23 09 23 – Direct Digital Control (DDC) System For HVAC

DIVISION 23 – Heating, Ventilating, and Air Conditioning

STATEMENT OF PURPOSE & BACKGROUND

- Scope:
  - Section includes control equipment for HVAC systems and integration to lighting control systems as outlined in the pages below.
- Statement of goals:
  - This section has been developed to provide a consistent framework for HVAC and lighting controls throughout the District.
- Related sections: see also:
  - Section 23 90 00 Instrumentation and Control for HVAC
  - Section 25 00 00 Automation and Controls
  - Section 26 09 23 Lighting Control Devices
- Revision history of section:
  - 08/13/2018 (date of adoption)
  - 09/10/2020
  - 03/14/2022
  - 09/16/2022 (added references to relevant sections, revised format)
  - 04/12/2024 *(updates to room sensor product)*
  - 05/05/2025 (2025 updates)
  - 05/08/2026 (2026 Updates)

GENERAL INFORMATION AND REQUIREMENTS

- See SPPS Standard Control Sequence and Schematic Templates in Section 23 00 00 General Information for HVAC.
- For projects with phased occupancy/completion, Controls contractor shall provide updated graphics at the completion of each phase.

OUTLINE SPECIFICATION

- The following pages contain the standard specification for Direct Digital controls for use throughout the school District.

SECTION 23 09 23 - DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. This specification Section includes control equipment for HVAC systems, and integration to Lighting control systems using the Tridium Niagara-4 framework with open NiCS (open Niagara Implementation Conformance Statement). Niagara-4 Supervisor software is required at the enterprise level, and Niagara-4 network controllers (JACE 9000, EDGE 10) are required for the middle level of the BAS. Communication at these levels shall be FOX, Tridium's TCP/IP-based protocol. Johnson Controls Inc. (JCI) Facility Explorer (FX) programmable VAV controllers (CVMs) or Vykon IO-R input/output modules are to be provided at the field level and are to be configured or programmed using the programmable controller tool made available by the manufacturer. Programmable controller tool shall connect to CVMs for programming via LAN/WAN routed through the Niagara-4 network controllers. It is acceptable to provide Niagara-4 network controllers at field level. Communication at the field level shall be open protocol BACnet, or FOX.

B. The District maintains a collection of graphic templates on a Niagara device in the District automation shop. The controls contractor shall utilize these templates as a starting point in developing the programming and graphics for this project. It is desired to adhere as closely as possible to these templates with minor deviations as necessary to meet project requirements. Any significant deviations must be coordinated with the District prior to beginning any work.
   1. These templates are intended to establish a consistent graphical interface, point naming, and folder structure. It is the controls contractor's responsibility to conform their work, including programming, to align with these standard templates. The District does not provide standard programming files for contractor use.

C. The District requires proactive testing of graphics and controller programming prior to installation and startup. The intent is to prove that work is prepared ahead of time and to minimize rushed work as projects approach the substantial completion date.
   1. At least six (6) weeks prior to installation in its final location, each middle-level controller shall be installed in a temporary location and available on the District IT network for remote review and comment by Commissioning agent(s) and District staff.
   2. Coordinate with District staff to identify temporary location in building for installing controller during the review process.
   3. Commissioning agent and District staff will review graphics, programming, and other items as needed. All major (middle-level) systems as well as a sample of each type of field-level controller must be available for review.

1.2 RELATED REQUIREMENTS:

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

B. Section 078413 - Penetration Firestopping

C. Section 079200 – Joint Sealants

D. Section 230900 – Instrumentation and Control for HVAC.

E. Section 260010 – Electrical Demolition

F. Section 260519 - Low-Voltage Electrical Power Conductors and Cables

G. Section 260533.13 - Conduit for Electrical Systems

H. Section 260533.16 - Boxes for Electrical Systems

I. Section 260553 - Identification for Electrical Systems

J. Section 260923 – Lighting Control Devices

K. Section 270528 - Pathways for Communications Systems

L. Section 271005 - Structured Cabling for Voice and Data

1.3 QUALITY ASSURANCE

A. DDC System Manufacturer Qualifications:
   1. Allowable DDC controller manufacturers and models as follows. No substitutions.
      a. Johnson Controls Inc. (JCI) Facility Explorer, CVM line of controllers.
         1) CVM Programmable Controllers for VAV Applications
      b. Vykon by Tridium line of controllers
         1) JACE-9000 Series Network Controllers
            a) Includes network port expansion cards as needed
         2) Edge-10 Network Controller
         3) IO-R-16/IO-R-34 Expansion Modules

B. Contractor must submit DDC System Provider Qualifications:
   1. Authorized representative of, and trained by, DDC system manufacturer
      a. Minimum of (5) Niagara-4 certified individuals on staff.
      b. Minimum of (2) field level controller product certified individuals on staff. Required certification is Johnson Controls Inc. course 4714, Facility Explorer® (FX) MSTP Field Controller Engineering.
   2. Each person assigned to Project shall have a minimum of (5) years past experience.
   3. In-place facility located within (75) miles of Project.
   4. Demonstrated past experience with over (20) BAS system installations, including individual systems including at least one system comprised of more than (5) Niagara-4 network controllers.
   5. Staffing resources of competent and experienced full-time employees that are assigned to execute work according to schedule.
   6. Service and maintenance staff assigned to support project during warranty period.

7. Product parts inventory to support on-going DDC system operation for a period of not less than five years after substantial completion.
8. DDC system manufacturer's backing to take over execution of work if necessary to comply with requirements indicated. Include project-specific written letter, signed by manufacturer's corporate officer, if requested.

1.4 DEFINITIONS

A. BACnet: An open communications protocol for building automation and ASHRAE 135 control networks. It is an ASHRAE, ANSI, and ISO standard protocol developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

B. EDGE 10: IP-based controller and gateway device running full Niagara-4 software stack.

C. FOX: Tridium's TCP/IP-based protocol used for communication between enterprise level Niagara-4 Supervisor server and middle- and field-level Niagara-4 network controllers.

D. Input/Output (IO)devices connected to a Niagara-4 network controller: Vykon IO-R modules. Input/output devices shall be located nearby the Niagara-4 network controller they are connected to. It is not acceptable to scatter input/output devices throughout building to control multiple central systems from a single Niagara-4 network controller; this is not considered stand-alone control. Acceptable models include, IO-R-16, and IO-R-34. The use of other hardware for this purpose is not permitted.

E. JACE 9000: IP-based controller and gateway device running full Niagara-4 software stack.

F. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits, Class 2.

G. Modbus: An open communications protocol for building automation and Modbus control networks. It is a standard protocol supported by the Modbus Organization, Inc.

H. Niagara-4: A software framework and development environment created by Tridium, Inc. that solves the challenges associated with building Internet-enabled products, device-to-enterprise applications, and distributed Internet-enabled automation systems.

I. Niagara-4 network controller: Vykon JACE 9000 or Vykon EDGE 10 controller with added license features, and add-on modules as required. Include 5-year software maintenance agreements (SMA) on all JACE controllers. SMA not available for, or required, on EDGE 10 controllers. Acceptable models include, J-9005, J-9010, J-9025, J-9100, J-9200, JEC-934, and VEC-10. The use of other hardware for this purpose is not permitted.

J. CGM: General purpose programmable controller, manufactured by Johnson Controls Inc. (JCI). Not permitted without prior approval from SPPS.

K. CVM: Application-specific programmable controller with built-in actuator and airflow transducer. Intended for variable air volume (VAV) box applications.

L. XPM: Expansion I/O devices for CVM controller, manufactured by Johnson Controls Inc. (JCI). Not permitted without prior approval from SPPS.

M. SA Bus: Sensor-Actuator Bus to support communication between CVM controllers and space thermostats.

N. TCP/IP: Short for Transmission Control Protocol/Internet Protocol. A protocol for communication between computers, used as a standard for transmitting data over networks and as the basis for standard Internet protocols.

1.5 SUBMITTALS

A. Product Data: For each type of product include the following:
   1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
   2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
   3. Product description with complete technical data, performance curves, and product specification sheets.
   4. Installation, operation, and maintenance instructions including factors effecting performance.
   5. Bill of materials indicating quantity, manufacturer, and extended model number for each unique product.
   6. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.
   7. Each submitted piece of product literature shall clearly cross reference specification and drawings that submittal is to cover.

B. Shop Drawings:
   1. General Requirements:
      a. Include cover drawing with Project name, location, Owner, Architect, Contractor, and issue date with each Shop Drawings submission.
      b. Include a drawing index sheet listing each drawing number and title that matches information in each title block.
      c. Prior to submitting an official set of shop drawings for review and approval, a controls programming and graphics kick-off meeting shall take place. Refer to PART 3 - EXECUTION.

   2. Schematic drawings for each controlled HVAC system indicating the following:
      a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
      b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.

c. A graphic showing location of control I/O in proper relationship to HVAC system.
d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
e. Unique identification of each I/O that shall be consistently used between different drawings showing same point.
f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays, and interface to DDC controllers.
g. Narrative sequence of operation.

3. Control panel drawings indicating the following:
   a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
   b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates, and allocated spare space.
   c. Front, rear, and side elevations and nameplate legend.
   d. Unique drawing for each panel.
   e. Point of connection to field power with requirements (volts/power) listed for each.

4. DDC system network riser diagram indicating the following:
   a. Each device connected to network with unique identification for each.
   b. Physical location of every device connected to the network, shown on a schematic floor plan.
   c. Interconnection of each different network in DDC system.
   d. For each network, indicate communication protocol, speed, and physical means of interconnecting network devices, such as copper cable type, or fiber-optic cable type. Indicate raceway type and size for each.
   e. Each network port for connection of an operator workstation or other type of operator interface with unique identification for each.

5. Monitoring and control signal diagrams indicating the following:
   a. Control signal cable and wiring between controllers and I/O.
   b. Point-to-point schematic wiring diagrams for each product.
   c. Control signal tubing to sensors, switches and transmitters.
   d. Process signal tubing to sensors, switches and transmitters.
   e. Pneumatic main air and control signal tubing to pneumatic damper and valve actuators, pilot-positioners if applicable, and associated transducers.

6. Color graphics indicating the following:
   a. Itemized list of color graphic displays to be provided.
   b. For each display screen to be provided, a true color copy showing layout of pictures, graphics and data displayed.
   c. Intended operator access between related hierarchical display screens.

C. System Description:
   1. Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.

2. Complete listing and description of each report, log and trend for format and timing and events which initiate generation.
3. System and product operation under potential power failure condition.
4. Description of testing plans and procedures.
5. Description of Owner training.

D. Samples:
1. For each type of exposed product, installed in finished space for approval of selection of aesthetic characteristics if requested.

E. Schedule and design calculations for control valves, control dampers and actuators.
1. Flow at Project design and minimum flow conditions.
2. Pressure drop across valve at Project design flow condition.
3. Maximum system pressure drop (pump close-off pressure) across valve at Project minimum flow condition.
4. Maximum close-off pressure.
5. Actuator selection indicating torque provided.
6. Actuator signal to control damper (on, close, or modulate).
7. Actuator position on loss of power.

F. Schedule and design calculations for selecting flow instruments.
1. Instrument flow range.
2. Project design and minimum flow conditions with corresponding accuracy, control signal to transmitter and output signal for remote control.
3. Extreme points of extended flow range with corresponding accuracy, control signal to transmitter and output signal for remote control.
4. Pressure-differential loss across instrument at Project design flow conditions.
5. Where flow sensors are mated with pressure transmitters, provide information for each instrument separately and as an operating pair.

G. Coordination drawings
1. Include details and descriptions on schematic control drawings as required to coordinate work with other trades.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For DDC system to include in emergency, operation and maintenance manuals.
1. In addition to items specified in "Operation and Maintenance Data," Section (017823) include the following:
a. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format. These PDF files shall also be inserted into BAS with an on-screen hyperlink to access from graphic screen.
b. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
c. As-built versions of submittal Product Data.
d. Names, addresses, e-mail addresses, and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
e. Backup copy of graphic files, programs, and database on electronic media such as a flash drive.

1) This includes all Niagara config.bog files, Johnson Controls .caf files, and Blueridge Lighting Controls .brt files.

f. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors on electronic media such as a flash drive.

g.

h. Conduct a final graphic review meeting with District and commissioning agent and include District-signed graphic approval as part of closeout documentation.

i. Licenses, guarantees, and warranty documents.

j. Any other pertinent Owner training materials.

1.7 WARRANTY

A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period.

1. Failures shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.
3. Warranty service shall occur during normal business hours and commence within four hours of Owner's warranty service request.
4. Warranty Period: (1) year from date of Substantial Completion.

PART 2 - PRODUCTS (DDC CONTROL SYSTEM HARDWARE AND SOFTWARE)

2.1 DDC SYSTEM MANUFACTURER AND PROVIDER REQUIREMENTS ARE LISTED IN THE QUALITY ASSURANCE ARTICLE NEAR THE TOP OF THIS SPECIFICATION SECTION.

2.2 WEB ACCESS

A. DDC system shall be web-based Niagara-4, utilizing HTML5

1. Web-Based Access to DDC System:
   a. DDC system software shall be based on server thin-client architecture, designed around open standards of Web technology. DDC system server shall be accessed using a Web browser over DDC system network, using District's LAN, and remotely over Internet through District's LAN.
   b. Intent of thin-client architecture is to provide operators complete access to DDC system via a Web browser. No special software other than a Web browser shall be required to access graphics, point displays, and trends; to configure trends, points, and controllers; and to edit programming.
   c. Web access shall be password protected.

B. DDC System Speed:

1. Response and display update Time of Connected I/O:

a. All point values connected to DDC system shall be updated at least every two seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
b. Graphic display refresh shall update within five seconds.
c. Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations shall not exceed graphic refresh rate.

C. Environmental Conditions for Controllers, Gateways, Instruments, and Actuators:
1. Products shall operate without performance degradation under ambient environmental temperature, pressure and humidity conditions encountered for installed location.
a. If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, cooled, and ventilated as required by product and application.

2. Products shall be protected with enclosures satisfying the minimum requirements described in the “ENCLOSURES” Article of this specification Section unless more stringent requirements are indicated.

D. DDC System Reliability and Redundancy:
1. Design, install, and configure DDC control system, to match mechanical/electrical systems and equipment reliability and redundancy design.
a. For example; if two chillers are installed, one being a back-up, it is expected that the back-up chiller will automatically start when the primary chiller fails. Two chillers were installed to ensure cooling remains active if a single device fails. The DDC control system must match this design intent, where the single failure of one DDC controller or DDC component does not prevent cooling of the building.

E. Electric Power Quality:
1. Ground Fault: Protect products from ground fault by providing suitable grounding. Products shall not fail due to ground fault condition. Install grounding wires as shown in manufacturer’s instructions.

F. Continuity of Operation after Electric Power Interruption:
1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems shall automatically return equipment and associated controls to operating state occurring immediately before loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

2.3 SYSTEM ARCHITECTURE

A. System architecture shall consist of no more than three levels of LAN and/or communication busses. It is not acceptable to utilize existing District-owned Niagara

gateway controllers for integration and/or routing of new field-level controllers, including Niagara input/output modules.

1. Level one - Enterprise level - Consists of a Niagara-4 Supervisor server. The Niagara-4 Supervisor is established and is located at the District office, 1930 Como Ave. The Niagara-4 Supervisor is overseen and maintained by District staff. All modifications must be pre-approved and coordinated with District staff. District staff access the Niagara-4 Supervisor using District provided workstations, connected to the District LAN/WAN using preferred web browser software. The Niagara-4 Supervisor provides a central location for accessing data from the middle level controllers being installed throughout District buildings. The District LAN/WAN is used for communication between Niagara-4 Supervisor and the middle level controllers, according to the Niagara Product Model. The communication protocol between Niagara-4 Supervisor and middle level controllers shall be FOX, Tridium's TCP/IP-based protocol.

2. Level two - Middle level – Consists of Niagara-4 network controllers (JACE 9000, EDGE 10) acting as gateway devices and/or controllers utilizing the included control engine capability and connected input/output devices located near Niagara-4 network controller to provide stand-alone control of larger, central systems that serve other subordinate systems within a building. Examples of larger, central systems include: cooling plants, heating plants, VAV air handling units serving terminal units, etc. It is acceptable to control multiple central systems using Niagara-4 input/output devices connected to a single network controller. It is encouraged to locate any Niagara-4 network controller acting as a gateway controller near a central system so it may serve multiple purposes. Middle level controllers connect to District LAN/WAN using FOX protocol. All middle level controllers must have their own network cable home run to a client-managed IDF or MDF switch. It is not acceptable to create a subnetwork of middle level controllers.
    a. Station names for Niagara devices shall be assemble as follows:
        1) <JACE or EDGE>_<5-DIGIT NETWORK ID>_< EQUIPMENT NAME>
    b. It is not acceptable to provide RTUs, AHUs, or similar equipment with full factory controls. The controls contractor shall plan to provide field-installed controls as specified in this section and elsewhere in the design documents. Coordinate with the equipment manufacturer to determine which equipment components will require some level of factory controls, and interface with these controls as necessary to achieve the design sequence of operation. Examples of where manufacturers may require some degree of factory controls include, but are not limited to:
        1) Direct-expansion (DX) cooling coils
        2) Gas-fired heat
        3) ECM fan walls
        4) Frost control for heat exchangers
    c. Any degree of factory controls on any piece of equipment shall be reviewed and approved by the Owner prior to purchase of equipment.
    d. All control devices shown on design documents shall be furnished and installed by the controls contractor. It is not acceptable to integrate factory control devices in place of field-installed devices shown on design documents.
    e. Where multiple central systems are controlled by Niagara-4 input/output devices connected to a single network controller, input/output modules must

be within the general vicinity of the network controller. Any input/output modules located more than 50 feet away or that require running wire through walls and/or floors must be pre-approved by the Owner.

3. Level three - Field level - consists of general purpose programmable controllers to provide stand-alone control of terminal units. Examples of terminal units include VAV boxes, fan coil units, heat pumps, induction units, unit heaters, smaller rooftop units serving a single zone, etc. Field level controllers shall be configured or programmed using Tridium Workbench wiresheet programming or the Johnson Controls Inc. CCT Controller Configuration Tool. Programmable controller tool shall be capable of connection to CVM field controllers via District LAN/WAN routed through the Niagara-4 network controllers. Communication trunks for level three field controllers shall connect to level two middle level controllers. It is acceptable to provide Niagara-4 network controllers at field level. Communication at the field level shall be open protocol BACnet, or FOX.
   a. The District requires that all programming reside on Niagara-4 controller wiresheets with limited exceptions. Johnson Controls CCT shall be used for standalone programming for VAV controllers, with all other programming located directly on a Niagara-4 controller wiresheet. Any exceptions must be approved by the District. For ancillary equipment such as exhaust fans and unit heaters this shall be accomplished as follows:
      1) Using additional Niagara-4 input/output expansion modules for grouped/centralized control of smaller equipment. Deploy modules such that they are not further than 300 feet from any controlled equipment.Coordinate with Owner to determine suitable controller locations.
      2) ~~Using Johnson Controls CGM controllers for grouped/centralized control of smaller equipment. CGM controllers must be configured as input/output only with all necessary programming completed using Tridium Workbench wiresheet programming.~~
   b. It is not acceptable to add ancillary equipment control to Johnson Controls CVM controllers. CVM controllers shall be used only for VAV control. CVM controllers may also be used for fin-tube radiation (FTR) control only if the FTR is serving the same space as the VAV.
      1) It is not acceptable to add expansion modules to CVM controllers.

2.4 NIAGARA-4 SUPERVISOR SERVER OR DESKTOP OPERATOR WORKSTATIONS

A. Niagara-4 Supervisor server exists and is located at District office, 1930 Como Ave. All BAS control projects must be added to this Niagara-4 Supervisor. Niagara-4 Supervisor, including versions and patches, is maintained by District. Server version upgrades and patches are not required as part of project.

B. Personal Computers, or Laptop workstations are not required as part of project. District staff access Niagara-4 Supervisor using District provided workstations, connected to the District LAN/WAN using preferred web browser software.

2.5 USER INTERFACE

A. Graphic Screens:
   1. Utilize graphic package included within Niagara-4 to create a complete graphical interface.
   2. Refer to example graphic screens located at the end of this specification section for a general idea of functionality, color, layout, etc. These are examples only: actual content shall represent the specific project.
   3. Develop graphic screens for a monitor with resolution size: 1600x1200. Graphic screens shall be sized with a canvas pane width 1890, and height of 900 pixels.
   4. Graphic screens shall include the following:
      a. Main sider and header on all graphic screens with hyperlinks:
         1) Overview with basic floor plans. Include hyperlinks to open both architectural, and mechanical drawings.
         2) AHU/RTU/ERU
         3) VAVs
         4) HW/Boiler system
         5) Pools (as needed)
         6) CW/Chiller system (as needed)
         7) Exhaust Fans
         8) Finned tube radiation (as needed)
         9) CUH/UH (as needed)
         10) Lighting
         11) Fire Smoke Dampers (as needed)
         12) Urinals (as needed)
         13) Security
         14) Lighting systems
      b. Logoff button on Main Header on all pages.
      c. Next/Previous buttons on all multiple page screens, such as VAV and AHU/RTU screens.
      d. AHU hyperlink button on all associated VAV screens
      e. Current user log on status
      f. Security Screen with:
         1) Security Status (key switch)
         2) Fire Alarm status
         3) Fire Trouble status
         4) Fire Tamper/Supervisory
         5) Fire Duct Smoke status (if existing)
         6) Dialer Reset
         7) Security Zones, Air Compressor, Boiler and Pool Water Detectors with:
            a) Point Name/Description
            b) Status (current value) per point
            c) Point Override per point
            d) Alarm Enable per point
         8) Freezer and Cooler with:
            a) Point Name/Descriptions
            b) Temperature
            c) Alarm Enable
         9) KWH Pulse Reading
         10) PDL on Security page.
         11) Hyperlink from SPPS main map to building main page.

12) Main header on main building page shall look like this:
"(CAFM# - BUILDING NAME – STREET ADDRESS)"
"1040 – WHEELOCK EARLY EDUCATION – 1521 Edgerton Street
13) Main page shall contain the following:
a) Main street view of main entrance (such as from Google)
b) Large map image of area with an address flag. Image shall be full screen size included in graphic within a scroll pane such that operator can scroll to view more of map if desired.
14) Main banner on all other pages shall look like the following:
"(CAFM#-BUILDING NAME)"
"3040-EXPO FOR EXCELLENCE ELEMENTARY"

5. Utilize default Niagara-4 coloring schemes for point status indication, alarm priority indication, etc.
6. Utilize default Niagara-4 (16) priority levels used by writable points modeled after corresponding BACnet propriety levels. In particular, follow the definitions pertaining to these levels:
   a. level 4 – User Defined (secondary software safety programming)
   b. level 8 – Operator Override
   c. level 10 – User Defined (normal programming)
   d. level 11 – Schedule
7. Niagara-4 point override options shall be limited for all points as follows.
   a. Hide all emergency choices. The slots pertaining to emergency actions shall be configured as hidden,
   b. Select either (Override/Auto) or (Set) choices, not both, for all points intended to be manipulated by District staff, such as hardware outputs and adjustable setpoints.
   c. Hide all action choices for points not intended to be manipulated by District staff, such as hardware inputs and monitoring points.
8. History chart trend screen shall be hyper-linked to every point with an associated history trend extension.
   a. Numeric points shall default to a history chart view.
   b. Boolean and Enumerated points shall default to a history table view.
9. Plan for each building floor, including interstitial floors, and each roof level of each building, showing the following:
   a. Room layouts with room identification and name.
   b. Location of critical sensors, including but not limited to differential pressure sensors and system bypass valves.
   c. Include a button with hyperlink to open the specific mechanical plan pages pertaining to the floor in a .pdf format. Mechanical plan pages shall include ductwork, piping, equipment, room sensors, and other pertinent information.
   d. For each zone unit connected to DDC system include a dynamic object with hyperlink to zone unit graphic, a red/clear/blue temperature spectrum binding referenced to setpoint, unit tag identifier, and zone temperature value. These objects shall be located on floor plan graphics within the specific zone they serve.
   e. For each piece of equipment connected to DDC system other than a zone unit, include; a button with hyperlink to equipment graphic, and unit tag identifier These buttons shall be located on floor plan graphics near their actual location.
10. Graphic display for each piece of equipment connected to DDC system shall include dynamic indication of all points associated with equipment. Include

accurate schematic diagram with flow directions, labels and animations. Include point identification, set points, customizable note, and sequence of operation. Pop-up windows shall be utilized to further organize points and break up the otherwise overwhelming amount of information on a single graphic screen.

11. PDF files of control O&M manuals and all other pertinent documentation to be inserted into BAS with an on-screen hyperlink to access from graphic screen.

B. Standard Reports: Standard DDC system reports shall be provided and operator shall be able to customize reports later.
   1. All I/O: With current status and values.
   2. All I/O in a manual override state: With current status and values.
   3. Alarm: All current alarms.
   4. Disabled I/O: All I/O points that are disabled.
   5. Logs:
      a. Alarm history.
      b. Audit history, displaying all operator initiated events.
      c. System messages.
      d. System events.
      e. Trends.

2.6 POINT NAMING – Typical

A. It is required that a logical and consistent point naming strategy be used. The point naming strategy described here may be used or alternative strategy may be submitted for engineer's approval prior to implementation. The naming abbreviations listed here show common abbreviations, it is expected that additional abbreviations be added when applicable.

B. Actual point names of Boolean, Numeric, Enumerated and String points shall be simple short names that are repeated as much as possible throughout system to take advantage of batch commands. For example, there should be many points throughout the system with the name "Zn_Temp". The key is that these repeat points are all in different, uniquely named folders. The full point name shall be derived from folder structure naming and extracted as needed automatically by the BAS. For example, when a point alarms and is issued to the alarm log, the full point name, extracted from the folder structure shall be included in the alarm message so it is known exactly which Zn_Temp of all the Zn_Temps throughout the system is in alarm.

C. Title case is used in this naming strategy to efficiently group abbreviations without the need to use several separator characters. When it is prudent to use a separator character, the use of the underscore character is preferred. Total character count in point naming is limited.

D. Order of text within the point name from left to right is important. Often alphabetical sorting techniques are inherent within BAS systems. This point naming strategy takes advantage of this by starting with broad location in the left-most characters and narrowing to fine detail in the right-most characters, all the while attempting to group like items.

E. **<Prefix>** = <Building Name>_<System Name>_< Equipment Name>

1. This prefix to be included in all full point names. Prefix shall be derived from folder structure and shall automatically change with folder renaming.
2. All equipment names must match the equipment tag on the construction documents. Review BAS and confirm equipment tags do not overlap with any existing equipment tags.

F. **<Point Name>** = <Component Name>_<Feature Name>
1. At least first feature name must be included. Additional feature names to be included as appropriate

G. **<Full Point Name>** = <Prefix>_<Point Name>
1. Example Full Point Names:
   a. NorthBldg_Ahu01_SaFan_Cmd
   b. NorthBldg_Ahu01_ClgChws_Temp
   c. NorthBldg_Ahu01_Oa_Flow
   d. Science_Vav05_Zn_Temp
   e. Science_Vav05_Zn_ClgUnocTempSp
   f. Science_Vav05_PriAirDmpr_Sig
   g. GB1_ClgPlnt_SecChwP2_Cmd
   h. GB1_ClgPlnt_ClgTwr1_FanA_Stat
   i. MplsBank_Energy_Hvac_kW
   j. MplsBank_Energy_Lights_kWh
   k. MainStPark_Lights_ExtLights_Cmd

<Building>_<System>_<Equipment>_<Component>_<Feature>

This folder name to be derived from building name shown on drawing set, examples might include:			
NorthBldg	North Building	MplsBank	Minneapolis Bank Building
GB1	1st - General Building	MainStPark	Main Street Park
Science	Science Building		

<Building>_<**System**>_<Equipment>_<Component>_<Feature>

This folder name (optional) is used when prudent to describe the larger system the point will be associated with. Often this will allow the logical grouping of equipment such as in central plants or helping to distinguish lighting control from HVAC control. Some examples include:			
ClgPlnt	Central Chiller Plant	HwPlant	Central Heating Plant
Energy	Energy Monitoring	Hvac	HVAC systems
Lighting	Lighting Systems		

<Building>_<System>_<**Equipment**>_<Component>_<Feature>

This is the folder name when not part of a system. This is part of the actual point name when part of a system. It is used to describe the specific piece of equipment the point is associated with. It can be derived from the designated equipment name shown on drawing set. Combine with multiple component names as appropriate to further clarify the piece of equipment, examples might include:			
Ahu1	Air Handling Unit #1 (folder)	Vav01	VAV #2 (folder)
SecChwp2	Secondary Chilled Pump #2 (point)	PriHwp7	Primary Heating Pump #7 (point)

<Building>_<System>_<Equipment>_<**Component**>_<Feature>

This part of the actual point name (optional) can be used to describe a component of a piece of equipment. Combine with multiple component names as appropriate to further clarify the component. Examples might include: Ahu01_**SaFan**_Cmd, ClgPlnt_ClgTwr1_**FanA**_Sts			
Dmpr	Control damper	Filt	Filter
Safety	Safety device value	Oa	Outside air section
EmStop	Emergency stop button	Ma	Mixed air section
Fan	Fan	Da	Discharge air section
Zn	Controlled zone, room or space		
Pri	Primary water loop	Ra	Return air section
Sec	Secondary water loop	Rlf	Relief air section
Chw	Chilled water	PreHt	Pre-heating coil and valve
Chws	Chilled water supply	Rht	Re-heating coil and valve
Chwr	Chilled water return	Htg	Heating
Hw	Heating water	Clg	Cooling
Hws	Heating water supply	DxCmp	Direct exp clg compressor
Hwr	Heating water return	Vlv	Control valve
Sump	Sump tank	RevVlv	Reversing Valve
Rad	Radiation	Vfd	Variable frequency drive
Humid	Humidifier	PriAir	Primary air section
Light	Lighting	Pump	Circulating pump
FrzStat	Freezestat	Iso	Isolation, as in isolation valve
Set	Part of a set, such as a pump set	Sys	Part of a specific system

<Building**>**_<System>_<Equipment>_<Component>_<**Feature**>

This last part of the actual point name is used to describe the feature of the equipment/component. The action, reading, calculated value, associated setpoint, etc. Combine with multiple feature or component names as appropriate to further clarify the feature. Examples might include: Vav05_Zn_**ClgUnocTempSp,** Vav05_Zn_**SpAdj,** Ahu01_SaFan_**Cmd,** Ahu01_Ra_**MaxCo2**			
Cmd	Command; on/off	Occ	Occupied value
Sig	Modulating signal; controller to device	Unocc	Unoccupied value
Sts	Status: on/off device to controller	StndBy	Stand-by value
FdBk	Feedback signal from device to cntrl	Co2	Carbon dioxide
Alm	Alarm status from device	Co	Carbon monoxide
Flow	Air or water flow	No2	Nitrogen dioxide
Temp	Temperature	Mode	Operating control mode
Rh	Relative humidity	Vel	Velocity
Enth	Enthalpy	Area	Area
Dew	Dewpoint temperature	Level	Level measurement
Press	Gauge pressure	Kfactor	Balancing constant
Dp	Differential pressure	Config	Configuration value
Sched	Schedule value	Pct	Percentage
Calc	Calculated value in software	Cap	Capacity
Sp	Setpoint value in software	Eff	Effective or resulting
Offset	Offset value	Select	Selected value
Hi	Highest value	OptStart	Optimum start value

Lo	Lowest value	Mwu	Morning warm-up
Min	Minimum value	Mcd	Morning cool-down
Max	Maximum value	Btuh	Power
Spec	Red/Blue floor plan color spectrum	Btu	Energy
Adj	Adjustment slider, button, knob, etc.	Int	Interior
Btn	Button, user initiated	Ext	Exterior
kW	Power - electrical	Lux	Lighting level - illuminance
kWh	Energy - electrical	PctRla	Percent run load amps
			Any name from the component list

2.7 ALARMING - Typical

A. It is required that a logical and consistent alarm strategy be used. The alarm strategy described here may be used or an alternative strategy may be submitted for engineer's approval prior to implementation. The typical alarms listed here show common situations. It is expected that additional alarms shall be added when applicable.

B. Additional, non-typical alarm extensions shall be added for specific situations described within the control sequences in drawing set.

C. Include alarm handling software to report all alarm conditions monitored and transmitted through DDC controllers, gateways and other network devices.

D. Include first in, first out handling of alarms according to alarm priority ranking.

E. Alarm handling shall be active at all times to ensure that alarms are processed even if an operator is not currently signed on to DDC system

F. Full point name shall be included in every alarm message, refer to "Point Naming" in this specification Section.

G. These steps shall be taken to prevent nuisance alarming. False alarms can quickly fill alarms logs causing real alarms to get overlooked.

H. All indicated alarm threshold, limit, and time delay values to be user adjustable.

I. Configure appropriate alarm deadband values to prevent rapid cycling of alarm transitions. Example: mixed air temperature alarm deadband shall be 2°F. Values to be user adjustable.

J. End-users shall be able to define additional alarms for any point in the system.

K. Alarms shall not be audible.

L. Alarm routing via email shall be configured and sent at Niagara-4 Supervisor server.

M. Alarm extensions shall be added at the Niagara-4 Supervisor server.

N. Example alarms:

Full Point Name (Source)	Class	Message
NorthBldg_Ahu1_SaFan_Cmd	Level 3	SUP_Fan Problem
NorthBldg_Ahu1_Filter_Sts	Level 3	ABS_Filter Dirty
NorthBldg_Ahu1_FrzStat_Alm	Level 1	ABS_Freeze Condition
NorthBldg_Ahu1_Clg_Alm	Level 3	SUP_Cooling Valve Problem
NorthBldg_Ahu1_Dmpr_Alm	Level 3	SUP_Cooling Damper Problem
Science_VAV_05_Zn_Temp	Level 3	SUP_Zone Temp Away From Sp, 79°F
Science_VAV_20_Zn_Temp	Level 1	ABS_Zone Temp Extremely Cold, 38°F
Science_VAV_38	Level 2	COM_Controller Offline, Comm Problem
Science_VAV_64_Zn_Temp	Level 2	RNG_Sensor Problem, -20°F
Science_Oa_Temp	Level 1	RNG_Sensor Problem, 150°F

O. **Classes**, three alarm classes as described here shall be programmed for each building. Create a separate console recipient for the three classes at each building. Intent is to provide a limited view of alarms in the log that pertain only to a particular building.
   1. **Level 3** – Class for maintenance type notifications. Log is checked daily/weekly.
   2. **Level 2** – Class for most alarms. Log is checked throughout the day.
   3. **Level 1** – Class for critical alarms. Emails are sent immediately.

P. **Types,** four alarm types as described here shall be programmed. Examples are shown here to set the level of expectation to apply these types of alarms to each of these typical situations.
   1. **Supervisory** Alarms, where the BAS system monitors itself. Programming to issue an alarm when a predicted result is not achieved as the result of a programmed control action, typically applies to outputs. All supervisory alarms shall have the prefix “SUP” in the alarm message to immediately provide more insight into how and why this alarm appeared on the alarm log.
      a. Command fail alarm shall be sent to the BAS any time the fan start/stop and status don't match for 60 seconds (adj).
         1) Do not include alarms in applications where a building occupant can enable/disable equipment via a local switch. Examples include exhaust fans with a wall-mounted on/off switch in the space they serve.
      b. Setpoint alarms, only active when control is active. For example, ZnTemp alarms shall only alarm when area is occupied, and has been occupied long enough for the temperatures to be normal. Setpoint alarms shall be sent to the BAS anytime a sensed value is not within tolerance of setpoint value within 15 minutes (adj).
   2. **Range** Alarms, where an input sensor is outside of its operating range. Indicates when a sensor has failed, power to the sensor has failed, wiring has been shorted or opened, etc. It is required to determine how every controller reads both an open and short for every input and program a specific range alarm for each. All range alarms shall have the prefix “RNG” in the alarm message to immediately provide more insight into how and why this alarm appeared on the alarm log.
      a. Hi limit alarm shall be sent to the BAS anytime an input sensor reads near the top of its range, and this value is above its normal control range. For example, outside air temperature reading of 150 Deg F.

b. Lo limit alarm shall be sent to the BAS anytime an input sensor reads near the bottom of its range, and this value is below its normal control range. For example, outside air temperature reading of -60 Deg F.

3. **Absolute** Alarms, where an input sensor is above or below a fixed threshold. Or where an alarm contact closes. All absolute alarms shall have the prefix "ABS" in the alarm message to immediately provide more insight into how and why this alarm appeared on the alarm log.
   a. Hi limit alarm shall be sent to the BAS anytime an input sensor reads above the high limit threshold. For example, when kitchen freezer temperature is greater than 0°F (adj) for a minimum of 10 minutes (adj). Or when kitchen cooler temperature is greater than 37°F (adj) for a minimum of 10 minutes (adj).
   b. Lo limit alarm shall be sent to the BAS anytime an input sensor reads below the low limit threshold. For example, any room temperature less than 40 Deg F.
   c. Discrete alarms shall be sent to the BAS anytime a monitored contact changes to an alarm state. For example, freezestat device trips or inhibitor chemical running low contact remains closed for 10 minutes (adj).
4. **Communication** Alarms, where a controller is offline. All communication alarms shall have the prefix "COM" in the alarm message to immediately provide more insight into how and why this alarm appeared on the alarm log.
   a. Any controller communication alarm shall be sent to the BAS anytime communication is lost to a controller for 10 minutes (adj).

Q. Required Alarms, the specific alarms described here shall be programmed for each piece of equipment.

Point Name (Source)	Class	Limit	Delay	Message
Fire_Alm	Level 1	Alarm	10 sec	ABS_Fire Alarm
Fire_Supervisory_Tamper_Alm	Level 1	Alarm	10 sec	ABS_Fire Supervisory/Tamper
HwPlant_Hws_Temp	Level 1	210°F	10 min	ABS_High Limit Temperature
HwPlant_Hws_Temp	Level 1	100°F	10 min	ABS_Low Limit Temperature
HtgPlant_Steam_Press	Level 1	5 psi	10 min	ABS_Low Limit Pressure
Ahu_Ma_Temp	Level 1	40°F	15 min	ABS_Low Limit Temperature
Ahu_FrzStat_Alm	Level 1	Alarm	10 sec	ABS_Freeze Condition
VAV_Zn_Temp	Level 2	100°F	15 min	ABS_Zone Temp Extreme Hot
VAV_Zn_Temp	Level 1	50°F	15 min	ABS_Zone Temp Extreme Cold
Kitchen_Cooler_Temp	Level 2	45°F	30 min	ABS_High Limit Temperature
Kitchen_Cooler_Temp	Level 2	30°F	30 min	ABS_Low Limit Temperature

Kitchen_Freezer_Temp	Level 2	15°F	30 min	ABS_High Limit Temperature
DataRoom_Temp (non A/C)	Level 2	90°F	15 min	ABS_ High Limit Temperature
DataRoom_Temp (A/C)	Level 2	80°F	15 min	ABS_ High Limit Temperature
Pool_Temp	Level 2	95°F	15 min	ABS_ High Limit Temperature
Pool_Temp	Level 2	78°F	15 min	ABS_ Low Limit Temperature
Security_Motion (when armed)	Level 2	Alarm	10 sec	ABS_Possible Intrusion Alarm
Water_Detection_Alm	Level 2	Alarm	10 sec	ABS_Possible Water Leak, Wet
Fire_Trouble	Level 2	Trouble	10 sec	ABS_Fire Trouble Situation
Fan_Sts (fan fail)	Level 3	Alarm	5 min	SUP_Fan Problem
Pump_Sts (pump fail)	Level 3	Alarm	5 min	SUP_Fan Problem
Ahu_DaPress (press when off)	Level 3	0.3 inwc	5 min	SUP_Unit Not Shutting Off
Generator_Sts	Level 3	Run	10 sec	ABS_Generator is Running
Generator_Alm	Level 3	Alarm	10 sec	ABS_Generator is in Alarm
Key_Switch_Sts	Level 3	Armed	10 sec	ABS_Key Switch Change
Key_Switch_Sts	Level 3	Disarmed	10 sec	ABS_Key Switch Change

2.8 HISTORY TRENDING – Typical

A. It is required that a logical and consistent history trend strategy be used. The history trend strategy described here may be used or alternative strategy may be submitted for engineer's approval prior to implementation. The typical history trends listed here show common situations, it is expected that additional history trends be added when applicable.

B. History trend extensions shall be added and configured for all typical situations described here. This includes every hardware point and every calculated software point that changes automatically by way of program logic.

C. Full point name shall be included in every trend name, refer to "Point Naming" in this specification Section.

D. All indicated trend configuration parameter values to be user adjustable.

E. All history trends shall store at minimum (3) years' worth of data before rolling to overwrite data. It is understood that change of value (COV) type trend sizes will have to be estimated, configure at least 10,000 records for these.

F. History extensions shall be added at the Niagara-4 network controller level and sent via the Fox network to the Niagara-4 Supervisor. History trend data shall be stored on the Niagara-4 Supervisor server.

G. End-users shall be able to define additional trends for any point in the system.

H. **Change of Value (COV)** trends are where a sample is logged whenever the value changes by a specified amount.
   1. Boolean and Enumerated point COV trends shall log a sample every change of state. Examples of Boolean or Enumerated points are; fan command, fan status and current mode.
   2. For Numeric points, COV trends are not recommended, use Interval trends instead.

I. **Interval trends** are where a sample is logged according to a preset regular time interval.
   1. Numeric point Interval trends log interval times shall be set as:
      a. 15 minute intervals for slower variables such as; outside temp, room temp, return temp, etc.
      b. 3 minute intervals for faster variables such as; discharge air temp, heating valve signal, building static pressure, etc.
   2. For Boolean and Enumerated points, Interval trends are not recommended, use COV trends instead.

2.9 USER LOGINS AND PERMISSIONS

A. Roles and user accounts are managed centrally on the Niagara-4 Supervisor by the District. User accounts shall be regularly synchronized out of the Niagara-4 Supervisor to each Niagara-4 network controller via the NiagaraNetwork.

B. Disable all user accounts within each Niagara-4 network controller that cannot be deleted, and are not used. These user accounts include admin and guest.

C. Provide all levels of login credentials to District for all provided software and hardware upon equipment being installed at a District facility. District shall have complete access throughout installation and warranty period. District will modify login credentials once warranty period has been completed. At a minimum, the following login credentials shall be provided for all Niagara-4 network controllers.
   1. Niagara Passphrase(s)
   2. Niagara Platform
   3. Niagara Station, Super-User Account

D. Coordinate with District to set up secure Platform, FOXs, and HTTPs communication between Niagara-4 network controllers and Niagara-4 Supervisor.

E. Niagara-4 network controllers minimum password and security requirements shall be set and maintained by District.

F. The home screen graphic for each specific building shall be assigned to the respective user account(s) for the specific engineer(s) assigned to that building. This shall limit the view of graphic screens based on login credentials.

G. The following categories exist within the Niagara-4 Supervisor. Assign these categories to all new, project-related objects within Niagara on the Niagara-4 Supervisor accordingly.

	Category	Objects to Assign Category to:
1	Time Schedules	Time schedules: routine weekly type
2	Time Schedules - Advanced	Time Schedules: calendar, and special purpose type
3	Setpoints_Basic	Setpoints pertaining to occupied room temperature only
4	Setpoints_Pump_Reset	Pump reset points only
5	Setpoints_Pump_LeadLag	Pump lead/lag setpoints only
6	Setpoints_Systems_Enable	System setpoints only. Example, OAT enable setpoint for boiler plant
7	Setpoints_Heat_Timer	Heat timer setpoints only
8	Setpoints_Advanced	Every setpoint including, resets, lead/lag, enable, etc. All setpoints
9	Setpoints_Air_Side	Setpoints associated with air systems: fans, dampers, etc.
10	Setpoints_Water_Side	Setpoints associated with water systems: pumps, valves, etc.
11	HwInOut	Hardware I/O points to override for testing
12	HwInOut_PhotoEye	Hardware I/O points to override for testing - photoeyes only
13	HwInOut_Water_Side	Hardware I/O points to override for testing – pumps, valves, etc.
14	HwInOut_Special_1	Reserved for District use
15	HwInOut_All	Hardware I/O points to override for testing - every hardware point
16	Config_Settings	Reserved for District use
17	Config_Settings_Advanced	All objects except UserService object
18	Alarm_Ack	Alarm classes to allow alarm acknowledgment action
19	User_Config	User service to allow management of user accounts

2.10 TIME SCHEDULES

A. Time scheduling shall match existing time scheduling strategy used within BAS. Refer to example graphic screens located near the end of this specification Section for a general idea of functionality. These are examples only, actual content shall represent the specific project.

B. Hyperlinks shall be included on graphics for convenient access to all schedules. Permissions shall be set to allow facilities staff to regularly adjust schedules.

C. Schedule objects shall be provided for each piece of equipment and lighting zone with choices to utilize the specific schedule object or a common building schedule object.

2.11 DDC CONTROLLERS

A. DDC system shall consist of a combination of Niagara-4 network controllers, programmable application controllers and application-specific controllers to satisfy performance requirements indicated.

B. DDC controllers shall perform monitoring, control, energy optimization and other requirements indicated.

C. DDC controllers shall use a multitasking, multiuser, real-time digital control microprocessor with a distributed network database and intelligence.

D. Each DDC controller shall be capable of full and complete operation as a completely independent unit and as a part of a DDC system wide distributed network.

E. Environment Requirements:
   1. Controller hardware shall be suitable for the anticipated ambient conditions.

F. Power and Noise Immunity:
   1. Controller shall operate at 90 to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% of nominal voltage.
   2. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios with up to 5 W of power located within 36 inches of enclosure.

G. DDC Controller Spare Processing Capacity:
   1. Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:
      a. Network Controllers: 15% spare. Average operating CPU% shall not be greater than 85% and “heap used” value shall not exceed 85% of “heap total”.
      b. Programmable Application Controllers: 15% spare.
      c. Application-Specific Controllers: 15% spare.

   2. Memory shall support network controller's operating system and database and shall include the following:
      a. Monitoring and control.
      b. Energy management, operation, and optimization applications.
      c. Alarm management.
      d. Historical trend data of all connected I/O points.
      e. Maintenance applications.
      f. Operator interfaces.
      g. Monitoring of manual overrides.

H. DDC Controller Spare I/O Point Capacity: Include spare I/O point capacity for each controller as follows:
   1. Network Controllers:
      a. Room in panel shall be allocated to allow for additional I/O devices and associated wiring needed to achieve 25% added point capacity in the future. Anticipated point mixture shall be planned at approximately 6-1/2% of each point type, AI, AO, BI and BO.

   2. Programmable Application Controllers:
      a. When applied to equipment other than a zone terminal unit, spare capacity requirements shall follow that of network controller.
      b. When applied to a zone terminal unit, no spare capacity is required.

   3. Application-Specific Controllers:
      a. Spare capacity requirements shall be identical to programmable application controllers.

I. Maintenance and Support: Include the following features to facilitate maintenance and support:

1. Mount microprocessor components on circuit cards for ease of removal and replacement.
2. Means to quickly and easily disconnect controller from network.
3. Means to quickly and easily connect to field test equipment.
4. Visual indication that controller electric power is on, of communication fault or trouble, and that controller is receiving and sending signals to network.

J. Input and Output Point Interface:
1. Hardwired input and output points shall connect to network controller I/O devices, programmable application and application-specific controllers.
2. Input and output points shall be protected so shorting of point to itself, to another point, or to ground will not damage controller.
3. Input and output points shall be protected from voltage up to 24 V of any duration so that contact will not damage controller.

2.12 NIAGARA NETWORK CONTROLLERS

A. General Network Controller Requirements:
1. Tridium Niagara-4 framework Niagara-4 network controllers with open NiCS (open Niagara Implementation Conformance Statement).
2. Include adequate number of device packs, 50-points per device pack, to achieve performance indicated.
3. Include 5-year software maintenance agreements (SMA) on all Niagara-4 JACE controllers. SMA not available for, or required on EDGE 10 controllers.
4. System shall consist of one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.
5. Data shall be shared between networked controllers and other network devices.
6. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
7. Controllers that perform scheduling shall have a real-time clock.
8. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
9. Controllers shall be fully programmable.
10. Controllers shall be capable of routing necessary configuration software tools to attached level three controllers.

B. Communication:
1. Network controllers shall be capable of communication with other devices on DDC system level one and/or level two networks.
2. Network controller also shall perform routing if connected to a level three network of programmable application, application-specific controllers or integrated equipment. Level three network shall be open protocol; BACnet. The use of other open protocols, including Lonworks, Modbus, or PUP is acceptable when integrating third party devices.
3. A separate level three network is required for each unique device manufacturer type. For example; a single level three network connecting several different size BACnet VAV controllers and FCU controllers from a common manufacturer would be acceptable, but it would not be acceptable to add a BACnet chiller to this same

network. A separate level three network would be required to connect the BACnet chiller or chillers. The only exception to this requirement would be for level three networks connecting less than (10) devices with Owner approval.

C. Serviceability:
   1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
   2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
   3. Controller shall maintain BIOS and programming information in event of a power loss for at least 96 hours.

2.13 GENERAL PURPOSE PROGRAMMABLE CONTROLLERS (CVM)

A. General Programmable Application Controller Requirements:
   1. Johnson Controls Inc. (JCI) Facility Explorer, FX-CVM line of controllers purpose-built for VAV applications.
   2. Include adequate number of controllers to achieve performance indicated.
   3. CVM controllers shall be readily available for purchase by the District from a local stocking distributor located no more than (50) miles from District office. Distributor shall be a separate entity from installing DDC System for HVAC contractor.
   4. Technical support for CVM controllers and programmable controller tool made available by the CVM manufacturer shall be provided by the same local stocking distributor.

2.14 CONTROL FUNCTIONALITY

A. Sequencing: Include application software based on sequences of operation indicated to properly sequence chillers, boilers, and other applicable HVAC equipment.

B. Control Loops:
   1. Support any of the following control loops, as applicable to control required:
      a. Two-position (on/off, open/close, slow/fast) control.
      b. Proportional control.
      c. Proportional plus integral (PI) control.
      d. Proportional plus integral plus derivative (PID) control.
         1) Include PID algorithms with direct or reverse action and anti-windup.
         2) Algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs.
         3) Controlled variable, set point, and PID gains shall be operator-selectable.
      e. Adaptive (automatic tuning).

C. Staggered Start: Application shall prevent all controlled equipment from simultaneously restarting after a power outage. Order which equipment (or groups of equipment) is started, along with the time delay between starts, shall be included.

D. Anti-Short Cycling:
   1. BO points shall be protected from short cycling.

2. Feature shall allow minimum on-time and off-time to be selected.

E. On and Off Control with Differential:
1. Include an algorithm that allows a BO to be cycled based on a controlled variable and set point.
2. Algorithm shall be direct- or reverse-acting and incorporate an adjustable differential.

F. Run-Time Totalization:
1. Include software with the capability to totalize run-times for BI points.

2.15 ENCLOSURES

A. General Enclosure Requirements:
1. Include enclosure door with secure latching mechanism.
2. All enclosures containing a DDC controller applied to equipment other than a zone terminal unit shall have hinged door.
3. All enclosures associated with DDC control system shall be alike color/style with a visible label identifying its tag/controlled equipment.
4. Individual enclosures shall not exceed 36 inches wide and 48 inches tall high.
5. Supply each enclosure with a complete set of as-built schematics, tubing, and wiring diagrams and product literature located in a pocket on inside of door.
6. Enclosure shall be NRTL listed according to UL 508 A.
7. Constructed of steel with factory applied galvanized coating or paint.
8. Internal panel mounting hardware, grounding hardware and sealing washers.
9. Grounding stud on enclosure body.

B. Internal Arrangement:
1. Internal layout of enclosure shall group and protect pneumatic, electric, and electronic components associated with a controller, but not an integral part of controller.
2. Arrange layout to group similar products together.
3. Include a barrier between line-voltage Class 1, and low-voltage Class 2 electrical wiring and electronic products.
4. Factory or shop install products, tubing, cabling and wiring complying with requirements and standards indicated.
5. Terminate field cable and wire using heavy-duty terminal blocks.
6. Install a maximum of two wires on each side of a terminal.
7. Include enclosure field power supply with a toggle-type switch located at entrance inside enclosure to disconnect power.
8. Include enclosure with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch.
9. Mount products within enclosure on removable internal panel/backplane.
10. All internal panel components to be labeled.
11. Route tubing cable and wire located inside enclosure within a raceway with a continuous removable cover.
12. Label controller end of cable, within 12 inches of termination, on cable jacket. Jacket shall not be stripped away at enclosure entry point.

13. Size enclosure internal panel to include at least 25% spare area on backplane of panel.

C. Environmental Requirements:
1. Evaluate temperature and humidity requirements of each product to be installed within each enclosure and locate panel accordingly.
2. Outdoors, Type 4X. Additional panel heater is required when components are not rated for design outdoor temperature and humidity levels.
3. Indoors, Dry Areas: Type 1.
4. Indoors, Wet Areas or Areas Exposed to Condensation or Washdown: Type 4X

2.16 ELECTRICAL POWER DEVICES

A. Transformers:
1. Transformer shall be sized for the total connected load, plus an additional 25% of connected load.
2. Transformer shall be UL Listed.
3. Transformer shall be at least 40 VA.
4. Transformer shall have secondary resettable breaker.

B. DC Power Supply:
1. Output voltage nominally 24-VDC or other voltage within 5%.
2. Output power minimum of 14W.
3. Input voltage nominally 120-VAC, 60 Hz. Lower voltage input is not acceptable.
4. Load regulation within 0.5% from zero- to 100-mA load.
5. Line regulation within 0.5% at a 100-mA load for a 10% line change.
6. Stability within 0.1% of rated volts for 24 hours after a 20-minute warmup.

2.17 PIPING AND TUBING

A. Pneumatic, and Pressure Instrument Signal Air, Tubing and Piping:
1. Products in this Article are intended for use with the following:
   a. Main air and signal air to pneumatically controlled instruments, actuators and other control devices and accessories.
   b. Signal air between pressure instruments, such as sensors, switches, transmitters, controllers and accessories.
2. Copper Tubing:
   a. Seamless phosphor deoxidized copper, soft annealed or drawn tempered, with chemical and physical properties according to ASTM B 75.
   b. Performance, dimensions, weight and tolerance according to ASTM B 280.
   c. Diameter, as required by application, not less than nominal 0.25 inch
   d. Wall thickness, as required by the application, but not less than 0.030 inch.
3. Copper Tubing Connectors and Fittings:
   a. Brass, compression type.
   b. Brass, solder-joint type.
4. Galvanized-Steel Piping:
   a. Galvanized pipe shall be ASTM A 53/A 53M, Schedule 40.
   b. Fittings, galvanized malleable iron, ASME B16.3, Class 150.
5. Polyethylene Tubing:

a. Fire-resistant black virgin polyethylene according to ASTM D 1248, Type 1, Class C and Grade 5.
b. Tubing shall comply with stress crack test according to ASTM D 1693.
c. Diameter, as required by application, of not less than nominal 0.25 inch.

6. Polyethylene Tubing Connectors and Fittings:
   a. Brass, barbed fittings.
   b. Brass, compression type.

2.18 CONTROL WIRE AND CABLE

A. Low Voltage Class 2 Power Wiring
   1. Wiring runs less than 150 feet
      a. Wire size shall be minimum 18 AWG.
   2. Wiring runs greater than 150 feet
      a. Wire size shall be minimum 16 AWG. Power/voltage drop calculation must be completed for all longer runs to determine if even larger wire is required.
   3. Conductors shall be twisted soft annealed copper strand.
   4. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame-retardant PVC.
   5. Outer jacket insulation shall have a 300-V, 221-deg F rating and shall be Type PLTC cable.
   6. Power cabling to have a plain white jacket.

B. Low Voltage Class 2 Input/Output wiring – Must be shielded.
   1. Wire size shall be minimum 18 AWG.
   2. Conductors shall be twisted soft annealed copper strand.
   3. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame-retardant PVC.
   4. Outer jacket insulation shall have a 300-V, 221-deg F rating and shall be Type PLTC cable.
   5. Shielding shall be 100% type, 1.35-mil aluminum/polymer tape, helically applied with 25% overlap, and aluminum side in with tinned copper drain wire.
   6. Input cabling to have a plain white jacket.
   7. Output cabling to have a plain white jacket.

C. LAN and Communication Cable: Comply with DDC system manufacturer requirements for network being installed.
   1. Cable shall be plenum rated.
   2. Cable shall comply with NFPA 70
   3. Comply with requirements specified in “Structured Cabling for Voice and Data” Section (271005) for all cabling
   4. Cable shall have a unique color that is different from other cables used on Project. The color BLACK has been selected for this cabling.
   5. Copper Cable for Ethernet Network:
      a. 1000BASE-TX.
      b. Provide Category 6/6A as per Division 27. Comply with all requirements of Division 27
      c. Minimum No. 23 AWG solid
      d. Unshielded Twisted Pair (UTP).

e. Thermoplastic insulated conductors, enclosed in a thermoplastic outer jacket, Class CMP as plenum rated.

D. Control Wire Standards: The following table summarizes the above information, and includes additional details and requirements:

TAG	APPLICATION	AWG	COND	SHIELD	STRANDED	PLENUM	LOW CAP	COLOR
H-BAC	HVAC BACNET COMM	22	3	YES	YES	YES	YES	BLUE
L-BAC	LIGHTING BACNET COMM	22	2	YES	YES	YES	YES	GREEN
NRIO	NRIO COMM	22	2	YES	YES	YES	YES	RASPBERRY
IO2	INPUTS/OUTPUT (2-COND)	18	2	YES	YES	YES	NO	WHITE
IO4	INPUTS/OUTPUT (4-COND)	18	4	YES	YES	YES	NO	WHITE
H-PWR	12V OR 24V POWER	18	2	NO	YES	YES	NO	WHITE
H-PWR16	12V OR 24V POWER	16	2	NO	YES	YES	NO	WHITE
LAN	IP NETWORK	CAT6				YES	NO	BLACK

2.19 RACEWAYS FOR CONTROL WIRING, CABLING, AND TUBING

A. Metal Conduits, Tubing, and Fittings:
1. Listing and Labeling: Metal conduits, tubing, and fittings shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. GRC: Comply with NEMA ANSI C80.1 and UL 6.
3. ARC: Comply with NEMA ANSI C80.5 and UL 6A.
4. IMC: Comply with NEMA ANSI C80.6 and UL 1242.
5. PVC-Coated Steel Conduit: PVC-coated IMC.
   a. Comply with NEMA RN 1.
   b. Coating Thickness: 0.040 inch minimum.
6. EMT: Comply with NEMA ANSI C80.3 and UL 797.
   a. Provide EMT that is BLUE in color to signify DDC purpose.
7. FMC: Comply with UL 1; zinc-coated steel or aluminum.
8. LFMC: Flexible steel conduit with PVC jacket and complying with UL 360.
9. Fittings for Metal Conduit: Comply with NEMA ANSI FB 1 and UL 514B.
   a. Conduit Fittings for Hazardous (Classified) Locations: Comply with UL 1203 and NFPA 70.
   b. Fittings for EMT:
      1) Material: Steel
      2) Type: Setscrew or Compression.
   c. Expansion Fittings: PVC or steel to match conduit type, complying with UL 651, rated for environmental conditions where installed, and including flexible external bonding jumper.
   d. Coating for Fittings for PVC-Coated Conduit: Minimum thickness of 0.040 inch, with overlapping sleeves protecting threaded joints.
10. Joint Compound for IMC, GRC, or ARC: Approved, as defined in NFPA 70, by authorities having jurisdiction for use in conduit assemblies, and compounded for use to lubricate and protect threaded conduit joints from corrosion and to enhance their conductivity.

B. Nonmetallic Conduits, Tubing, and Fittings:
   1. Listing and Labeling: Nonmetallic conduits, tubing, and fittings shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
   2. ENT: Comply with NEMA TC 13 and UL 1653.
   3. RNC: Type EPC-40-PVC, complying with NEMA TC 2 and UL 651 unless otherwise indicated.
   4. LFNC: Comply with UL 1660.
   5. Rigid HDPE: Comply with UL 651A.
   6. Continuous HDPE: Comply with UL 651A.
   7. Coilable HDPE: Preassembled with conductors or cables, and complying with ASTM D 3485.
   8. RTRC: Comply with UL 2515A and NEMA TC 14.
   9. Fittings for ENT and RNC: Comply with NEMA TC 3; match to conduit or tubing type and material.
   10. Fittings for LFNC: Comply with UL 514B.
   11. Solvent cements and adhesive primers shall have a VOC content of 510 and 550 g/L or less.
   12. Solvent cements and adhesive primers shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Department of Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

C. Metal Wireways and Auxiliary Gutters:
   1. Description: Sheet metal, complying with UL 870 and NEMA 250, Type 1 unless otherwise indicated, and sized according to NFPA 70.
      a. Metal wireways installed outdoors shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
   2. Fittings and Accessories: Include covers, couplings, offsets, elbows, expansion joints, adapters, hold-down straps, end caps, and other fittings to match and mate with wireways as required for complete system.
   3. Wireway Covers: Hinged or Screw-cover type unless otherwise indicated.
   4. Finish: Manufacturer's standard enamel finish.

D. Surface Metal Raceways: Galvanized steel with snap-on covers complying with UL 5.

E. Comply with requirements in Division 26/27 for pathways other than conduit (where allowed by Division 27).

F. All cabling shall be installed in designated pathways,either hooks or conduit depending on the location as specified in Division 26/27. Where the requirements of Division 26/27 conflict with the requirements of this specification section, the more stringent requirement shall take precedence. Zip-tied cabling to conduit or other supports is not acceptable.
   1. All cabling in exposed areas shall be installed in conduit.
   2. All cabling and conduit shall follow building lines, running alongside or perpendicular to walls and joists wherever possible in order to provide an overall cleaner installation appearance.

G. Comply with requirements in “Low-Voltage Electrical Power Conductors and Cables” Section 26 05 19 electrical power conductors and cables.

H. Comply with requirements in “Conduit for Electrical Systems“ Section 26 05 33.13 and “Boxes for Electrical Systems” Section 26 05 33.16 for electrical power raceways and boxes.

PART 3 - EXECUTION

3.1 CONTROLS PROGRAMMING AND GRAPHICS KICK-OFF MEETING

A. Prior to submitting shop drawings for official review, schedule meeting with District. Contractor shall be well-prepared to discuss, at a minimum, the following topics:
   1. Equipment names/tags
   2. Wire types, colors, and routing
   3. This specification Section and related drawings
   4. Controls network architecture, including planned controller locations shown on a schematic floor plan.
   5. District shall present and discuss graphic template standards. It is desired to adhere as closely as possible to these templates with minor deviations as necessary to meet project requirements. Any significant deviations must be coordinated with the District prior to beginning any work.
   6. District shall present and discuss standards including:
      a. Niagara-4 network controller; names, IP addresses, FOXS communications, and authentication including passphrase, platform, station, and user synchronization.
      b. BACnet addressing strategy.
      c. District self-performed ongoing BAS maintenance and upgrade strategy.
   7. BAS commissioning – new building checklist
   8. Controller Offline Reports

3.2 DDC SYSTEM INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT

A. Communication Interface to Equipment with Integral Controls and Other Building Systems:
   1. DDC system shall have communication interface with equipment and building systems having integral controls and having a communication interface for remote monitoring and/or control. At a minimum, all chillers, boilers, electrical meters, natural gas meters, water meters, fire alarm panel, security system, cooler/freezer temperature monitoring points, and emergency generators shall require integration. If communication cards were not factory installed on this equipment, notify the provider of this equipment so they may provide field installed communication cards. In some cases, it is acceptable or required to integrate using hardware points in lieu of communication cards as described in the subparagraphs below.
   2. Furnish and install communication wiring from DDC system to equipment.
   3. Perform all steps necessary for integration. These steps may include:

a. Research and gathering effort to identify how to integrate each piece of equipment and identify the significance of each integrated point.
   1) Provide complete list of available integration points to District, for approval, prior to integration. This list shall identify the points planned to be integrated, and the points planned to be passed over. The function of each point available for integration shall be described.
b. Provide equipment interface configuration, addressing instruction, integrated point descriptions, etc. to make interface fully functional.
c. Provide trial and error troubleshooting as required. This may require communication with equipment manufacturer for technical support.
d. Testing of interface. Disconnect communication bus and confirm that points do indeed display as "down". Confirm values are accurate by comparing with onboard equipment display screen. Test writable points and confirm written values are accepted by comparing with onboard equipment display screen and equipment operation.
e. Create a meaningful graphic screen displaying integrated points in a logical fashion with accompanying system schematic diagram.
f. Add trending and alarming as appropriate and/or as shown on point lists.

4. Chillers
   a. At a minimum, the listed integrated software points shall be available. If integrated software point is not available, provide devices and hardware points as required to provide these values.

1)	Chiller Command	Read/Write
2)	Chiller Evap Water Flow Proof	Read
3)	Chiller Alarm	Read
4)	Chiller Alarm Reset	Read/Write
5)	Chiller Alarm – Status Message	Read
6)	Chiller Mode – Status Message	Read
7)	Chiller Chilled Water Supply Temp Setpoint	Read/Write
8)	Chiller Capacity Percent	Read
9)	Chiller Capacity Percent Limit	Read/Write
10)	Chiller Entering Water Temp	Read
11)	Chiller Leaving Water Temp	Read

5. Boilers
   a. At a minimum, the listed integrated software points shall be available. Multiple boilers may be controlled from a central controller referred to as a boiler control system (BCS). Integration to the BCS is required. If integrated software point is not available, provide devices and hardware points as required to provide these values. All points shall be read-only, the BAS shall not control the BCS and/or Boiler(s). This list includes points for both hot water and steam boilers – integrate as applicable.

1)	BCS and/or Boiler Commands	Read
2)	Boiler Water Flow Proofs	Read
3)	Boiler Isolation Valve Positions	Read
4)	BCS and/or Boiler Alarms	Read
5)	BCS and/or Boiler Alarms – Status Message	Read
6)	BCS and/or Boiler Modes – Status Message	Read
7)	BCS and/or Boiler Water Supply Temp Setpoint	Read
8)	BCS and/or Boiler Outside Air Temperature	Read
9)	BCS and/or Boiler Outside Air Lockout Setpoint	Read
10)	BCS and/or Boiler Supply Spt Reset Parameters	Read

11) BCS and/or Boiler Capacity Percents Read
12) Boiler Entering Water Temps Read
13) Boiler Leaving Water Temps Read
14) Boiler Steam Header Pressure Read
15) Boiler Condensate Return Temp Read
16) Boiler Firing Status Read
17) Boiler Switch Status Read
18) Boiler Room Flood Read
a) A single point water detector shall be provided by DDC System for HVAC contractor to alarm in the event of a water leak. This shall be a hardware point connection to the DDC system directly; this sensor is not furnished with, or connected to the BCS.

6. Electrical Meters
   a. At a minimum, the listed integrated software points shall be available. If integrated software point is not available, provide devices and hardware point as required to provide at minimum energy kWH.
      1) Energy kWH Read
      2) Power kW Read
      3) Power Factor Read
      4) Volts, line to line each phase Read
      5) Amps Read
7. Natural Gas Meters
   a. At a minimum, the listed hardware points shall be available.
      1) Energy BTU Read
      2) Power BTU/Hr Read
8. Water Meters
   a. At a minimum, the listed hardware points shall be available.
      1) Small Port Flow (Gpm) Read
      2) Large Port Flow (Gpm) Read
      3) Small Port Volume (Gallons per pulse) Read
      4) Large Port Volume (Gallons per pulse) Read
9. Fire Alarm Panel
   a. The following points shall be made available as hardwired points from the fire alarm panel. There shall not be any communication interface with the panel, hardwired points only.
      1) Alarm Condition
      2) Trouble Condition
      3) Tamper/Supervisory Condition
10. Security System
    a. At a minimum, the listed hardware points shall be available.
       1) Armed/Disarmed Key Status Read
          a) Key status value shall be linked to all time schedule programming to force unoccupied whenever the security system is armed.
11. Cooler/Freezer Temperature Monitoring Points
    a. At a minimum, the listed hardware points shall be available.
       1) Cooler Temperature Read
          a) A single point, temperature thermistor sensor shall be provided by DDC System for HVAC contractor to monitor conditions. This shall be a hardware point connection to the DDC system directly;

this sensor is not furnished with, or connected to the refrigeration system.

2) Freezer Temperature Read

a) A single point, temperature thermistor sensor shall be provided by DDC System for HVAC contractor to monitor conditions. This shall be a hardware point connection to the DDC system directly; this sensor is not furnished with, or connected to the refrigeration system.

12. Emergency Generator

a. At a minimum, the listed hardware points shall be available.

1) Run Status Read

B. Integration with existing American Auto-Matrix control system:

1. Verify any field measurements, controller counts, and circuiting arrangements shown on Drawings. Drawing and descriptions of existing American Auto-Matrix (AAM) control system are based on casual field observations and existing record documents. DDC System for HVAC contractor shall field verify this information prior to disturbing existing installation.
2. Identify any AAM controllers that will remain in operation after construction is completed.
   a. Provide new dedicated communication wiring to support these devices, routed back to their original network controller which is licensed for a communication driver to support these devices.
   b. Verify all controllers on this network are online and communicating.
   c. Retain existing programming for these controllers.
3. Schedule work with new construction.
4. Coordinate work with District Staff

C. Integration with Lighting Control System

1. A complete, operational, and validated lighting control system is being provided as specified in “Lighting Control Devices” Section 26 09 23.
2. Provide at least one new dedicated Niagara-4 network controller(s) for integration to the lighting control system. The Niagara-4 network controller(s) shall be as specified in part 2, and connected to the LAN as specified in part 3. Provide all necessary interfaces for connection(s) to lighting controls system. This may be single or multiple; BACnet-IP, BACnet-MS/TP, or other connections. Refer to Division 26 sections for more information.
3. As part of this specification Section, DDC system for HVAC contractor shall provide integration to lighting system, including at a minimum these tasks:
   a. Request an electronic copy of the lighting control submittals from Division 26 lighting controls contractor.
   b. Provide programming of all integrated network features, including central timeclock control.
   c. Provide central monitoring and graphics for entire lighting control system on DDC system for HVAC. This shall include floor plans with animated lighting zones, and hyperlinks to each lighting zone system graphic. Lighting zone system graphic for each zone shall follow the same requirements used for each DDC system for HVAC zone system graphic.
   d. Coordinate with Division 26 lighting controls contactor to validate integrated segment network features, including central timeclock control. Point integration intent is shown in this table. As part of this specification Section,

DDC system for HVAC contractor shall verify information shown in table is accurate to current lighting system version; adjustments shall be made as required.

e. At a minimum, the listed integrated software points shall be available. These points shall be required for each lighting zone. The may be multiples of each device within each lighting zone.

1)	Zone Wall Switch, status (each)	Read/Write
2)	Zone Motion Sensor, status (each)	Read
3)	Zone Daylight Sensor, lumens (each)	Read
4)	Zone Binary Outputs, status (each)	Read/Write
5)	Zone Analog Outputs, level signal (each)	Read/Write
6)	Zone Time Schedule, after/normal hours	Read/Write

3.3 DEMOLITION FOR HVAC AND LIGHTING CONTROL SYSTEMS

A. Scheduling and Coordination

1. Schedule work with new construction.
2. Conduct demolition to minimize interference with adjacent and occupied building areas.
3. Coordinate demolition work with other Contractors, General Contractor, and Owner.
4. Coordinate and sequence demolition so as not to cause shutdown of operation of adjacent areas.
5. Label all wires prior to disconnecting from existing controllers. Refer to other sections for wire labeling requirements.
6. Shut-down Periods:
   a. Arrange timing of controller offline periods with Owner. Do not shutdown any controller function without prior written approval submitted 7 days prior to shutdown.
   b. Keep controller offline period to a maximum of four hours or use intermittent periods as directed by Owner.
   c. Provide temporary wiring as needed so as not to exceed controller offline times.
7. Identify salvage items in cooperation with Owner. After removal, turnover salvaged items to Owner. Items not claimed by the Owner shall be removed from the site and shall be disposed of properly.
8. Include an allowance for tracing and re-terminating up to ten (10) additional input and output points that are discovered during construction and are not already included in any construction documents.
   a. This shall include upsizing input/output control modules as needed to support additional terminations.
   b. This shall include programming and graphics to support additional input/output points. Coordinate with Owner.
   c. Any inputs/outputs discovered beyond this allowance shall be immediately brought to the District's attention.

B. Execution

1. Verify any field measurements and circuiting arrangements shown on Drawings. Demolition drawings are based on casual field observations and existing record

documents. Report discrepancies to Architect/Engineer before disturbing existing installation.

2. Verify that abandoned wiring and equipment serve only abandoned facilities. Beginning of demolition means installer accepts existing conditions.
3. Disconnect electrical and pneumatic control systems in walls, floors, and ceilings to be removed. Remove abandoned wiring, and pneumatic tubing to source of supply. Provide pneumatic tubing caps to maintain a tightly sealed pneumatic control air control system.
4. Provide temporary wiring and pneumatic tubing connections to maintain existing control systems in service during construction. Disable control systems only to make switchovers and connections. Minimize outage duration. Temporarily relocate control wiring, pneumatic tubing, thermostats and other control devices to prevent damage or disposal resulting from other demolition efforts.
    a. Notify Owner at least 48 hours before partially or completely disabling system.
    b. Make temporary connections to maintain service in areas adjacent to work area.
5. Perform work for removal and disposal of equipment and materials containing toxic substances regulated under the Federal Toxic Substances Control Act (TSCA) in accordance with applicable federal, state, and local regulations.
6. Remove, relocate, and extend existing installations (including conduit, wiring, pneumatic tubing, boxes, and fastening devices) to accommodate new construction. Remove exposed abandoned conduit, including abandoned conduit above accessible ceiling finishes. Cut conduit flush with walls and floors, and patch surfaces.
7. It shall be this DDC System for HVAC contractor's sole responsibility for proper demolition of existing HVAC and lighting control systems including but not limited to the following. Under no circumstances shall improper demolition or cut cabling or damaged devices be the responsibility of the Owner. Any cabling or devices damaged that are outside the area of demolition or serving areas outside the area of demolition shall be replaced with new cabling/devices (not spliced, reinstalled, nor relocated). Any cabling or devices demolished that are outside the area of demolition shall be replaced with new cabling/devices (not spliced, reinstalled, nor relocated).
8. No portion of demolished control electrical circuits, cabling, wiring, pneumatic tubing, conduit, or equipment may be abandoned in place.
9. Demolition shall include cleanup of existing software programming and graphics such that the programming environment and user interface are maintained in a clean and accurate state following any demolition work. This effort includes, but is not limited to, the following:
    a. Collect backups of any and all affected programming and graphics prior to beginning any demolition work, in the event any portion needs to be restored.
    b. Delete demolished controllers, including all virtual/proxy folders located elsewhere in the programming environment.
    c. Update all graphics to remove references to demolished equipment/graphics, including floor plans, summary tables, previous/next buttons, and relevant district-wide summary pages.

    Review all linking and references from controllers to be deleted to confirm there will be no adverse affect from their removal. If there will be adverse affects, bring this to the attention of the construction team or replicate the functionality outside of the controllers before deletion.

3.4 CONTROL DEVICES FOR INSTALLATION BY OTHER INSTALLERS

A. Deliver selected control devices, specified in Section 23 09 00 – Instrumentation and Control for HVAC, to identified equipment and systems manufacturers for factory installation and to identified installers for field installation.

B. Deliver the following to duct fabricator and Installer for installation in ductwork. Include installation instructions to Installer and supervise installation for compliance with requirements.
   1. Automatic control dampers
   2. Airflow sensors and switches
   3. Pressure sensors

C. Deliver the following control devices specified in Section 23 09 00 – Instrumentation and Control for HVAC, to plumbing and HVAC piping installers for installation in piping. Include installation instructions to Installer and supervise installation for compliance with requirements.
   1. Automatic control valves
   2. Pipe-mounted flow meters
   3. Pipe-mounted sensors, switches and transmitters.
   4. Tank-mounted sensors, switches and transmitters.

3.5 GENERAL INSTALLATION REQUIREMENTS

A. Room sensor application.
   1. Provide JCI NSB8BTN140-0 network temperature sensors, utilizing the SA bus with warmer/cooler adjust and occupant override at these types of locations; Classrooms, Offices, Open Offices, and Conference Rooms.
   2. Provide basic, flat-plate style temperature sensors at these types of locations; Corridors, Gymnasiums, Cafeterias, Vestibules, and Theaters.
   3. For any terminal unit (VAV) serving area types other than those noted above, provide JCI NSB8BTN040-0 network temperature sensors, temperature-only utilizing the SA bus.
   4. Include foam insulation backing on all room sensors to prevent air infiltration from wall cavities.

B. Install room sensors such that they are centered at 48 inches A.F.F.

C. Pull a minimum of four (4) conductors to any wall-mounted room temperature sensor, even flat-plate style temperature sensors, to allow for future replacement with full-featured room sensors.

D. Install products to satisfy more stringent of all requirements indicated.

E. Install products level, plumb, parallel, and perpendicular with building construction.

F. Support products, tubing, piping wiring and raceways. Brace products to prevent lateral movement and sway or a break in attachment.

G. If codes and referenced standards are more stringent than requirements indicated, comply with requirements in codes and referenced standards.

Fabricate openings and install sleeves in ceilings, floors, roof, and walls required by installation of products. Before proceeding with drilling, punching, and cutting, check for concealed work to avoid damage. Patch, flash, grout, seal, and refinish openings to match adjacent condition.

H. Firestop penetrations made in fire-rated assemblies. Comply with requirements in "Penetration Firestopping." Section (078413)

I. Seal penetrations made in acoustically rated assemblies. Comply with requirements in "Joint Sealants." Section (079200).

J. Fastening Hardware:
   1. Stillson wrenches, pliers, and other tools that damage surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening fasteners.
   2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
   3. Lubricate threads of bolts, nuts and screws with graphite and oil before assembly.

K. If product locations are not indicated, install products in locations that are accessible and that will permit service and maintenance from floor, equipment platforms, or catwalks without removal of permanently installed furniture and equipment.

3.6 NIAGARA-4 SUPERVISOR SERVER CONFIGURATION

A. All BAS control projects must be added to this server as specified earlier in this specification Section.

3.7 LAN, ROUTER AND GATEWAY INSTALLATION

A. Furnish and install LAN drops, near Niagara-4 network controllers. This work shall be coordinated with the District IT staff, and Division 26 lighting control contractor. LAN cabling shall connect to District network equipment.

B. Provide temporary construction LAN, including switches and cabling as required to keep pace with construction schedule. Permanent District LAN drops may be delayed; it is not acceptable to delay construction as a result. Temporary construction LAN shall be demolished and Niagara-4 network controllers transferred permanently to District LAN once District LAN drops become active. Reconfigure TCP/IP settings as required to support connectivity through entire process.

C. Locations of all necessary LAN drops must be communicated in writing, with locations clearly identified on floor plans. District I.T. staff will review and identify location of network equipment where tie-ins are to be made.

D. LAN cabling termination at network equipment end.
   1. Provide RJ-45 plug for connection to network equipment.
   2. Label cable with Niagara-4 network controller identification name.

E. LAN cabling termination at Niagara-4 network controller end.
   1. Provide RJ-45 receptacle mounted near Niagara-4 network controller. Provide a short LAN patch cable to connect Niagara-4 network controller to receptacle.
   2. Label RJ-45 receptacle with network equipment identification name.

3.8 CONTROLLER INSTALLATION

A. Install controllers in enclosures to comply with indicated requirements.

B. The only controllers that are permitted to be installed above ceilings are for terminal units such as VAVs and lighting controllers. Refer to Section 3.11 for details on grid labeling requirements. All other controllers must be installed in easily accessible, non-student locations such as mechanical rooms or storage closets, close to the piece(s) of equipment they control.
   1. Controllers may only be field-installed on the roof, including inside of roof-mounted equipment, with prior approval from the SPPS Project Manager.

C. Connect controllers to field power supply.

D. Install controller with latest version of applicable software and configure to execute requirements indicated.

E. Test and adjust controllers to verify operation of connected I/O to achieve performance indicated requirements while executing sequences of operation.

F. Installation of Network Controllers:
   1. Quantity and location of network controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
   2. Install controllers in a protected location that is easily accessible by operators.

G. Installation of Programmable Application Controllers:
   1. Quantity and location of programmable application controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
   2. Install controllers in a protected location that is easily accessible by operators.
   3. Top of controller shall be within 84 inches of finished floor.

H. Application-Specific Controllers:
   1. Quantity and location of application-specific controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
   2. For controllers not mounted directly on equipment being controlled, install controllers in a protected location that is easily accessible by operators.

3.9 ENCLOSURES INSTALLATION

A. Attach wall-mounted enclosures to wall using galvanized steel struts in dry areas and stainless-steel struts in wet areas:

B. Align top of adjacent enclosures.

3.10 ELECTRIC POWER CONNECTIONS

A. Provide Class 1, and Class 2 electrical power to DDC system products requiring electrical power connections. Coordinate with Division 26.

B. Design of electrical power to DDC system products is delegated to DDC system provider and installing trade. Work shall comply with NFPA 70 and other requirements indicated.

C. Comply with requirements in Division 26 for electrical power circuit breakers.

D. Comply with requirements in Section 26 05 19 - Low-Voltage Electrical Power Conductors and Cables for electrical power conductors and cables.

E. Comply with requirements in Section 26 05 33.13 – Conduit for Electrical Systems and Section 26 05 33.16 - Boxes for Electrical Systems for electrical power raceways and boxes.

F. As an exception to splicing requirements in other sections, lever nuts are permitted for use on all low-voltage wiring 24VAC and below.

G. All DDC system components must be powered from dedicated 120VAC, 20 amp power circuits. Existing 120VAC, 20 amp circuits may be reused only if they are confirmed to be dedicated to the DDC system.

H. Provide separate, isolated Class 2 electrical power for all controllers. Controllers may share an isolated circuit provided all devices on that circuit utilize the same type of power rectification (half-wave or full-wave) and the circuit is appropriately sized based on the total maximum power draw of all controllers.

3.11 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Comply with requirements in Section 26 05 53 – Identification for Electrical Systems for identification products and installation.

B. Where product is installed above ceiling, also install location identification on ceiling grid directly below. This includes all control equipment including, but not limited to, control valves, dampers, and sensors, HVAC and lighting control panels, and terminal units such as VAV boxes, fan coil units, and heat pumps.
   1. All grid labels shall be printed on 3/4” yellow labels with black text.

C. Include identification on all DDC devices including; room sensors, duct sensors, pipe sensors, relays, power supplies, controllers, control dampers and controls valves

D. Include identification on all transformers and power supplies that indicate what they serve and where they are served from.

3.12 NETWORK NAMING AND NUMBERING

A. Coordinate with District to provide unique naming and addressing for networks and devices. This includes BACnet device instance numbering, BACnet network numbering, and IP addresses.

3.13 CONTROL WIRE, CABLE AND RACEWAYS INSTALLATION

A. Comply with NECA 1.

B. Comply with TIA 568-C.1.

C. Existing materials; control wire, cable and raceways, reuse or remove.
   1. Comply with electrical demolition requirements specified in Section 26 00 10 - Electrical Demolition".
   2. Coordinate with District staff.
   3. Remove, relocate, and extend existing installations to accommodate new construction. All existing installations that are not reused for new construction shall be removed.
   4. Remove exposed abandoned conduit, including abandoned conduit above accessible ceiling finishes.
   5. Remove conduit, wire, boxes and fastening devices to avoid interference with new installation.
   6. Repair adjacent construction and finishes damaged during demolition and extension work

D. Wiring Method: Install cables in raceways/pathways and cable trays. Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
   1. Where the requirements of Division 26/27 conflict with the requirements of this specification section, the more stringent requirement shall take precedence.
   2. Install plenum cable in environmental air spaces, including plenum ceilings.
   3. Comply with requirements for cable trays specified in Division 26/27.
   4. Comply with requirements for raceways and boxes specified in Division 26.
   5. All cabling shall be installed in designated pathways (hooks, conduit, or cable tray) depending on the location. Comply with requirements specified in Division 26/27. Zip-tied cabling outside conduit or other supports is not acceptable.
   6. Provide conduit from field devices (sensors) installed in a wall up to the accessible ceiling space (above ceiling). Insulating bushings are required at all bare conduit ends to protect cable from abrasion. Above ceiling all cabling shall be installed in hooks, conduit, or cable tray as specified in Division 26/27
   7. All cabling in exposed areas shall be installed in conduit.
   8. All cabling and conduit shall follow building lines, running alongside or perpendicular to walls and joists wherever possible in order to provide an overall cleaner installation appearance.

E. Field Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.

F. Conduit Installation:

1. Install conduit expansion joints where conduit runs exceed 200 feet and where conduit crosses building expansion joints.
2. Coordinate conduit routing with other trades to avoid conflicts with ducts, pipes and equipment and service clearance.
3. Maintain at least 3-inch separation where conduits run axially above or below ducts and pipes.
4. Limit above-grade conduit runs to 100 feet without pull or junction box.
5. Do not install raceways or electrical items on any "explosion-relief" walls, or rotating equipment.
6. Do not fasten conduits onto the bottom side of a metal deck roof.
7. Flexible conduit is permitted only where flexibility and vibration control is required.
8. Limit flexible conduit to 3 feet long.
9. Conduit shall be continuous from outlet to outlet, from outlet to enclosures, pull and junction boxes, and shall be secured to boxes in such manner that each system shall be electrically continuous throughout.
10. Direct bury conduits underground or install in concrete-encased duct bank where indicated.
    a. Use rigid, nonmetallic, Schedule 80 PVC.
    b. Provide a burial depth according to NFPA 70, but not less than 24 inches.
11. Secure threaded conduit entering an instrument enclosure, cabinet, box, and trough, with a locknut on outside and inside, such that conduit system is electrically continuous throughout. Provide a metal bushing on inside with insulated throats. Locknuts shall be the type designed to bite into the metal or, on inside of enclosure, shall have a grounding wedge lug under locknut.
12. Conduit box-type connectors for conduit entering enclosures shall have an insulated throat.
13. Connect conduit entering enclosures in wet locations with box-type connectors or with watertight sealing locknuts or other fittings.
14. Offset conduits where entering surface-mounted equipment.
15. Insulating bushings are required at all bare conduit ends to protect cable from abrasion.
16. Seal conduit runs by sealing fittings to prevent the circulation of air for the following:
    a. Conduit extending from interior to exterior of building.
    b. Conduit extending into pressurized duct and equipment.
    c. Conduit extending into pressurized zones that are automatically controlled to maintain different pressure set points.

G. Wire and Cable Installation:

1. Cables serving a common system may be grouped in a common raceway. Do not group conductors from different systems or different circuit classifications (Class 1 and Class 2 circuit wiring shall not be grouped in a common raceway.)
2. Install cables with protective sheathing that is waterproof and capable of withstanding continuous temperatures of 194 deg F with no measurable effect on physical and electrical properties of cable.
    a. Provide shielding to prevent interference and distortion from adjacent cables and equipment.
3. Installation of Cable Routed Exposed under Raised Floors:
    a. Install plenum-rated cable only.
    b. Install cabling after the flooring system has been installed in raised floor areas.

c. Coil cable 6 feet long not less than 12 inches in diameter below each feed point.

4. Identify each wire on each end and at each terminal with a number-coded identification tag. Each wire shall have a unique tag.
5. Provide strain relief.
6. Terminate wiring in a junction box.
   a. Clamp cable over jacket in junction box.
   b. Individual conductors in the stripped section of the cable shall be slack between the clamping point and terminal block.
7. Terminate field wiring and cable not directly connected to instruments and control devices having integral wiring terminals using terminal blocks.
8. Install signal transmission components according to IEEE C2, REA Form 511a, NFPA 70, and as indicated.
9. Keep runs short. Allow extra length for connecting to terminal boards. Do not bend flexible coaxial cables in a radius less than 10 times the cable OD. Use sleeves or grommets to protect cables from vibration at points where they pass around sharp corners and through penetrations.
10. Ground wire shall be copper and grounding methods shall comply with IEEE C2. Demonstrate ground resistance.
11. Wire and cable shall be continuous from terminal to terminal without splices.
12. Do not install bruised, kinked, scored, deformed, or abraded wire and cable. Remove and discard wire and cable if damaged during installation, and replace it with new cable.
13. Pulling Cable: Comply with BICSI ITSIM, Ch. 4, "Pulling Cable." Monitor cable pull tensions.

3.14 DDC SYSTEM FOR HVAC CONTRACTOR DDC SYSTEM I/O CHECKOUT PROCEDURES

A. Check instruments for proper location and accessibility.

B. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will affect performance.

C. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material and support.

D. For pneumatic products, verify that air supply for each product is properly installed.

E. Control Damper Checkout:
   1. For pneumatic dampers, verify that pressure gages are provided in each air line to damper actuator and positioner.
   2. Verify that control dampers are installed correctly for flow direction.
   3. Verify that proper blade alignment, either parallel or opposed, has been provided.
   4. Verify that damper frame attachment is properly secured and sealed.
   5. Verify that damper actuator and linkage attachment is secure.
   6. Verify that actuator wiring is complete, enclosed and connected to correct power source.
   7. Verify that damper blade travel is unobstructed.
   8. Verify that any configurable switches on device are set properly.

F. Control Valve Checkout:
   1. For pneumatic valves, verify that pressure gages are provided in each air line to valve actuator and positioner.
   2. Verify that control valves are installed correctly for flow direction.
   3. Verify that valve body attachment is properly secured and sealed.
   4. Verify that valve actuator and linkage attachment is secure.
   5. Verify that actuator wiring is complete, enclosed and connected to correct power source.
   6. Verify that valve ball, disc, or plug travel is unobstructed.
   7. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.
   8. Verify that any configurable switches on device are set properly.

G. Instrument Checkout:
   1. Verify that instrument is correctly installed for location, orientation, direction, and operating clearances.
   2. Verify that attachment is properly secured and sealed.
   3. Verify that conduit connections are properly secured and sealed.
   4. Verify that wiring is properly labeled with unique identification, correct type and size and is securely attached to proper terminals.
   5. Inspect instrument tag against approved submittal.
   6. For instruments with tubing connections, verify that tubing attachment is secure and isolation valves have been provided.
   7. For flow instruments, verify that recommended upstream and downstream distances have been maintained.
   8. For temperature instruments:
      a. Verify sensing element type and proper material.
      b. Verify length and insertion.
   9. Verify that any configurable switches on device are set properly

3.15 DDC SYSTEM FOR HVAC CONTRACTOR DDC SYSTEM I/O ADJUSTMENT, CALIBRATION AND TESTING:

A. Calibrate each instrument installed that is not factory calibrated and/or provided with calibration documentation. Calibrate according to instrument instruction manual supplied by manufacturer.

B. Provide NIST traceable diagnostic and test equipment for calibration and adjustment.

C. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

D. Control Dampers:
   1. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100% open to 100% closed and back to 100% open.
   2. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

E. Control Valves:
   1. Stroke and adjust control valves following manufacturer's recommended procedure, from 100% open to 100% closed and back to 100% open.
   2. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

F. Switches: Calibrate switches to make or break contact at set points indicated.

3.16 DDC SYSTEM FOR HVAC CONTRACTOR DDC SYSTEM CONTROLLER CHECKOUT

A. Verify power supply.
   1. Verify voltage, polarity, and protection.
   2. Verify that ground fault protection is installed.
   3. If applicable, verify that power conditioning units are installed.

B. Verify that wire and cabling is properly secured to terminals and labeled with unique identification.

3.17 DDC SYSTEM FOR HVAC CONTRACTOR DDC CONTROLLER I/O CONTROL LOOP TESTS

A. Test every control loop to verify operation is stable and accurate.

3.18 DDC SYSTEM FOR HVAC CONTRACTOR DDC SYSTEM VALIDATION TESTS

A. Perform validation tests before requesting final review of system with District. The District has a standard template checkout sheet for use by the contractor. If the contractor would prefer to use a different checkout form, they must first submit it for approval by the District.

B. After validation testing is complete, submit completed validation test checklist.

C. Validation Test:
   1. Verify operation of every I/O point and connected device in DDC system.
   2. Make adjustments to out-of-tolerance I/O points.
      a. Identify I/O points not ready and need future verification.
      b. Simulate abnormal conditions to verify proper function of safety devices.
      c. Replace instruments and controllers that cannot maintain performance indicated after adjustments.
   3. Simulate conditions to verifying proper sequence of control.
   4. Readjust settings to design values and observe ability of DDC system to establish desired conditions.
   5. After 24 hours following initial validation test:
      a. Re-check I/O points that required corrections during initial test.
      b. Identify I/O points that still require additional correction and make corrections necessary to achieve desired results.

6. After validation testing is complete, prepare and submit a report showing status of all I/O points. Identify adjustments or corrections made and indicate instruments that were replaced.
7. Submit completed validation test checklist and schedule final review date(s).

3.19 DISTRICT FINAL REVIEW AND COMMISSIONING WITH DDC SYSTEM FOR HVAC CONTRACTOR ASSISTANCE

A. DDC system final review with District Staff shall include an on-site demonstration to all parties participating in final review, including commissioning agent. DDC System for HVAC contractor shall include time to actively participate in entire final review and commissioning process.

B. Should more than two final review sessions be required, DDC system manufacturer and Installer shall compensate entity performing review for total costs, labor and expenses, associated with third and subsequent reviews.

C. Commissioning shall include, but not be limited to, the following:
1. Briefly review validation report submitted prior and discuss.
2. Accuracy and calibration of 25% of terminal unit points (VAVs, unit ventilators, etc) randomly selected by reviewers. If review finds that some I/O points are not properly calibrated and not satisfying performance requirements indicated, additional terminal unit points may be selected by reviewers.
3. Accuracy and calibration of 100% of central equipment points (AHUs, chillers, boilers, towers, etc).
4. HVAC equipment and system hardwired and software safeties and life-safety functions are operating according to sequence of operation. 100% of these points shall be tested.
5. Correct sequence of operation after electrical power interruption and resumption after electrical power is restored for randomly selected HVAC systems.
6. Operation of randomly selected dampers and valves in normal-on, normal-off and failed positions.
7. Reporting of alarm conditions for randomly selected alarms, including different classes of alarms, to ensure that alarms are properly received by operators and operator workstations.
8. Trends, summaries, logs and reports set-up for Project.
9. For at least 25% of HVAC systems randomly selected by reviewers, use graph trends to show that sequence of operation is executed in correct manner and that HVAC systems operate properly through complete sequence of operation including different modes of operations indicated. Show that control loops are stable and operating at set points and respond to changes in set point of 20% or more.
10. Software's ability to communicate with controllers, operator workstations, uploading and downloading of control programs.
11. Software's ability to edit control programs.
12. Data entry to show Project-specific customizing capability including parameter changes.
13. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.
14. Execution of digital and analog commands in graphic mode.

15. Online user guide and help functions.
16. System speed of response compared to requirements indicated.
17. For Each Network and programmable Controller:
    a. Memory: Programmed data, parameters, trend and alarm history collected during normal operation shall not be lost during power failure.
    b. Standalone Ability: Demonstrate that controllers provide stable and reliable standalone operation using default values or other method for values normally read over network.
    c. Electric Power: Ability to disconnect any controller safely from its power source.
    d. Wiring Labels: Match control drawings.
    e. Network Communication: Ability to locate a controller's location on network and communication architecture matches Shop Drawings.
    f. Nameplates and Tags: Accurate and permanently attached to control panel doors, instrument, actuators and devices.
    g. Communications and Interoperability: Demonstrate proper interoperability of data sharing, alarm and event management, trending, scheduling, and device and network management. Requirements must be met even if only one manufacturer's equipment is installed.
        1) Data Presentation: On operator workstation, demonstrate graphic display capabilities.
        2) Reading of Any Property: Demonstrate ability to read and display any used readable object property of any device on network.
        3) Set Point and Parameter Modifications: Show ability to modify set points and tuning parameters indicated.
        4) Peer-to-Peer Data Exchange: Network devices are installed and configured to perform without need for operator intervention to implement Project sequence of operation and to share global data.
        5) Alarm and Event Management: Alarms and events are installed and prioritized according to Owner. Demonstrate that time delays and other logic are set up to avoid nuisance tripping. Show that operators with sufficient privileges are permitted.
        6) Schedule Lists: Schedules are configured for start and stop, mode change, occupant overrides, and night setback as defined in sequence of operations.
        7) Schedule Display and Modification: Ability to display any schedule with start and stop times for calendar year. Show that all calendar entries and schedules are modifiable from any connected operator workstation by an operator with sufficient privilege.
        8) Archival Storage of Data: Data archiving is handled by operator workstation and server and local trend archiving and display is accomplished.
        9) Modification of Trend Log Object Parameters: Operator with sufficient privilege can change logged data points, sampling rate, and trend duration.
        10) Device and Network Management:
            a) Display of network device status.
            b) Time synchronization.
            c) Backup and restore network device programming and master database(s).

3.20 CUSTOMER TRAINING

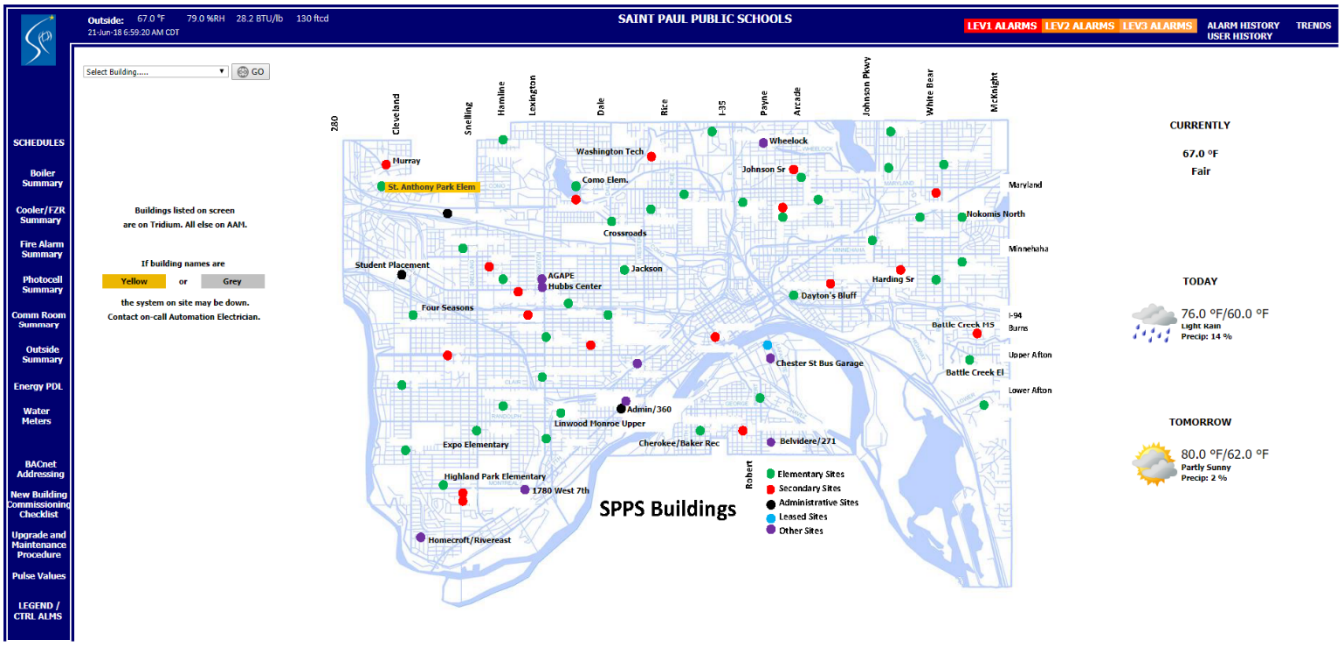
A. DDC System for HVAC contractor's representative with complete knowledge of Project-specific system installed shall train Owner's maintenance personnel to adjust, operate, and maintain DDC system.

B. Customer Training:
   1. Base extent of training on scope and complexity of DDC system indicated and training requirements indicated. Provide extent of training required to satisfy requirements indicated even if more than minimum training requirements are indicated.
   2. Minimum Training Requirements:
      a. Provide not less than 4 hours of training total. Two, 2-hour sessions.
      b. First training session just prior to substantial completion and second training session during first week of occupancy.
      c. Training shall occur within normal business hours at a mutually agreed upon time, arranged at least 10 business days in advance.
      d. Plan in advance of training for five attendees
      e. Training Outline:
         1) Submit training outline for Owner review while arranging training date.
         2) Outline shall include a detailed agenda, training objectives and synopses for each lesson planned.
      f. Provide a preprinted sign-in sheet for each training session and circulate sign-in sheet at beginning of each session and solicit attendees to sign or initial in applicable location.
      g. At end of each training day, send Owner an e-mail with an attachment of scanned copy (PDF) of circulated sign-in sheet for each session.
      h. Provide each attendee with a color hard copy of all training materials and visual presentations. Email a PDF copy of all training materials to attendees.
      i. Minimum Training Content Shall Include:
         1) Basic operation of system.
         2) Understanding DDC system architecture and configuration.
         3) Understanding each unique product type installed including performance and service requirements for each.
         4) Understanding operation of each system and piece of equipment controlled by DDC system including sequences of operation, each unique control algorithm, and each unique optimization routine.
         5) Logging on and off system.
         6) Accessing graphics, reports, and alarms.
         7) Adjusting and changing set points and time schedules.
         8) Recognizing DDC system malfunctions.
         9) Understanding content of operation and maintenance manuals including control drawings.
         10) Understanding physical location and placement of DDC controllers and I/O hardware.
         11) Accessing data from DDC controllers.
         12) Stepping through graphics penetration tree, displaying all graphics, demonstrating dynamic updating, and direct access to graphics.
         13) Demonstrating DDC system performance through trend logs and command tracing.

14) Demonstrating spreadsheet and curve plot software, and its integration with database.
15) Demonstrating the HVAC systems and equipment controlled by DDC system:
16) Using graphed trends, show that sequence of operation is executed in correct manner and that HVAC systems operate properly through complete sequence of operation including seasonal change, occupied and unoccupied modes, warm-up and cool-down cycles, and other modes of operation indicated.
17) Hardware interlocks and safeties function properly and DDC system performs correct sequence of operation after electrical power interruption and resumption after power is restored.
18) Reporting of alarm conditions for each alarm, and confirm that alarms are received at assigned locations, including operator workstations.
19) Control loops respond to set point adjustment and stabilizes within time period indicated.
20) Sharing of previously graphed trends of all control loops to demonstrate that each control loop is stable and set points are being maintained.
21) Modifying alarms including annunciation and routing.
22) Modifying point trend logs including graphing and printing on an ad-hoc basis and operator-defined time intervals.
23) Adding new operators and making modifications to existing operators.
24) Operator password assignments and modification.
25) Operator authority assignment and modification.

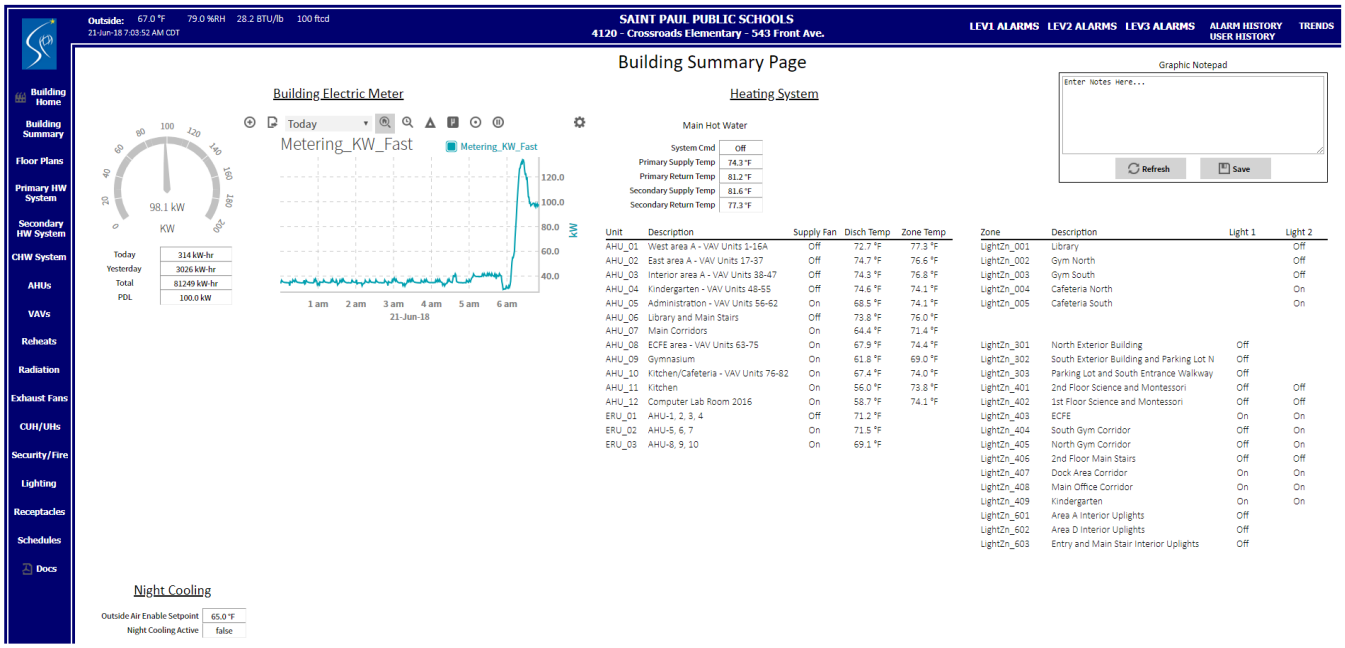
3.21 Graphic Examples

A. District Home

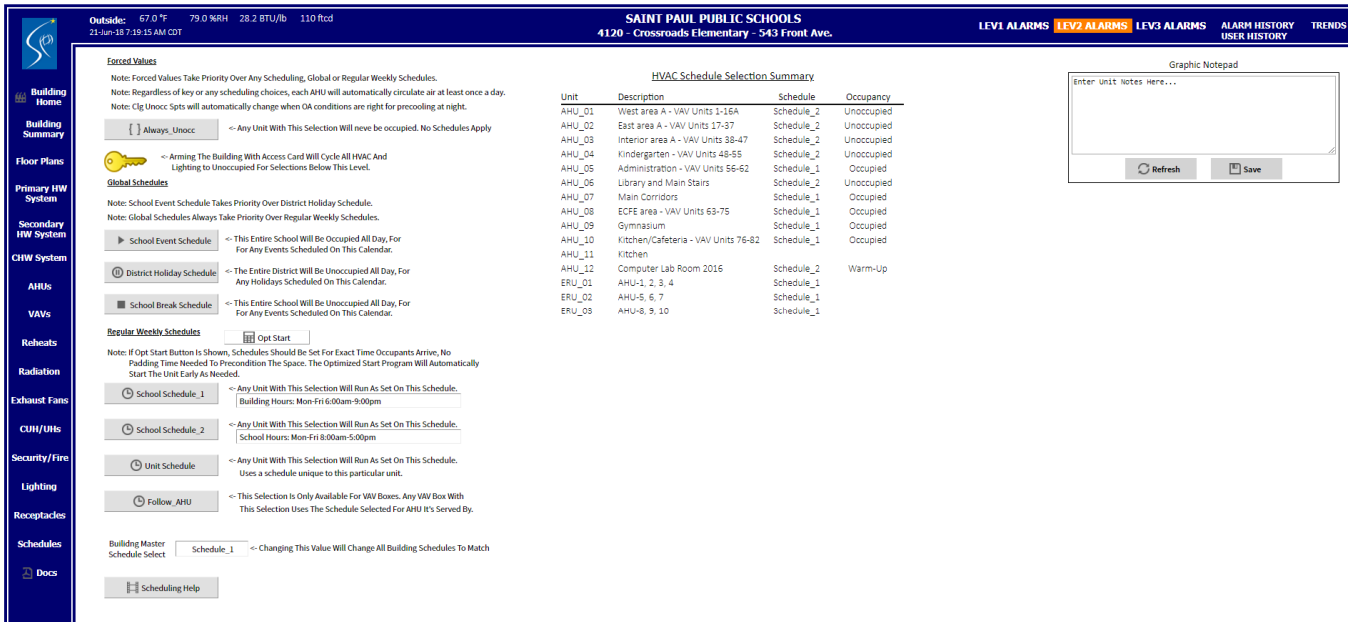


B. Building Home

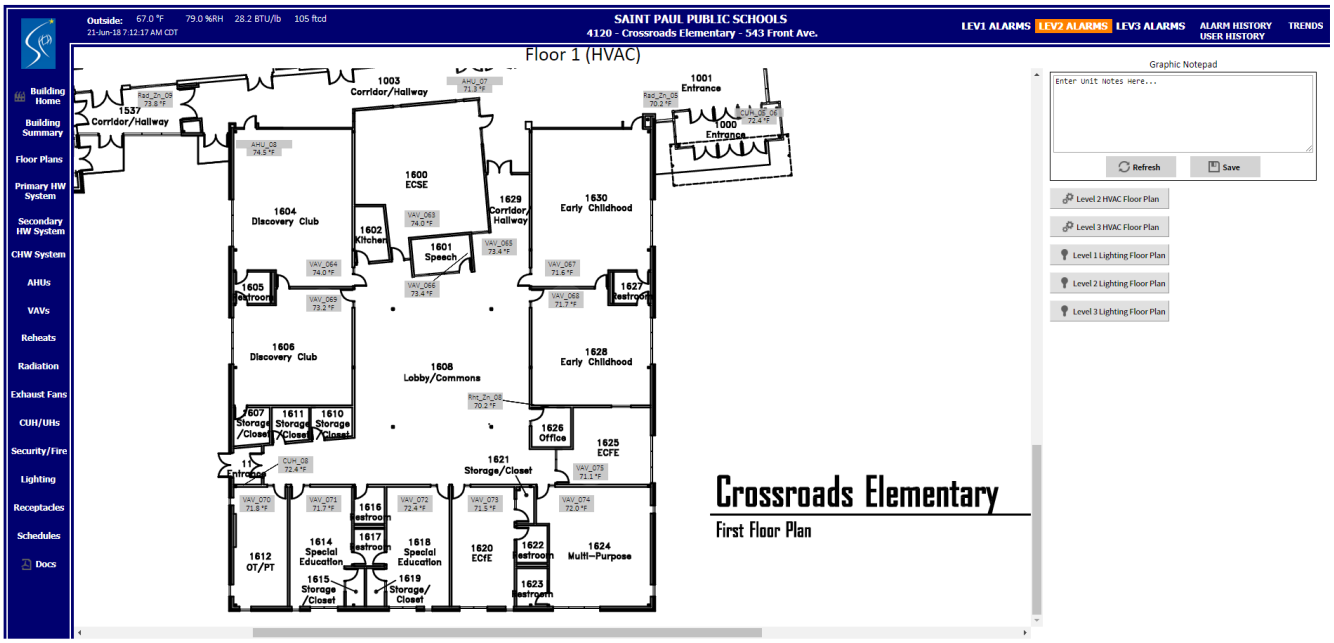
C. Building Summary



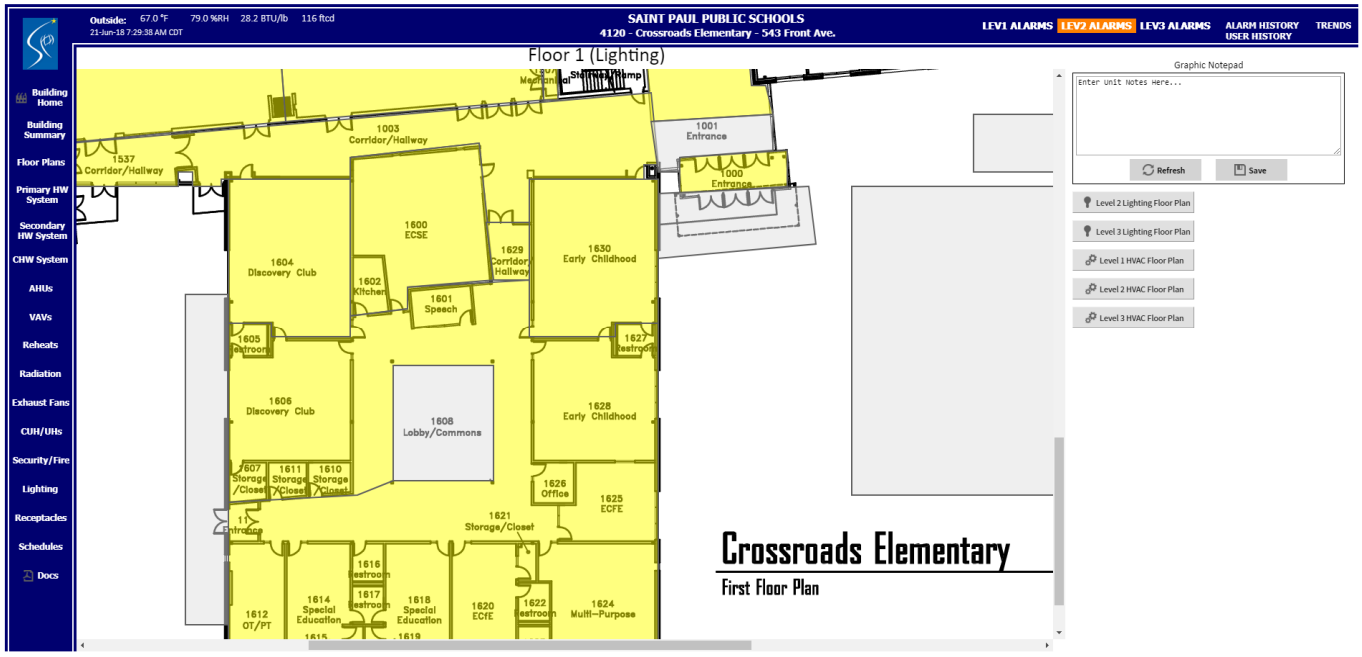
D. Building Scheduling Summary



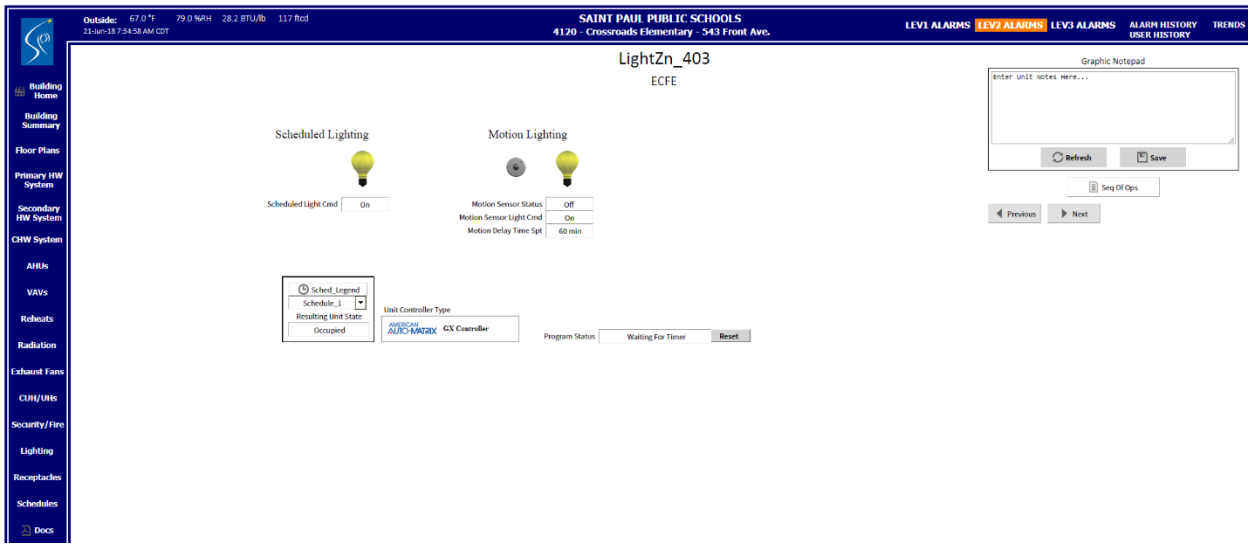
E. Building Floor Plan (HVAC)



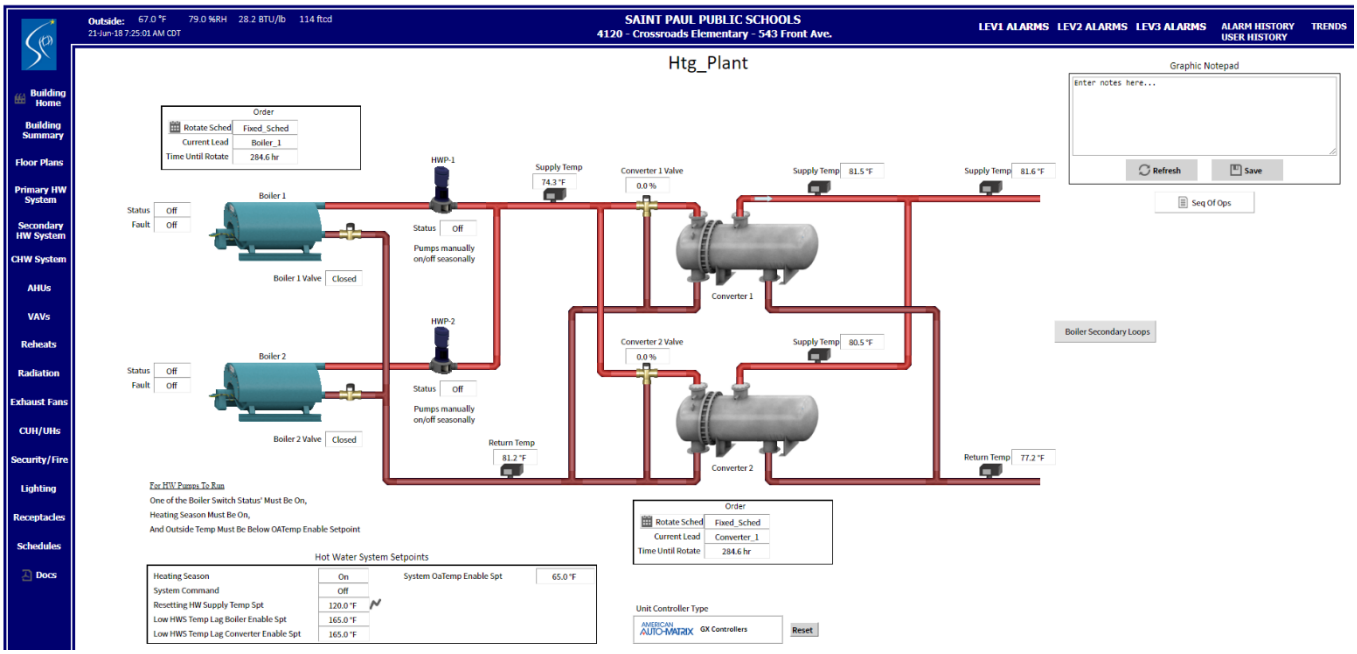
F. Building Floor Plan (Lighting)



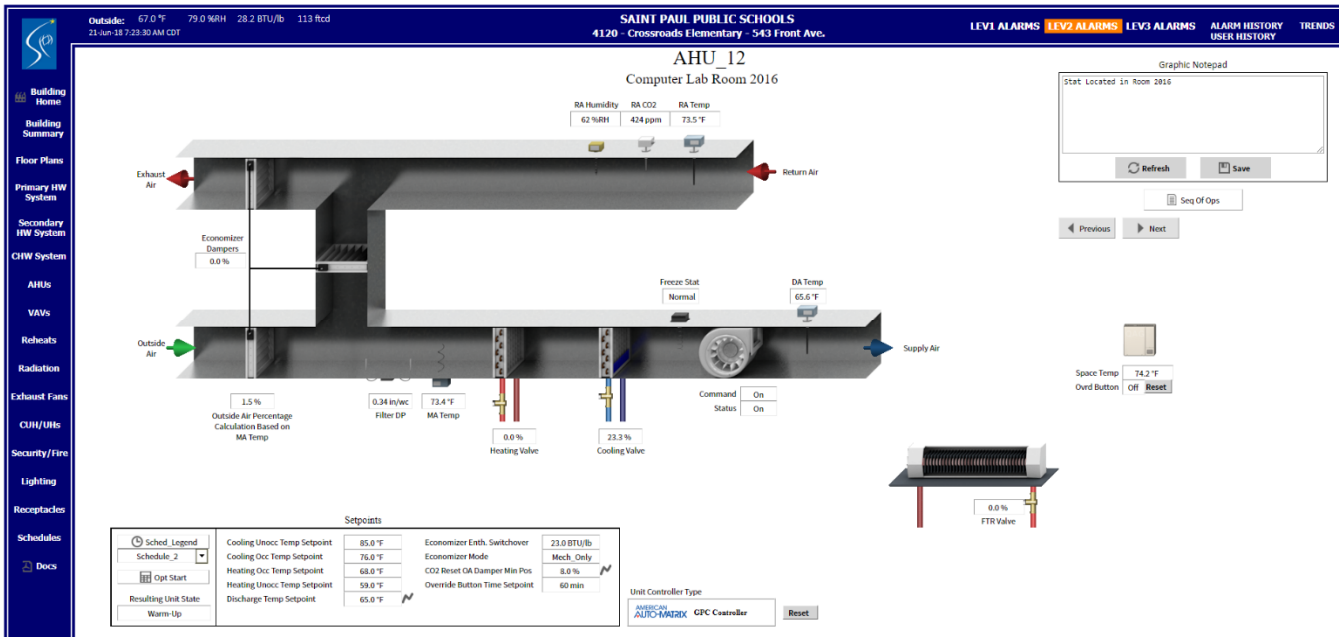
G. Typical Lighting Zone



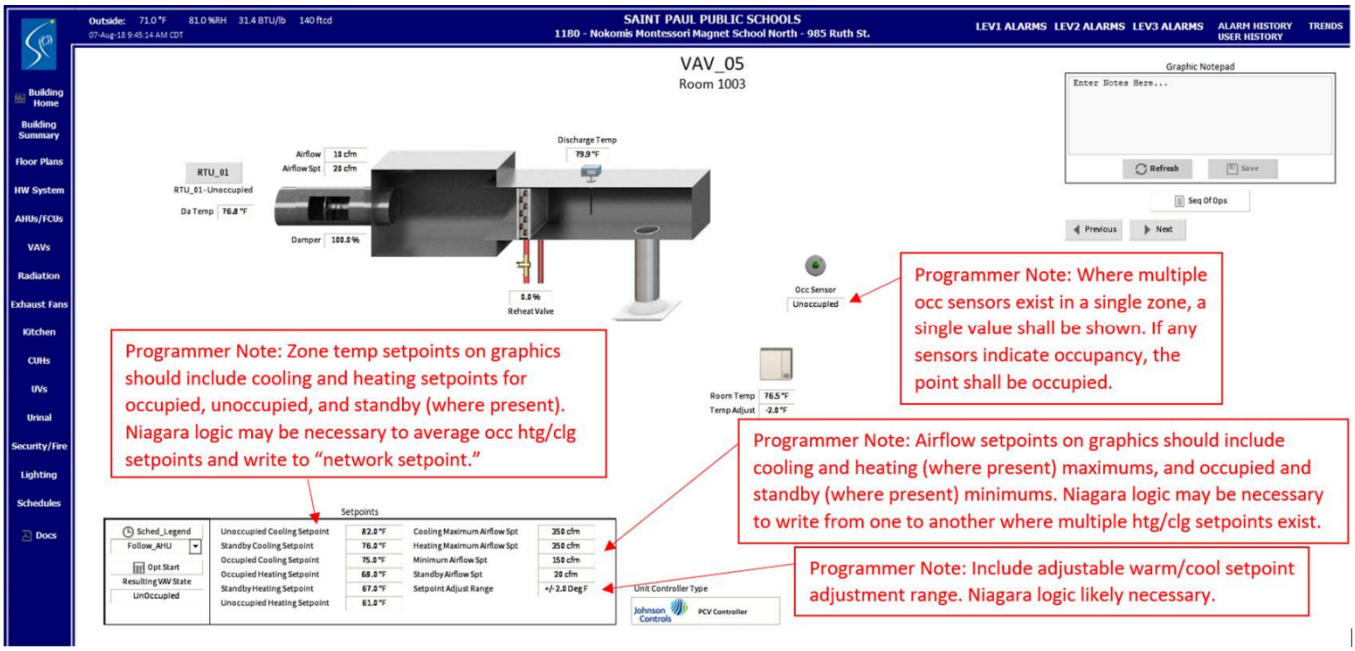
H. Central Heating Plant



I. Typical Air Handling Unit (AHU)



J. Typical Variable Air Volume Box (VAV)



END OF SECTION 230923