PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes control sequences for HVAC systems, subsystems, and equipment.

B. Related Sections include the following:
   1. Section 230900 "Building Automation System (BAS) Controls" for control equipment and devices and for submittal requirements.

1.3 DEFINITIONS

A. BAS: Building Automation System

B. DDC: Direct digital control.

C. VAV: Variable air volume

D. VFD: Variable frequency drive.

1.4 ABBREVIATIONS

A. The following abbreviations may be used in graphics, schematics, point names, and other UI applications where space is at a premium.
   1. AC - Air Conditioning
   2. ACU - Air Conditioning Unit
   3. AHU - Air Handling Unit
   4. AI - Analog Input
   5. AO - Analog Output
   6. AUTO – Automatic
   7. AUX – Auxiliary
   8. BI -Binary Input
   9. BO -Binary Output
   10. C –Common
   11. CHW - Chilled Water
   12. CHWP - Chilled Water Pump
   13. CHWR - Chilled Water Return
   14. CHWS - Chilled Water Supply
   15. DA - Discharge Air
   16. EA - Exhaust Air
   17. EF - Exhaust Fan
   18. EVAP – Evaporators
   19. FCU - Fan Coil Unit
   20. HOA - Hand / Off / Auto
   21. HRU - Heat Recovery Unit
   22. HTEX - Heat Exchanger

23. HW – Domestic Hot Water
24. HWC – Domestic Hot Water Recirculation
25. HWP - Heating Water Pump
26. HWR – Heating Water Return
27. HWS - Heating Water Supply
28. MAX – Maximum
29. MIN – Minimum
30. MISC – Miscellaneous
31. NC - Normally Closed
32. NO - Normally Open
33. OA - Outdoor Air
34. RA - Return Air
35. RF - Return Fan
36. RH - Relative Humidity
37. RTU - Roof-top Unit
38. SA - Supply Air
39. SF - Supply Fan
40. SP - Static Pressure
41. TEMP – Temperature
42. VAV - Variable Air Volume
43. VVTU - Variable Volume Terminal Unit
44. W/ - with
45. W/O – without

1.5 BACNET COMMUNICATIONS INTERFACE

A. For all equipment designated with a BACnet communication interface module, the controls contractor shall review the sequence of operation identified below and co-ordinate with each approved equipment manufacturer to provide the designated points either through the interface or a hard wire connection (at no additional cost) where capability is not available through interface.

B. The controls contractor shall identify points to be either commanded, trended or monitored through the interface. At a minimum, the BAS shall have capability to access the following functions for the system and all subequipment: system enable, equipment enable, status, alarm, temperature, pressure, reset signals, maintenance alarm, operation mode, run time, firing/input rate, set point adjustment, delay and scheduling.

C. The controls contractor shall coordinate with each approved equipment manufacturer to provide a full list of available points available through the interface. All functions to be mapped through the interface should be submitted for engineer approval.

1.6 TRIM AND RESPOND RESET LOGIC

A. Definitions:
1. SP_0 - Initial set point
2. SP_{min} – Minimum set point
3. SP_{max} – Maximum set point
4. T_d - Delay timer
5. T – Time step
6. I – Number of ignored requests
7. R – Number of requests from zones/systems

8. SP_{trim} – Trim amount
9. SP_{res} – Respond amount
10. $SP_{res\text{-}max}$ – Maximum response per time interval

B. Controls contractor shall provide trim and respond reset logic as follows:
1. Controls contractor shall provide trim and respond reset logic as noted below in sequence of operation. Trim and respond logic shall reset set point within the range of SP_{min} to SP_{max} until zones request a response.
2. The reset logic shall be active while the associated device is proven on, starting T_d after initial device start command. When active, every time set T, trim the set point by SP_{trim}. If there are more than I requests, respond by changing the set point by SP_{res} times (R-I). But the net response shall be no more SPres-max. The sign of SP_{trim} must be the opposite of SP_{res} and $SP_{res\text{-}max}$. Controller shall keep trimming the set point until zones requests a response.
3. The control loop shall be tuned based on the field conditions. Typical startup conditions are as follows:
   a. Requests: If the loop is less than 85%, send 0 requests. If the loop is greater than 95%, send 1 request.
   b. Importance Multiplies: Multiply zones requests by IM, Default value IM=1. Allow rogue zones to be ignored (IM=0). Identify integral of requests hour time to identify rogue zones.

PART 2 - PRODUCTS (NOT APPLICABLE – REFER TO 230900)

PART 3 - EXECUTION

All sequences written here are schematic in nature and are outline in format. Contractor is responsible for writing detailed sequences in the design-built phase, to meet the projects criteria. Glumac's schematic design narrative should also be referenced and used for temperature setpoints, humidity setpoints and other criteria for the project.

3.1 OPERABLE WINDOWS FOR NATURAL VENTILATION

A. The windows in the office, meeting, conf, café, etc non-lab spaces shall be operable. The occupant shall be able to open the windows manually and the window closed status shall be monitored by the BMS. Integral window switches shall be installed to shut down VAV in space when windows are opened.

3.2 VARIABLE AIR VOLUME TERMINAL UNIT – HEATING WATER REHEAT WITH CARBON DIOXIDE (CO2) MONITORING

Note to Contractor: VAV Box control for non-laboratory spaces shall be fully coordinate and integrated with the requirements of the laboratories. Below is an outline specification only which should be re-written to meet the specific project requirements and comply with Title 24 needs:

A. Features
1. Cooling damper and actuator
2. Heating water reheat coil
3. Carbon dioxide monitoring
4. All setpoints shall be user adjustable

B. Run Conditions - Scheduled: The unit shall run according to a user definable time

schedule and maintain the following modes:

1. Occupied Mode Temperatures:
   a. Cooling setpoint - 75^0F
   b. Heating setpoint - 70^0F
2. Unoccupied Mode Temperatures (night setback):
   VAV boxes shall be tied to occupancy sensors to setback when room is unoccupied.
   a. Cooling setpoint - 85^0F
   b. Heating setpoint - 55^0F
3. Four air flow control setpoints shall apply as follows:
   a. Occupied cooling maximum air flow as scheduled
   b. Occupied heating maximum air flow as scheduled
   c. Occupied cooling/heating minimum air flow as scheduled
   d. Unoccupied cooling/heating minimum air flow as scheduled
4. Alarms shall be provided:

C. Minimum Ventilation on Carbon Dioxide (CO2) Concentration: To Meet Title 24 requirements

D. Air Flow Control::
   1. Occupied:
   2. Unoccupied:

E. Reheat Coil Control Valve: The reheat coil control valve shall fail in the last position (non-spring return).

F. Reheating - High Discharge Air Temperature Limit:

G. Discharge Air Temperature:

H. Occupancy Sensor Operation:

I. Environmental Index:

3.3 LABORATORIES

A. Occupancy is determined by an occupancy schedule. Occupancy or unoccupancy air flow set points shall apply. The total exhaust air volume and the total supply air volume for the lab is monitored and controlled to maintain a positive or negative airflow relative to the exhaust air flow.

B. Each fume hood shall be served by its own controller. The fume hood controller calculates the total fume hood open area based on the fume hood's fixed openings, bypass opening, leakage area and sash position as indicated by the sash sensor(s). The fume hood controller also continuously calculates the fume hood exhaust CFM required to maintain the average face velocity set point based on the total open area of the fume hood and the average face velocity (adjustable) set point. The fume hood controller uses a fume hood exhaust terminal to measure actual fume hood exhaust CFM and modulate the fume hood exhaust valve or damper to control and maintain the required fume hood average face velocity using a proportional, integral and derivative (PID) closed loop control algorithm.

C. The fume hood controller maintains the fume hood exhaust CFM at the desired min-

imum set point value (adjustable) when the total fume hood open area results in less than the desired minimum fume hood exhaust CFM. This minimum fume hood exhaust set point is set to the value recommended by the fume hood manufacturer to maintain adequate fume containment and dilution.

D. Emergency purge mode:

E. The CAV controller shall modulate the terminal damper or air valve to maintain a constant exhaust air volume.

F. The lab control module (LCM) receives the total value of the fume hood exhaust CFM set point via a totalizing device connected to the fume hood controllers and measures the actual room general exhaust CFM. The LCM calculates total room exhaust CFM by adding the room general exhaust CFM, the CAV nozzle exhaust CFM and the total fume hood exhaust set points together. The LCM modulates the room general exhaust to ensure that a minimum total room exhaust necessary to meet the required room ventilation rate is continuously maintained using a proportional, integral and derivative (PID) closed loop control algorithm.

G. The space CO2 levels shall be monitored at the BMS workstation. If the CO2 level rises above 900 ppm (adj), the supply air cfm shall be reset to the maximum allowable value that would still maintain pressurization. The room shall remain at the higher airflows until the CO2 level drops below 800 ppm (adj) for 15 mins (adj). An alarm shall display on the BMS is the co2 level rises above 1000 ppm.

H. Located next to each of the fume hood terminals shall be a ventilation button. This button will be separate from the emergency purge button. When this button is activated by the occupant, the lab space shall go into maximum ventilation mode as described above. In case of a spill or emergency, standard emergency procedures must be followed by the occupants.

I. A priority structure applies to the above control applications to ensure that safety is maintained as the highest control priority when HVAC systems or individual components cannot meet all demands placed upon the system.

1. Fume hood control is the highest control priority.

2. Room pressurization is second highest priority.

3. Room ventilation is the third level of priority.

4. Room temperature control is the fourth level of priority.

3.4 VARIABLE AIR VOLUME AIR HANDLING UNIT – CHILLED AND HEATING WATER

A. Features
1. Chilled water coil
2. Supply fan air flow monitoring
3. Return fan air flow monitoring
4. Outside air flow monitoring
5. Air economizer
6. Trim and respond static air pressure reset
7. Trim and respond supply air temperature reset

8. All setpoints shall be user adjustable

B. Run Conditions - Requested:

C. Alarms:

D. Supply Fan:

E. Supply Air Duct Static Pressure Control:

F. Return Fan:

G. Return Fan Speed Control:

H. Building Static Pressure Control: Coordinate with Lab Controls

I. Supply Air Temperature Setpoint - Optimized:

J. Cooling Coil Valve:

K. Heating Coil Valve:

L. Air Economizer:

M. Minimum Outside Air Ventilation:

N. Minimum Outside Air Ventilation - Carbon Dioxide (CO_2) Control:

O. Heating Maximum Air Flow: 90 deg (Adj)

P. Pre-occupancy:

Q. Prefilter Differential Pressure Monitor:

R. BAS shall monitor the differential pressure across the final filter.

S. Mixed Air Temperature:

T. Return Air Humidity:

U. Return Air Temperature:

V. Supply Air Temperature:

3.5 EXHAUST FAN - ON/OFF TOILETS

A. Run Conditions - Interlocked:

B. Fan Status: Heating:

3.6 LABORATORY EXHAUST FANS

A. Each VFD shall communicate all system information status and control parameters back to the central control system via a BACnet communication protocol.

B. The control system shall show the fans running by lighting green led's and show fans stopped by lighting red led's.

C. The control system must have controls for manual and automatic operation.

D. All control equipment to be housed in NEMA enclosures.

E. Exhaust system shall operate continuously; fans shall be started and stopped automatically from the bms. The automatic damper shall open before the fan starts, motorized dampers to open at least 60 seconds (adjustable) prior to energizing the fan.

F. The leadlag laboratory exhaust fan control system shall control the sequential operation of the exhaust fans on a common plenum, and the periodic cycling of the (n+1) standby fan while maintaining the system design static pressure (adjustable) to within + or - 10% for a 30 second period of time during sequencing.

G. The control system shall have a mode to reduce the quantity/speed of fans in operation and minimize outside bypass air while maintaining the exit velocity required.

H. The standby fan shall be activated on a two week (adjustable) cycle, for a period of one hour (adjustable). Standard standby cycle to be field modified, if required.

I. Exhaust manifold static pressure measurement exhaust manifold static pressure shall be measured in common rooftop exhaust manifold between the fan intakes at two points by independent sensors. The exhaust fans shall module speed to main the worst case exhaust duct below the minimum setpoint as determined by the air balancer. The location shall be submitted for review and approval, and incorporated into the controls as-built drawings. The exhaust system control sequence shall ensure that the manifold static pressure does not fall below the minimum static pressure required for safe system operation at design conditions (pressure set point determined at air balance) at the designated measurement location(s).

J. The baseline manifold static pressure set point (estimated to be negative 0.5 - 1.0 in. W.g. under normal operation) shall be determined during balance.

K. The static pressure set point shall be reset + / - 0.2 in w.g. by automatic control from the baseline static pressure set point based on the exhaust damper demand.

L. The static pressure set point shall generate an alarm if the static pressure varies from the set point by greater than 0.1" w.g. for over 1 minute.

M. Fan speed control: exhaust fan speed shall be varied by control loop in order to maintain the manifold static pressure at set point. When multiple fans are operating, they shall operate in parallel at identical speeds. A zero speed command shall be interpreted as a stop command at the VFD level; a speed command greater than zero shall be interpreted as a start command at the VFD level.

N. Minimum fan speed: the exhaust fan minimum allowable fan speed shall be determined at balance to be the fan speed that corresponds to the appropriate stack exit velocity.

O. The bypass damper shall modulate to maintain the static pressure setpoint when the exhaust fan is operating at minimum speed.

3.7 ZONE COILS FOR CLEANROOM

A. Features
   1. Heating water coil in ductwork

B. Run Conditions - Scheduled:
   1. Alarms shall be provided as follows:
   2. Zone Setpoint:

C. Reheating Coil Valve:

3.8 FAN COIL UNIT

A. Run Conditions - Scheduled:
   1. Zone Setpoint:
   2. Fan:

B. Cooling Coil Valve:

C. Fan Status:

D. Environmental Index:

3.9 CHILLED WATER LOOP PUMPS

A. Main loop distribution system with two pumps piped in parallel, one pump as stand-by, with variable frequency drives (VFD).

B. The main loop chilled water pumps alternate to equalize runtime. The pump with the least runtime is the lead pump. The pump with the most runtime is the lag pump. Selection of the lead pump is evaluated on a weekly basis and shall change on Sunday nights at 11.59 pm.

C. When the CHW system is on, the lead CHW pump starts. The VFD modulates pump speed to maintain system differential pressure (adjustable) as sensed near the end of the piping run. The system differential pressure set point shall be determined during the balancing phase of the project.

D. Collect data internal to the VFD and transmitted to the BMS via the network shall confirm the pumps are in the desired state (i.e. on or off) and the BMS shall generate an alarm if status deviates from DDC start/stop control. If the lead pump goes into alarm, the lag pump starts. The BMS system generates a VFD trouble alarm independent from the pump status.

E. Main loop distribution system from main campus CHW loop::

F. When differential pressure, as sensed near the entrance of the building, in the main campus chilled water loop reaches a predetermined set point, the building distribution pumps shall be stopped, the motorized dampers to the lead/lag pumps shall be closed and the motorized 2-position n.c. by-pass valve shall be opened.

G. Differential pressure set point shall be determined during the balancing phase of the project.

H. When CHW pumps are off, the campus CHW loop shall maintain system set point.

I. If the campus CHW loop differential pressure is below set point, the lead building distribution pump shall be energized.

3.10 VARIABLE-PRIMARY DISTRIBUTION - HEATING WATER LOOP PUMPS

A. The hot water system consists of two steam to water heat exchangers piped in parallel, with two recirculation pumps operating in parallel. Hot water distribution pump will have variable frequency drive (VFD). The system is BMS controlled with electronic actuation.

The system operates as follows (all suggested set points and settings are adjustable.):

B. The HHW system will run continuously based on building demand or as programmed by the building operator (e.g. time-of-day schedule).

C. When HHW distribution pump operation is proven, the associated steam control valve in the circuit shall be enabled for operation.

D. The associated steam control valve in turn shall start/stop the recirculation pump(s) in operation when demand is satisfy on the building and not heating hot water is required in the building..

E. Each heat exchanger is capable and will be staged by the BMS to maintain a hhw supply temperature set point. This set point will be automatically reset based on main system supply temperature. Main system hhw supply temperature automatically reset based on outside air temperature.

F. If the distribution pump fails, an alarm is generated and the pump is turned off.

G. Data internal to the vfd and transmitted to the bms via the fln network the pump is in the desired state (i.e. on or off) and the bms shall generate an alarm if status independent from the pump status.

H. The bms system monitors the controls for the pump status and a common alarm condition.

I. The hhw distribution system with two pumps piped in parallel, one pump as standby, with variable frequency drives (vfd).

J. The main loop hhw pumps alternate to equalize runtime. The pump with the least runtime is the lead pump. The pump with the most runtime is the lag pump.

K. Selection of the lead pump is evaluated on a weekly basis and shall change on sunday nights at 11.59 pm.

L. When the hhw system is on, the lead hhw pump starts. The vfd modulates pump speed to maintain system differential pressure (adjustable) as sensed near the end

of the piping run. The system differential set point shall be determined during the balancing phase of the project.

3.11 POWER MONITORING INTERFACE

A. Metering Requirement shall be determined by design build contractor in detailed design phase to meet the LEED M&V credit requirements

B. Electrical Power Interface Monitor:

3.12 VARIABLE FREQUENCY DRIVE INTERFACETrending Requirement shall be determined by design build contractor in detailed design phase to meet the LEED M&V credit requirements

B. Variable Frequency Drive (VFD) Interface Monitor:

3.13 BTU METERMetering Requirement shall be determined by design build contractor in detailed design phase to meet the LEED M&V credit requirements

B. The BAS shall monitor the BTU meter for energy usage on a continual basis. These values shall be made available to the system at all times.
   1. Alarm shall be generated as follows:
      a. Meter Failure: Sensor reading indicates a loss of pulse output from the BTU meter.

C. Peak Demand History:

The BAS shall monitor and record the peak (high and low) demand readings from the BTU meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

D. Usage History: The BAS shall monitor and record BTU meter readings so as to provide an energy usage history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

3.14 CHILLED WATER ENERGYMetering Requirement shall be determined by design build contractor in detailed design phase to meet the LEED M&V credit requirements

B. Chilled Water Demand - Energy Meter: The BAS shall monitor the chilled water supply temperature, chilled water return temperature and chilled water flow to the building and calculate current energy demand on a continual basis. These values shall be made available to the system at all times.
   1. Alarm shall be generated as follows: Invalid Reading: Sensor readings indicate an invalid demand value.

C. Peak Demand History: The BAS shall monitor and record the peak (high and low) demand readings from the chilled water energy meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

D. Usage History: The BAS shall monitor and record chilled water energy meter readings so as to provide an energy usage history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

3.15 HEATING WATER ENERGYMetering Requirement shall be determined by design build contractor in detailed design phase to meet the LEED M&V credit requirements

B. Heating Water Demand - Energy Meter: The BAS shall monitor the heating water supply temperature, heating water return temperature and heating water flow to the building and calculate current energy demand on a continual basis. These values shall be made available to the system at all times.
   1. Alarm shall be generated as follows: Invalid Reading: Sensor readings indicate an invalid demand value.

C. Peak Demand History: The BAS shall monitor and record the peak (high and low) demand readings from the heating water energy meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

D. Usage History: The BAS shall monitor and record chilled water energy meter readings so as to provide an energy usage history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

3.16 DOMESTIC HOT WATER ENERGYMetering Requirement shall be determined by design build contractor in detailed design phase to meet the LEED M&V credit requirements

B. Domestic Hot Water Demand - Energy Meter: The BAS shall monitor the domestic hot water supply temperature, domestic cold water supply temperature and domestic hot water supply flow to the building and calculate current energy demand on a continual basis. These values shall be made available to the system at all times.
   1. Alarm shall be generated as follows: Invalid Reading: Sensor readings indicate an invalid demand value.

C. Peak Demand History: The BAS shall monitor and record the peak (high and low) demand readings from the hot water energy meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

D. Usage History: The BAS shall monitor and record chilled water energy meter readings so as to provide an energy usage history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

3.17 ELECTRIC METERMetering Requirement shall be determined by design build contractor in detailed design phase to meet the LEED M&V credit requirements

B. The BAS shall monitor the electric consumption on a continual basis. These values shall be made available to the system at all times.
   1. Alarm shall be generated as follows: Meter Failure: Sensor reading indicates a loss of pulse output from the electric meter.

C. Peak Demand History: The BAS shall monitor and record the peak (high and low) demand readings from the electric meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

D. Usage History: The BAS shall monitor and record electric meter readings so as to provide a power consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

E. Demand Levels: The BAS shall set the system demand level (adjustable) based on

the current power consumption readings from the electric meter. There shall be six daily time periods in which the demand shall be adjusted on three levels. These demand levels shall be available for facility equipment to utilize for demand limiting.

1. Demand Level 1: Power consumption has exceeded the first demand level threshold (adjustable).
2. Demand Level 2: Power consumption has exceeded the second demand level threshold (adjustable).
3. Demand Level 3: Power consumption has exceeded the third demand level threshold (adjustable).

3.18 GAS METER

A. Metering Requirement shall be determined by design build contractor in detailed design phase to meet the LEED M&V credit requirements and campus requirements.

B. The BAS shall monitor the gas consumption on a continual basis. These values shall be made available to the system at all times.
   1. Alarm shall be generated as follows: Meter Failure: Sensor reading indicates a loss of pulse output from the gas meter.

C. Peak Demand History: The BAS shall monitor and record the peak (high and low) demand readings from the gas meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

D. Usage History: The BAS shall monitor and record gas meter readings so as to provide a gas consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

E. Gas metering consumption shall communicate with BAS for data output to dashboards.

3.19 OUTSIDE AIR CONDITIONS

A. The BAS shall monitor the outside air temperature and dewpoint (humidity) and calculate the outside air enthalpy on a continual basis. These values shall be made available to the system at all times.

B. Sensor Failure Alarm:

C. Outside Air Temperature History:

3.20 WATER FLOW METERMetering Requirement shall be determined by design build contractor in detailed design phase to meet the LEED M&V credit requirements

A. Water Meter: The BAS shall monitor the water consumption on a continual basis. These values shall be made available to the system at all times.
   1. Alarm shall be generated as follows: Meter Failure: Sensor reading indicates a loss of pulse output from the water meter.

B. Peak Demand History: The BAS shall monitor and record the peak (high and low) demand readings from the water meter. These readings shall be recorded on a daily, month-to-date, and year-to-date basis.

C. Usage History: The BAS shall monitor and record water meter readings so as to provide a water consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

3.21 STEAM CONDENSATE PUMP

A. Equipment operation and Alarms:

3.22 EMERGENCY GENERATOR

A. Generator Operation:
1. Alarms:

B. Change-Over Operation:

END OF SECTION