stopped per zone as created by DOAS distribution system; i.e. heat pumps served by a particular DOAS will be zoned as one.

B. Spaces such as Cafeteria, Multi-Purpose Room, Gymnasia, Locker Rooms are controlled as distinct start/stop zones. Spaces such as Wresting, Dance, Auxiliary Gyms are normally grouped into a control zone.

C. Exhaust fans (not controlled by local switch or thermostat) are started/stopped or enabled/disabled along with the zones they serve. Design of exhaust and relief fans shall correlate DOAS, RTU/ERU, or AHU zoning so fans can be started/stopped in conjunction with zone operation.

D. Pumps (with VFDs) serving heat pump water loop shall run 24/7.

1.4 SUBMITTALS: Temperature controls submittals shall be reviewed by the Energy Management consultant before being sent to the mechanical consulting engineer. After completing his review, the Energy Management consultant will forward all but two copies to the mechanical consulting engineer. The Energy Management consultant will retain one reviewed copy and forward one reviewed copy to MCPS Energy Management. Upon completion of the review by the mechanical consulting engineer, he shall return the reviewed copies to the Architect for distribution; one copy bearing the consulting engineers review stamp shall be returned to the Energy Management consultant.

PART 2 – PRODUCTS

2.1 CONTROL COMPONENTS: Control components are specified by the Energy Management Consultant. Design mechanical engineer shall assure that system design is compatible MCPS standard control devices

A. Dampers, when not part of a manufactured system, will be furnished under the control section with installation by Division 15. Air leakage in the damper closed position will be specified not to exceed 15 cfm per square foot of damper at 6 inches water gauge differential unless design engineer requires different performance. Return air dampers are to be normally open; outdoor intake dampers are to be normally closed.

B. Control Valves: Control valves shall be two-way or three-way pattern and shown on contract drawings. Valves for condenser water shut-off are normally 2-way line size; 3-way line size valves are used to accommodate minimum condenser water flow. Proportional control valves shall be sized for a maximum pressure drop of 5 psig at rated flow. All valves are to be provided by controls contractor, constructed for tight shutoff and shall operate satisfactorily against system pressures and differentials. Valves with size up to and including 2" shall be "screwed" type with 250 psi static pressure body rating; 2-1/2" and larger valves shall be 'flanged' configuration. Butterfly valves may be used for modulating control in 6” and larger sizes; butterfly valves shall not be used for shut-off duty or smaller than 6” sizes.

C. Valve and damper actuators are electric and furnished by the EMS contractor except for HVAC equipment provided with factory furnished controls. Approved actuators are Belimo AF and LF series with manual override or similar of Delta and Siemens.

1. Spring returns are provided for all actuators associated with equipment introducing outdoor air for freeze protections.

2. End switches to prove valves or dampers open are provided in response to sequences of operation.

D. Safeties:

1. Temperature safeties such as low limits and freezestats, where not components of factory furnished control system, will be specified by the EMS Consultant. Freezestats are normally automatic reset type, except those furnished for RTUs/ERUs are manual reset.

2. Smoke detectors/dampers:

a. Smoke detectors are to be specified in Division 16.

b. Smoke dampers are to be specified by the design mechanical engineer with installation by Division 15.

1) Wiring of smoke detectors to fire alarm system shall be by Division 16.

2) Wiring of smoke detectors to smoke dampers shall be by Division 16.

3) Control section of the specification will provide for the wiring of smoke detectors to fan starters. Design mechanical engineer shall provide the Energy Management consultant with clearly specified smoke and fire control sequences, particularly if a smoke control mode is specified.

E. Sensors:

1. Temperature: Electronic, RTD copper wound or Balco wire wound types, 1000 ohm at 70° F, or thermistor resistance sensor, maximum 10,000 ohms at 70° F; accurate to ±0.5°F over their maximum operating temperature limits. Sensing elements shall be of a configuration such as to accurately sense temperature of the mediu m (water or air) over the full range of the piping, duct, casing, or equipment. All temperature sensors in piping shall be installed in wells with conductive gel.

   a. Space sensors are provided with override push-button for heat pumps and equipped with RJ-11 (or similar) plug-in jacks for communication via a portable interface terminal, equipped with setpoint adjusters software limited to ±2°F above/below the programmed heating/cooling setpoints; furnished without thermometers or displays.

   b. Space sensors in Cafeteria, Locker Rooms, Corridors, Storerooms, and Gyms shall be flush mounted or protected with suitable vandal-proof guards mounted independent of sensors.

2. Humidity sensors: Range shall be 10-90% RH with ±2% RH accuracy; wall mounted or insertion type as required by the installation.

3. Carbon Dioxide Sensors: Wall or duct insertion type, 0-2000 ppm range, typical accuracy of ±30 ppm or ±2% of reading between 60°F and 90°F, 0-10 VDC or 4-20 mA output, less than 5% drift over 5 years, 5 year calibration interval; equal to Vaisala GMD20. Wall mounted units shall be furnished with blank off cover for LCD display with separate tamperproof wireguard.

4. Static Pressure Sensors:

   a. Duct static pressure sensors shall be of the solid state diaphragm type with integral 2-wire, 4-20 mA signal conditioning and high and low adjustments; 0-5" w.g. range.

   b. Space Pressure Sensor: Solid state, temperature compensated piezoresistive balanced bridge, 4-20 mA output, -0.25 to +0.25" w.g. range, ±0.02% at 77°F accuracy, ±0.2% drift/year stability.

5. Differential Pressure Sensing in Piping: Pressure sensors for control of Variable Frequency Drives on pumping systems shall be of the solid state type with a NEMA 1 cast aluminum housing; static error band shall not exceed ±0.5% of full scale; -40° to +200° F operating temperature range and temperature compensated; externally accessible Zero and span adjustments; 4-20 mA output.

F. THERMOSTATS:

1. Thermostats: Electric thermostats shall be two position type as dictated by the control sequence. Coordinate with each project LEED scorecard to ensure compliance with credit EQ6.2 – Controllability of Systems – Thermal Comfort.

2. Low-Temperature Protection Thermostats: Low-temperature protection thermostats are all automatic-reset type except manual resets are provided for RTUs/ERUs.

2.2 FACTORY CONTROLS: Factory furnished control systems are those that are provided with manufactured systems such as boilers, City Multi variable refrigerant flow systems, and direct expansion cooling split systems.

2.3 DIRECT DIGITAL CONTROL: Micro-processor based electric/electronic controls will be specified for:

A. All air handling units.

B. All water source heat pumps. Control valves, valve actuators, space sensors, microprocessors for space temperature control will be furnished by the control contractor and field installed.

C. DOAS: Control valves, damper and valve actuators; temperature, humidity, CO_2 sensors, microprocessors for temperature control will be furnished by the control contractor for factory mounting by DOAS/ERU manufacturer.

PART 3 – EXECUTION

3.1 MECHANICAL/ELECTRICAL INTERFACE: Mechanical-electrical coordination is required during design to enable the control systems to function properly. Power sources shall be provided for EMS controllers; refer to Section 15002.

3.2 MECHANICAL EQUIPMENT/EMS INTERFACE: Mechanical design engineer and EMS consultant shall coordinate contract specifications so control elements of equipment specified by design engineer are coordinated with control elements specified by EMS consultant and vice-versa. Of particular attention:

A. Water Source Heat Pumps: Equipment manufacturer to provide microprocessor for refrigerant system safeties and terminal strip for EMS control of units' start/stop and space temperature control of heating/cooling functions. EMS provides condenser water valve, microprocessor, and temperature sensors for field mounting.

B. Dedicated Outdoor Air Systems (DOAS) & Energy Recovery Units (ERU): Equipment manufacturer to provide microprocessor for refrigerant system safeties. EMS controls units' start/stop, dampers, and temperature control. EMS provides condenser water valve for field mounting. EMS furnishes microprocessor, sensors, actuators to DOAS/ERU manufacturer for factory installation.

C. Boilers: Boiler manufacturer to provide microprocessor for multiple boiler staging/sequencing control and all temperature sensors required to do so. EMS enables/disables boiler manufacturer's controller and monitors failure alarm generated by the boiler manufacturer's controller.

D. Cooling Tower: Tower manufacturer provides water level control, basin heater control. EMS provides control of fan start/stop and speed. Control contractor to provide hardwire interlock between cooling tower pump(s) and cooling tower fan(s) so fan(s) cannot run unless pump is running.

3.3 MECHANICAL DESIGN OBLIGATIONS: Mechanical design engineer shall show the following control elements on contract drawings:

A. Location of differential pressure sensing in piping for control of pumps' VFDs.

B. Location of static pressure sensing in ductwork for control of fans' VFDs.

C. Location of all space temperature sensors and thermostats.

D. Location of all temperature sensors in piping.

E. Control of exhaust fans; i.e. note in fan schedule whether fan is controlled by EMS, thermostat, local switch.

3.4 EMS DESIGN/DELIVERABLES:

A. Contract Drawings: EMS Consultant is to provide Control Drawings for inclusion into the contract document sets; Control Drawings shall include:

1. Building Zone Maps: Building Zone Maps shall be reduced size complete floor-by-floor drawings, each floor shall be depicted in a field that can be printed on an 8-1/2" x 11" sheet or an 11" x 17" sheet. Zone Maps shall show:

a. Building floor plan background shall show walls, doors, stairs, etc.

b. North Arrow

c. HVAC equipment controlled by the EMS shall be depicted symbolically:

1) AHUs, RTUs, DOASs, ERUs, EFs, etc shall be identified with designations consistent with those shown on HVAC design drawings.

2) Incremental equipment and VAV terminals (Heat Pumps, Fan Coils, Unit Ventilators, Cabinet Heaters) shall be identified by Zone and equipment numbers; e.g. UV 3-1 indicates #1 UV in Zone 3; V 4-4 indicates #4 UV in Zone 4;.

3) Space temperature sensors shall be shown and identified by Zone. Coordinate with Project Engineer to avoid any conflicts.

4) Simple duct runs shall be shown when it is not obvious as to which rooms are served by a piece of HVAC equipment.

d. Main Mechanical Rooms housing boilers, pumps shall be identified by name; equipment need not be shown.

e. Building Services Manager's office shall be identified by name.

f. A narrative descriptive listing of Zones; e.g. Zone 4, Classrooms, DOAS-2, Heat Pumps, Cabinet Heaters; Zone 7, Gym, HV-1.

2. Equipment/Systems Flow Diagrams: AE is to provide equipment/systems flow diagrams in CADD. EMS Consultant is to add control devices to the diagrams consistent with sequences of operations. These flow diagrams form the basis for EMS graphic depiction of equipment/systems and shall be complementary to sequences of operations and points lists. Wiring diagrams are not required.

a. Remote locations of sensing devices shall be provided by the Mechanical Design Engineer and should be shown on the mechanical drawings. The remote items shall be identified on flow diagrams. Included are such items as:

1) Differential pressure sensors for control of pumps' VFDs.

2) Static pressure sensors for VAV AHUs

3) Space temperature, humidity, pressure, CO_2, etc.

b. Control flow diagrams shall depict all control devices required for the equipment/system and clearly distinguish those that are:

1) Furnished by the controls contractor

2) Equipment manufacturer furnished

3) Employed/controlled by EMS

4) Local electric not incorporated into the EMS.

3. Sequences of Operations: The control sequences of operations are those provided by mechanical design engineer for HVAC equipment/systems. EMS consultant shall review the provided sequences, and modify them as necessary to be consistent with MCPS standards, correct with actual system design and controls provided. EMS consultant's revised sequences are subject to the approval of the design engineer.

4. Points Lists: EMS points lists, including hardware and software categories, shall be printed on the control drawings.

5. Flow Diagram, Sequence of Operation, and Points List for each system shall be presented on the same page (in the same box); i.e. all control requirements shall be contained on one drawing for each system. Multiple equipment/systems may be printed on the same page; i.e. each system does not need to be printed on a separate page.

B. Contract Specifications: EMS Consultant is to provide Section 15900, Temperature Controls and Automation System for inclusion into the contract document sets. Specifications shall include all control hardware and software required to be provided by the controls contractor pertinent to the project. Procedural requirements for the installation, performance verification, and documentation of the controls installation shall be specified. Included among the specific specification requirements are:

1. Hardware:

   a. Only previously approved EMS controllers can be used; any new controllers proposed by a vendor must receive MCPS approval prior to bidding a project.

   b. Only previously approved device hardware (sensors, actuators, etc.) can be used; any new devices proposed by a vendor must receive MCPS approval prior to bidding a project.

   c. All EMS temperature sensors installed for a project shall be of the same type; the only exclusion is where flush plate sensors are required. Flush plate sensors are required where a surface mounted sensor may be subject to damage, such as in Gyms, Locker Rooms, Corridors, Multi-Purpose Rooms, Cafeterias, etc.

   d. All space located sensors and thermostats shall be mounted with centerline 48" above finished floor.

   e. Controls contractor to furnish and install electric thermostats for electric cabinet heaters.

   f. Controls contractor shall install wiring and controls furnished by equipment manufacturers such as thermostats for split systems.

2. Software:

   a. Space temperature setpoints shall be specified to be 70ºF heating / 76ºF cooling per MCPS standards. Space temperature sensors provided with setpoint adjusters shall have adjustments software limited to ±2ºF. Coordinate with each project LEED scorecard to ensure compliance with credit EQ6.2 – Controllability of Systems – Thermal Comfort.

   b. Scheduling: Operating schedules shall be adjustable via a graphic utility. Scheduling feature shall include multiple seven-day master and regular schedules, plus holiday, special, and "snow day" schedules. A yearly calendar feature shall allow assignment of holidays and automatic reset of system real time clocks for transitions between daylight savings time and standard time. Schedules shall reside in building controllers, not on the system server. Each type of schedule shall have start time and stop time. Normal conventions shall be that "stop", "unoccupied", or "off" shall place the controlled building/zone/equipment in the unoccupied mode; "start", "occupied", or "on" shall place the controlled building/zone/equipment in the occupied mode. Default of the schedule shall be "off" (stop, unocc); operator entries shall be required to schedule equipment "on" (start, occ). Equipment shall be assigned to Zone schedules. Each and all zones shall controllable by any of the five types of schedules in any combination and the schedules shall operate concurrently. Schedule Types:

      1) Master Schedule: Provide a repeatable 7-day master schedule. All zones assigned to the Master Schedule shall respond to the daily on/off entered in that schedule. Each day schedule shall be able to have multiple on/off times. This schedule is construed as that which controls the building on a regular, daily basis.

         Each building shall be provided with 10-month and 12-month Master schedules.

      2) Regular Schedule: Provide repeatable 7-day Regular schedules for each Zone. Each day of the schedule shall function with multiple on/off times. Regular schedules shall be used to provide "on" times in addition to those scheduled in the Master schedule.

      3) Holiday Schedule: Holiday schedules shall temporarily modify the Master and Regular schedules. It shall be possible to schedule holidays a year in advance. Holidays shall be entered by date; Master and Regular schedules shall respond to the holiday schedule for the date entered.

      4) Special Schedule: Special schedules supersede all other schedules. Special schedules are single event schedules entered by time and date. Single event schedule shall be able to be entered up to one year in advance of the event. A minimum of 12 single event schedules per year per zone shall be provided. (The cessation of the single event schedule shall be inherent once the date and time have passed).

5) "Snow Day" Schedule: Provide a single point command accessible to the Energy Management personnel so that when the "Snow day" command is issued, all assigned schools are placed in their local "snow day" schedules.

c. Overrides

1) Touch Screen in School: A touch screen graphic for manual override of the "OFF" for all Scheduled Start/Stop Zones shall be located in the Administration Area, coordinate location with MCPS Energy Management. Override program shall to start any desired zone's equipment by touch screen. The program shall permit operator selection of zones and shall enable all related equipment for that particular zone. The program shall index the selected zone to an "ON" mode in a minimum of one-hour increments for a period of up to six hours in the override condition. Once overridden, the zone equipment shall operate in the occupied mode, including exhaust fan interlocks.

2) Timed override feature shall allow an operator to temporarily change the state of scheduled equipment. An override command shall be selectable to apply to an individual unit, all units assigned to a given master schedule, or to all units in a building. Timed override shall terminate at the end of an operator selectable time, or at the end of the scheduled occupied/unoccupied period, whichever comes first. A password level that does not allow assignment of master schedules shall allow a timed override feature.

3) Provide equipment override programs for all energy recovery units, air handling units, and heating and ventilating units. Program shall allow operator to override RTU/ERU, AHU, or HVU “Off” command to enable individual units for operation without overriding Zone command. Duration of override shall be for 3 hours. Intent is to allow DOASs, RTUs/ERUs, AHUs, or HVUs to run for maintenance servicing without requiring other equipment in the zone to operate as would be required if the Zone were overridden on.

4) Provide a single point outdoor air damper override. Intent is to allow the EMS operator to command all outdoor air intake dampers controlled by EMS to be closed by a single command.

5) Provide a single point Zones override. Intent is to allow the EMS operator to command all Zones to the unoccupied mode, effectively closing all outdoor air dampers and shutting down exhaust fans.

6) Override shall be possible for analog or time clock values for a given period of time, until a given time or permanently. Overrides may be cleared at the keyboard or through programmable user functions.

3. Communications: Web based with phone modem back-up

4. Administration:

a. Warranties: The entire control system shall be guaranteed free from all mechanical, electrical, and software defects for a period of two (2) years. The Energy Management Automation System (EMS) shall be guaranteed free from all mechanical and electrical defects for a period of five (5) years. During the two year warranty period, the Controls Contractor shall be responsible for the proper adjustments of all systems, equipment, and apparatus installed by him and do all work necessary to insure efficient and proper functioning of the systems hardware and software.

b. During the additional 3-years guarantee (5 years total) for EMS parts and labor, the EMS Contractor shall be responsible for the repair and/or replacement of defective EMS hardware (microprocessors, sensors, transducers, relays, etc.) in response to notification of failures issued by MCPS. Where a failure has occurred that necessitates reloading of software, the work shall be performed by the Contractor. Final control devices such as valves, dampers, actuators, etc. shall be subject to the two year warranty only.

c. Software Upgrades: Over the two year guarantee period, the Contractor shall provide and install all software upgrades released by the manufacturer as applicable to the systems installed.

d. Spare Parts Allowance: The Contractor shall include in the controls bid an allowance for spare parts equal to 2% of the base cost of installation; i.e. if the Contractor's proposed cost for the controls installation is "x", the submitted bid shall be (1.02"x"). The use and application of the 2% spare parts allowance shall be solely at the discretion of MCPS.

3.5 PLACING IN SERVICE AND ACCEPTANCE:

A. EMS Contractor shall be present and participate in the start-up of DOASs, RTUs/ERUs and Heat Pumps. Control sequences of operations and coordination of interlocks with equipment manufacturers' controls/safeties shall be demonstrated to the satisfaction and acceptance of MCPS, the design team, and the commissioning authority.

B. Prior to final acceptance and authorization for final payment by the Owner, Control System inspections shall be made by the EMS Engineer, Mechanical Design Engineer, and representatives of the Owner's construction, maintenance, and energy management departments. The inspections shall be in four parts. An inspection shall be performed regarding the physical installation of the EMS equipment, wiring, etc., a separate inspection regarding head-end (graphics) software programming; and on-site software programming and controls system performance verification shall be performed in both cooling and heating seasons. Any deficiencies discerned during one inspection shall be corrected prior to performing the subsequent inspection.

C. On-site performance verification shall be preceded by trends submissions by the contractor with review and comment by the EMS consultant. Trending shall be presented at hourly intervals for a 24 hour period, unless directed otherwise. Systems being monitored shall be operated with an occupancy schedule; i.e. indications that a system was scheduled off for the 24 hours of the history and remained off are of no value. Occupancy schedule and all system setpoints (both calculated and manual inputs) shall be provided with the histories. To assure that trends suitably demonstrate appropriate operations, heating trends shall be run when outdoor air drops to an occurrence of at least 35°F during the trend period, cooling season trends can be run whenever outdoor air rises to an occurrence of at least 85°F during the trend period.

D. For the end-of warranty, the Controls Contractor shall arrange to meet with the EMS Engineer and the Owner within thirty (30) days prior to the specified end of the 2-year guarantee period for the purpose of compiling a list of items that require correction under specified guarantees. Should the Contractor fail to schedule the final meeting, then the 2-year controls system Guarantee shall be automatically extended until such time as the meeting takes place; and the Contractor shall be fully responsible for correcting such deficiencies as if they occurred under the original guarantee period.

3.6 COORDINATION WITH MCPS ENERGY MANAGEMENT: EMS Consultant is to provide information directly to MCPS Energy Management:

A. Two copies, each in a 1" 3-hole binder, containing the following

1. Section 15900 specifications

2. Zone Map and Zone descriptions

3. Control drawings (flow diagrams, sequences, points list) on folded 11"x17" sheets.

B. Copies of all addenda and revisions issued via email and hard copy.

C. EMS Consultant is to provide copy of the controls submittals directly to MCPS Energy Management when EMS Consultant's review is complete and package is forwarded to the design engineer. Transmittal to the design engineer shall remind design engineer to provide MCPS Energy Management with copy of their review comments.

3.7 EMS/TAB Coordination: In addition to routine coordination between controls contractor and test and balancing contractor, EMS contractor shall:

A. Obtain true systems setpoints from the TAB contractor, including:

1. Piping system differential pressure setpoints for controlling pumps' VFDs.

2. Duct static pressure setpoints for controlling fans' VFDs.

B. Validate that air flow and/or water flow monitoring records in the automation systems comparably with values recorded by TAB.

3.8 ENERGY MANAGEMENT ROUTINES / GLOBAL OPERATIONS: The following energy management routines are to be provided:

A. OPTIMIZED START: Optimized start programs shall be accomplished by monitoring outdoor temperature, individual space temperature, and historical data of building recovery time. The program shall automatically evaluate the thermal inertia of the structure, the capacity of the HVAC system to either increase or reduce space temperatures, indoor and outdoor conditions to determine the minimum time of HVAC system operation needed to satisfy the space environmental requirements at the start of the occupied cycle. The program shall monitor the controlled equipment status to verify that the start command was carried out, and provide an alarm when the equipment does not start, fails, or is locally overridden. Each piece of equipment shall perform optimized start individually responsive to its space temperature; indicate such on the Input/Output Summary Tables (Points Lists).

1. Heat pumps shall perform optimum start individually in response to their respective space temperature sensor.

2. RTU's/ERU's capable of recirculating air and performing space temperature control shall perform optimized start in the heating mode.

3. RTU's/ERU's capable of economizer operations shall perform cooling optimized start only if economizer operations are employable; optimized start with mechanical cooling shall not be permitted.

B. TIME PROGRAMMED COMMANDS (TPC):

1. The TPC program shall reduce the heating space temperature setpoint and raise the cooling space temperature setpoint during unoccupied hours. The software shall limit the amount of setback during periods of extremely cold weather to facilitate morning warm-up and prevent freeze-ups. Setback shall initially be set with the scale of 55°F indoors at outdoor air temperatures of 50°F and warmer and 60°F indoors at 25°F or colder outdoor air temperatures. Set-up temperature shall be 90°F. Systems not capable of mechanical cooling shall not perform night set-up.

2. Provide software to reduce the HVAC thermal load during warm-up or cool-down cycles prior to the occupancy of the building. Heating-only units shall not perform cool-down.

3. Heat pumps shall perform TPC individually in response to their respective space temperature sensor.

4. Only RTU's/ERU's that are controlled by space temperature sensor and are capable of re-circulating air shall perform TPC.

C. PHASE AND VOLTAGE MONITORING: EMS shall monitor incoming electrical power to the building. In the event of any problem with voltage or phasing, the EMS shall display an alarm and log irregularities.

D. EMERGENCY GENERATOR: EMS shall monitor Emergency Generator operations.

E. SUMMER/WINTER CHANGEOVER: There is no central summer/winter changeover of building condenser water system. Space air temperatures dictate heating/cooling indexing for heat pumps. Space temperature sensors shall have heating setpoints of 70°F and cooling setpoints of 76°F (with ±2ºF local adjustment). RTU's/ERU's will be indexed to summer/winter based upon outdoor air temperature.

1. All space temperature sensors and thermostats shall have heating setpoints of 70°F and cooling setpoints of 76°F. Cooling setpoints shall also be provided for heating and ventilating equipment not capable of mechanical cooling (economizer operates to cooling setpoint). Heating only sensors/thermostats shall only have a heating setpoint; cooling only sensors/thermostats shall only have a cooling setpoint.

2. Space sensor local adjustment limitation. Software shall limit local setpoint adjustment to ±2°F offset from the programmed setpoints (initially 70°F heating/76°F cooling). Programmed

setpoint and actual setpoint due to local adjustment shall be displayed in all relative trends and graphics.

3.9 CONTROL SEQUENCES OF OPERATION: The following sequences are provided as guides to the design team to assist in assuring that equipment is appropriately specified and controlled.

A. Condenser Water Pumps (serving the building heat pump loop):

1. Geothermal System, Main & Stand-by Pumps:

a. Selection of Main Pump shall be alternated weekly; pump shall run continuously. Upon failure of the Main Pump, the Stand-by Pump shall run. Pump speed shall be controlled to maintain the system pressure setpoint. When more than one differential sensing location is designed, pump shall ramp so no sensor drops below its pressure setpoint, allowing the other sensor(s) to possibly exceed their setpoint.

b. Pump and VFD failures shall be alarmed in EMS.

c. Building impending freeze alarm shall be generated by monitoring building heat pump loop return temperature. Alarm condition shall be whenever outdoor air temperature is below 35°F (adjustable) and when return temperature drops below 50°F (adjustable) for 40 minutes. This alarm shall be displayed in the EMS and also be provided to MCPS Security Division via hardwire connection to the Security System installed at the building via a contact output in the EMS. MCPS Security Division will connect to EMS provided relay and monitor this output through the security system's hardware and software.

2. In some instances, notably smaller additions with cooling tower, condenser water pumps may only run upon a call from heat pumps.

3. All equipment served by the building heat pump water loop shall be locked-out whenever there is no heat pump loop flow.

B. Cooling Tower Loop:

1. Whenever building heat pump system water pump is running and the building heat pump loop water supply temperature is 86ºF or higher, the cooling tower loop pump shall run. The pump shall stop when building heat pump water loop supply temperature drops below 83ºF.

2. Cooling Tower: Whenever cooling tower pump is running, the EMS shall modulate the cooling tower fan speed to maintain the cooling tower water supply temperature setpoint (initially set at 82ºF, adjustable). Whenever the cooling tower water pump is de-energized the fan VFD shall be de-energized.

a. The make-up water valve shall be modulated to maintain the cooling tower pan water level as sensed by the tower water level sensor (manufacturer’s controls).

b. Whenever the outside air temperature below 35ºF, the cooling tower pan heater shall be energized (manufacturer’s controls).

C. Building Heat Pump Water Loop Heat Addition: Whenever building heat pump water pump is running and the building heat pump water loop return water is below 70ºF, the EMS shall enable the boiler manufacturer’s sequencer/controller. When enabled, boiler manufacturer’s controller shall stage and modulate boilers to maintain a minimum heat pump loop supply water temperature setpoint of 65ºF (adjustable). EMS shall disable the manufacturer’s controller when return water rises above 75ºF.

D. DOAS/ERU: Refer to Section 15103.

E. HEAT PUMPS: Heat pumps shall be indexed occupied/unoccupied via start/stop zone commands. During unoccupied modes, heat pumps shall normally be off. During occupied modes, heat pump supply fans shall run continuously. Each heat pump shall operate as follows:

1. Unoccupied:

a. Night set-back/set-up: Fan and compressor shall cycle to satisfy set-back/set-up temperature; reversing valve shall be positioned for heating or cooling as needed.

b. Warm-up/Cool-down: Heat pumps shall perform warm-up/cool-down individually to satisfy their occupied space temperature setpoint, performing optimized start individually to achieve the occupied space temperature at the start of occupancy.

c. Override: Individual override of the unoccupied mode shall be made by manual selection at the space temperature sensor.

2. Occupied: The fan shall run continuously, compressor shall cycle in either heating or cooling mode to maintain space temperatures, reversing valve shall be positioned for heating or cooling as needed.

3. Compressor: Upon a call for compressor operation, the water control valve shall be commanded open first. When the valve is fully open, an end switch on the control valve shall enable the operation of the compressor. Compressor operation shall be cycled based upon load conditions as sensed by the space temperature sensor. When the demand for compressor operation is satisfied, the compressor shall stop and the water control valve shall then close; positive proof of compressor off status (current switch) is required before valve can close. (Manufacturer's controls shall provide for compressor minimum on/off time delay when the unit is initially energized, manually reset, switched between modes, or cycled within a single mode.)

4. Reversing Valve: The reversing valve shall be energized in the cooling mode. Once the valve is energized for cooling it shall stay energized until a heating cycle is initiated. In the event of a power failure the reversing valve shall fail to the heating mode. (Manufacturer's controls shall delay reversing valve operation after compressor shutdown to reduce noise due to refrigerant migration.)

5. Random Starts: Units within a zone shall be randomly started with 5-10 sec delays between each start to prevent all units within a zone from energizing at the same time.

6. Safeties: The following safeties shall be provided, either by the Controls Contractor or by heat pump manufacturer. Controls Contractor shall verify safeties provided by heat pump manufacturer to eliminate redundancy and to assure that all required safeties are provided.

a. Compressor shall be prevented from operating if fan command and status do not match after 30 second verification delay.

b. Compressor shall be operated with minimum 3 minute on and 3 minute off cycles to maintain oil return for extended life of the compressor.

c. Space temperature sensor failure shall shut down heat pump and initiate a sensor failure alarm.

d. A condensate overflow switch alarm shall shut down fan and compressor and initiate an EMS alarm.

F. ELECTRIC HEATERS: Fans and heating elements cycle to maintain space thermostat setpoint.

G. EXHAUST FANS

1. All general building exhausts will be controlled by EMS; fans will run when their corresponding Zone is in the occupied mode.

2. Economizer Relief Fans: Control will be by EMS, however, design engineer must clearly specify sequence; e.g. static pressure, damper tracking, temperature, single speed fan, two speed fan, VFD, etc.

3. Kiln Hood: EMS installed current switch sensing Kiln status runs exhaust fan when kiln is on. Once started, fan runs for one hour after Kiln goes off.

4. Special system exhausts are not normally controlled by EMS, and are furnished with local electric controls such as follows:

a. Cooling thermostatic control, 80ºF setpoint: boiler room, mechanical room, elevator machine room, electric room, outdoor storage room.

b. Wall switches with timers: science classrooms, workrooms and health room.

c. Light Switch: Ceiling exhaust fans for small toilet rooms and storage rooms

d. Smoke relief fans: control by fire protection system

e. Copy machines exhaust: either interlocked with copy machine or provided with wall switch

f. Compactor room, trash room: Fan runs continuously; turns off in response to space thermostat (40ºF setpoint).

END OF SECTION