PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes control equipment for HVAC systems and components, including control components for terminal heating and cooling units not supplied with factory-wired controls. This section includes:
   1. Control equipment.
   2. Software.
   3. Sensors.
   4. Control Instruments.
   5. Controllers.
   6. Wiring and conduit in connection with HVAC Instrumentation and Controls in accordance with Division 16.
   7. Power supply to HVAC Instrumentation and Controls, unless otherwise specified under Division 16.
   8. Duct smoke detectors unless otherwise specified under Fire Alarm System.
   9. Commissioning of HVAC Instrumentation and Controls.
   10. Trending and coordination with other trades for Commissioning of HVAC Systems.
   11. Siemens shall modify and upgrade existing control graphics and programming as Part of this work.

1.2 SEQUENCE OF OPERATION

A. Division 15 Section “Sequence of Operation”.

1.3 SUBMITTALS

A. Submit the specified number of sets of documentation in the following phased delivery schedule.
   1. Valve schedules.
   2. Equipment data cut sheets.
   3. System schematics, including sequence of operations, system riser diagrams, point to point wiring, control point lists, interface wiring diagrams, panel layouts, and floor plans with equipment, FIP, MCC, VAV.
   4. Visio® or AutoCAD compatible as-built drawings including floor plans

B. Upon project completion, submit operation and maintenance manuals, consisting of the following:
   1. Manufacturer's equipment parts list of all functional components of the system, disk of system schematics, including wiring diagrams and description of sequence of operations.
   2. As-Built interconnection wiring diagrams.
   3. User’s documentation containing product, system architectural and programming information.
   4. Trunk cable schematic showing remote electronic panel locations, and all trunk data.
   5. List of connected data points, including panels to which they are connected and input device (ionization detector, sensors, etc.).
   6. Conduit routing diagrams.
   7. Copy of the warranty.
   8. Operating and maintenance cautions and instructions.
   9. Recommended spare parts list.

1.4 QUALITY ASSURANCE

A. Installing Company Qualifications: Installing company qualifications shall be a member of open system alliance or a BACNET via IP certified. Five years of experience in installation of similar systems for similar projects shall be required. The installing company shall have experience in completing a minimum of three local projects of similar size with the type of DDC system specified for this project within the last five years. The installing company shall have a Building Automation Service Department within San Diego County with a 2-hour minimum response time for emergency service.

B. Control of all exterior points is to be handed by the Campus photocell via the BAS and control of the interior points by the BAS scheduler. Please coordinate with the lighting contractor and provide all scheduling, programming, and graphics related to project in the BAS system.

C. On new construction all utilities to building shall be metered and monitored through the BAS. This is to include Electricity (KW and KWH monitoring), Gas (pulse output to read in Therms or cf), and Domestic water (pulse output to read in cf down to a minimum of 5 gpm.).

D. Manufacturer Qualifications: A firm experienced in manufacturing automatic temperature-control systems similar to those indicated for this Project and with a record of successful in-service performance. The manufacturer's products shall be compatible with BACNET for windows, current version, and current BACNET service package.

E. All DDC controllers for this project shall be manufactured by single manufacturer and shall be the manufacturer's latest standard of design at the time of the bid.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to unit manufacturer.

1.6 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
   1. Room Temperature Sensor: Provide one for each unique type.
   2. Zone Controllers: Provide one for each unique type.

B. Replacement Materials: One replacement relay mechanism for each unique damper motor, valve motor, controller, and sensor.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturer: Subject to compliance with requirements, installing company qualifications, and manufacturer's qualifications, provide products by the following. The manufacturer shall be a member of BACNET Association. The system must communicate with the existing system and not require a secondary monitoring system.

2.2 DDC EQUIPMENT AND SOFTWARE

A. The intent of graphic-based software is to provide an ergonomic interface to the DDC system that encourages effective and efficient interaction with the system. Graphic-based software shall provide graphical representation of the building, the buildings mechanical systems, and the DDC and other inter-connected peripheral systems. The current value and point name of every I/O point shall be shown on at least one graphic and in its appropriate physical location relative to building and mechanical systems.

1. Graphics shall closely follow the style of the control drawings in representing mechanical systems, sensors, controlled devices, and point names.
2. Graphic Title: Graphics shall have an identifying title visible when the graphic is being viewed.
3. Dynamic Update: When the workstation is on-line with the control system, point data shall update dynamically on the graphic images.
4. Graphic Penetration: Provide graphic penetration for selection of individual graphics for hierarchical affect.
5. Graphic Types: Graphic-based software shall have graphics of the building exterior, building section, floor plans, and mechanical systems. Provide the following graphics.
   a. Building Exterior Graphic: Show exterior architecture, major landmarks, and building number.
   b. Building Section Graphic: Show stacked floors in section graphic with appropriate floor name on each floor.
   c. Floor Plan Graphics: Provide single graphic for each floor, unless the graphic will contain more information than can reasonably be shown on a single graphic. Each heating or cooling zone within a floor plan shall have a zone name and its current temperature displayed within the zone outline. Show each controlled variable in the zone. Provide visual indication for each point that is in alarm.
   d. Mechanical System Graphic: Provide two-dimensional drawings to symbolize mechanical equipment; do not use line drawings. Show controlled or sensed mechanical equipment. Each graphic shall consist of a single mechanical system; examples are a graphic for an air handling unit, a graphic for VAV box, a graphic for a heating water system, and a graphic for chiller system. Place sensors and controlled devices associated with mechanical equipment in their appropriate locations. Place point name and point value adjacent to sensor or controlled device. Provide visual indication of each point in alarm. Condition, such as zone temperature, associated with the mechanical system shall be shown on the graphic. Point values shall update dynamically on the graphic.
6. Graphic Editing: Full capacity as afforded by a draw software package shall be included for operator editing of graphics. Graphics may be created, deleted, and modified, and text added. Provide capability to store graphic symbols in a symbol directory and incorporate these symbols into graphics. A minimum of sixteen colors shall be available.
7. Dynamic Point Editing: Provide full editing capability for deleting, adding, and modifying dynamic points on graphics.
8. Trending: Trend data shall be displayed graphically, with control variable and process variable plotted as functions of time on the same chart. Graphic display of trend data shall be a capability internal to the workstation software and not a capability resulting from download of trend data into a third-party spreadsheet program such as Lotus, unless such transfer is automatic and transparent to the operator, and third-party software is included with the workstation software package. At the operator's discretion trend data shall be plotted real time.

B. Control Units: Modular, comprising processor board with programmable, nonvolatile, random-access memory.
   1. Units monitor or control each input/output point; process information; execute commands from other control units, devices, and operator stations; and download from or upload to operator station.
   2. Stand-alone mode control functions operate regardless of network status. Functions include the following:
      a. Global communications.
      b. Discrete/digital, analog, and pulse input/output.
      c. Monitoring, controlling, or addressing data points.
      d. Testing and developing control algorithms without disrupting field hardware and controlled environment.

C. LANs: Capacity for a minimum of 10 workstations connected to multiuser, multitasking environment with concurrent capability to access DDC network or control units.
   1. Media: Ethernet, peer-to-peer CSMA/CD, operating at 10 MBps.
   2. Media: ARCNET (attached resources computer network), peer to peer, operating at 2.5 MBps.
   3. Media: PL

D. Software: Update to latest version of software at Project completion. Include and implement the following capabilities from the control units:
   1. Units of Measure: Inch-pound and SI (metric).
   2. Load Control Programs: Demand limiting, duty cycling, automatic time scheduling, start/stop time optimization, night setback/setup, DDC with fine tuning, and trend logging.
   3. HVAC Control Programs: Optimal run time, supply-air reset, and enthalpy switchover.
   4. Programming Application Features: Include trend point, alarm messages, weekly scheduling, and interlocking.

2.3 CONTROL PANELS

A. Control Panels: Unitized cabinet with suitable brackets for wall or floor mounting, located adjacent to each system under automatic control. Provide common keying for all panels.
   1. Fabricate panels of 0.06-inch- thick, furniture-quality steel, or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock and with manufacturer's standard shop-painted finish.
   2. Panel-Mounted Equipment: Temperature and humidity controllers, relays, and automatic switches; except safety devices. Mount devices with adjustments accessible through front of panel.
   3. Door-Mounted Equipment: Flush-mount (on hinged door) manual switches, including damper-positioning switches, changeover switches, thermometers, and gages.
   4. Graphics: Color-coded graphic, laminated-plastic displays on doors, schematically showing system being controlled, with protective, clear plastic sheet bonded to entire door.
   5. Provide one uninterrupted power supply for each main control panel.

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B. DDC Control system components shall be connected to emergency power circuitry as shown by Division 16.

2.4 ANALOG CONTROLLERS

A. Step Controllers: Six- or 10-stage type, with heavy-duty switching rated to handle loads and operated by electric motor.

B. Electric, Outdoor-Reset Controllers: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range, adjustable set point, scale range minus 10 to plus 70 deg F, and single- or double-pole contacts.

2.5 SENSORS

A. Electronic Sensors: Vibration and corrosion resistant; for wall, immersion, or duct mounting as required.
   1. Thermistor Temperature Sensors (Thermistor):
      a. Accuracy: Plus or minus 0.5 deg F at calibration point.
      b. Wire: Twisted, shielded-pair cable.
      c. Insertion Elements in Ducts: Single point, 8 inches (20 cm) long; use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft. (1 sq. m).
      d. Averaging Elements in Ducts: 36 inches (91 cm) long, flexible; use where prone to temperature stratification or where ducts are larger than 9 sq. ft. (1 sq. m); length as required.
      e. Insertion Elements for Liquids: Brass socket with minimum insertion length of 2-1/2 inches (64 mm).
      f. Room Sensors: Match room thermostats, locking cover.
      g. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
      h. Room Security Sensors: Stainless-steel cover plate with insulated back and security screws.
   2. Resistance Temperature Detectors (RTD): Platinum.
      a. Accuracy: Plus or minus 0.2 percent at calibration point.
      b. Wire: Twisted, shielded-pair cable.
      c. Insertion Elements in Ducts: Single point, 8 inches (20 cm) long; use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft. (1 sq. m).
      d. Averaging Elements in Ducts: 36 inches (91 cm) long, flexible; use where prone to temperature stratification or where ducts are larger than 9 sq. ft. (1 sq. m); length as required.
      e. Insertion Elements for Liquids: Brass socket with minimum insertion length of 2-1/2 inches.
   3. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
      a. Accuracy: 2 percent of full scale with repeatability of 0.5 percent.
      b. Output: 4 to 20 mA.
      c. Duct Static-Pressure Range: 0 to 5 inches wg.
   4. Flow Meters: Provide Ultrasonic or Magnetic Tube Flow Meter with digital display of flow rate, total and 4-20 mA signal in NEMA 4X enclosure.
      a. Accuracy: ± 0.5% of full scale reading at calibrated velocity.
      b. Output: pulse
   5. Liquid Pressure Transmitters: Provide Liquid Pressure Sensors with accuracy of ± 1% operating environment or –40 degrees F to 260 degrees F with output signal of 4-20 mA.
   6. Current Sensing Relays: Solid State AC switch with internal current transformer. The switch shall operate when the current level sensed by the internal current transformer exceeds the threshold value set by the adjustment knob. Provide relays

with split core design for the range suitable for application. Coordinate with electrical contractor.

7. Current Transformer: Provide current transformers rated for the specified amperage. The transformer shall provide 0 to 5 VDC output signal.
8. Differential Pressure Switches: A diaphragm operated snap switch shall actuate the electrical circuit upon sensing of Differential Pressure. The set point range shall be 1 inch WC to 12 inch WC.
9. Differential Pressure Sensor: Provide multiple, stainless steel airflow sensor with pitot tube. The sensor shall have an output signal of 4-20 mA. The differential pressure sensor transmitter shall be a single device.
10. Electronic Valve/Damper Position Indication: Visual scale indicating percent of travel.
11. Air Flow Measuring Station: As specified in Section 15726 “Air Handling Units.” Coordinate with air handling unit manufacturer.
12. Humidity Sensors: Bulk polymer sensor element.
    a. Accuracy: 2 percent full range with linear.
    b. Room Sensors: With locking cover matching room thermostats, span of 25 to 90 percent relative humidity.
    c. Duct and Outside-Air Sensors: With element guard and mounting plate, range of 0 to 100 percent relative humidity.
13. Pressure Transmitters: Direct acting for gas or liquid; range suitable for system; proportional output 4 to 20 mA.
14. Duct smoke Detectors: Comply with NFPA requirements. Coordinate with Division 16 and Fire Alarm Systems.
15. Gateways and Direct LAN Connections: Coordinate with HVAC equipment manufacturers, provide and install a complete and operational control Gateway and or Direct LAN connection to the HVAC equipment. Coordinate with equipment manufacturers and other trades to avoid omission or duplication and assure a complete and operating system.
16. Room Temperature Sensor: White, with concealed thermometer, temperature display, and override switch. Install on a sealed airtight insulated backing base.

B. Switches and sensors applications:
1. Status Inputs for Fans: Current sensing relay or VFD proof.
2. Status Inputs for Pumps: Current sensing relay or VFD proof.
3. Status Inputs for other Electric Motors: Current-sensing relay or VFD proof.
4. Duct Temperature Sensors: 100 Ohm RTD Duct Sensors with operating range of 20 degrees F to 120 degrees F.
5. Room Temperature Sensors: Thermistor to 55-95 degrees F with $\pm$ 0.5 degrees F accuracy.
6. Chilled Water Pipe Temperature Sensors: 1000 Ohm RTD Liquid Immersion Sensors with operating range 20 degrees F to 70 degrees F.
7. Hot Water Pipe Temperature Sensors: 1000 Ohm RTD Liquid Immersion Sensors with operating range of 30 degrees F to 250 degrees F.
8. Provide and install all other components indicated for complete and operational system.

2.6 ELECTRIC THERMOSTATS

A. Line-Voltage, On-Off Thermostats: Bimetal-actuated, open contact or bellows-actuated, enclosed, snap-switch type, or equivalent solid-state type, with heat anticipator, integral manual on-off auto selector switch.
1. Dead Band: Maximum 2 deg F (1 deg C).

2.7 ACTUATORS

A. Electronic Damper, Large-Valve Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
   1. Valves: Size for torque required for valve close-off at maximum pump differential pressure.
   2. Dampers: Size for running torque calculated as follows:
      a. Opposed-Blade Damper with Edge Seals: 5 inch-pounds/sq. ft. of damper.
      b. Dampers with 2 to 3 Inches wg of Pressure Drop.
   3. Coupling: V-bolt and V-shaped, toothed cradle.
   4. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
   5. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on non-spring-return actuators.
   6. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-V dc.
   7. Proportional Signal: 2- to 10-V dc or 4 to 20 mA.
   8. Temperature Rating: 40 to 104 deg F.
   9. Temperature Rating (Smoke Dampers): Minus 22 to plus 250 deg F.
   10. Run Time: 12 seconds open, 5 seconds closed.

2.8 CONTROL VALVES (Pressure Independent Valves) PIV

A. Building Chilled Water Valves and Heating Hot Water Valves: All control valves shall be PIV. Valves shall be two positions and flanged, wafer lug style, with a molded in resilient seat providing bubble-tight shut-off to 150 psi.

B. General for Air Handler Coils: All control valves shall be PIV, SS trim. Control valves up to 4 inches shall be sized for a maximum of 4 psi pressure drop at rated flow. Valves shall be packless, modulating, electrically or magnetically actuated, with a control range ability of 500 to 1.

C. Reheat Valves: The reheat valves shall be PIV. The body shall be globe style with a bronze body and a control range ability of 50:1.

2.9 DAMPERS

A. Dampers: AMCA-rated, opposed-blade design; 0.1084-inch minimum, galvanized-steel frames with holes for duct mounting; damper blades shall not be less than 0.0635-inch galvanized steel with maximum blade width of 8 inches. Rated for leakage at less than 10 cfm per sq. ft. of damper area, at differential pressure of 4 inches wg when damper is being held by torque of 50 in. x lbf; when tested according to AMCA 500D.

2.10 VARIABLE AIR VOLUME TERMINAL UNITS

A. VAV terminal units shall be as specified in Section 15840, “Air Terminal Units.”

B. Terminal Unit Controls:
   1. UL 916 and FCC Part 15. Controls for pressure independent boxes shall consist of a velocity sensing device in the primary air entering box, a supply air room temperature sensing element, a damper actuator, and an adjustable microprocessor-based VAV box controller. Controls shall operate a damper for cooling and a duct coil for heating. Actuator shall open or close the device to which it is applied within 6 minutes.

2. Controls for pressure independent boxes with recirculating fans shall consist of a velocity sensing device in the primary air entering the box, a supply air room temperature sensing element, an adjustable microprocessor-based VAV box controller, a damper with actuator, and a duct pressure switch to operate the recirculation fan. Controller shall operate the damper for cooling and the recirculating fan and duct coil for heating.
3. Provide one hand-held communication and programming device with an instruction manual.

2.11 SUNSHINE SHIELDS/RAIN SHIELDS

A. Provide sunshields for outside air temperature sensing elements to prevent the sun from directly striking temperature sensing elements. Provide sunshields with adequate ventilation so that the sensing element responds to the ambient temperature of surroundings. The top of each sunshield shall have galvanized metal or aluminum rain shield projecting over the face of the sunshield. Sunshields shall be painted white or shall be unpainted aluminum.

2.12 CONTROL CABLE

A. Electronic and Fiber-Optic Cable for Control Wiring: As specified in Division 16 Section. Install control wiring in conduit except as specified under Part 3 of this section.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install software in control units and operator workstation. Implement all features of programs to specified requirements and as appropriate to sequence operation.

B. Connect and configure equipment and software to achieve sequence of operation specified.

C. Install guards on thermostats in the following locations:
1. Entrances.
2. Public areas.
3. Where indicated.

D. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.

E. Install hydronic instrument wells, valves, and other accessories according to Division 15 Section “Hydronic Piping.”

F. Install DDC Controllers for a complete and operational system. Install all DDC controllers inside NEMA rated control panels.

G. Install control wiring and electrical work in accordance with California Electrical code and Division 16. In addition to the requirements specified herein, the wiring installation shall meet the requirements of EIA/TIA Standard 586, Commercial Building Standard for telecommunication pathways and spaces.

H. Wiring Inside Conduit: Mechanical Rooms, exposed areas and wiring above non-accessible ceilings. Minimum conduit size is 1/2".

I. Plenum Rated Wiring: Concealed areas above ceilings. Coordinate with electrical contractor. Support final connection wiring in accordance to National Electrical Code and at every four feet. Diagonal installation shall not be accepted. Provide sleeves for wall penetrations.

J. Control wiring color coding shall be consistent throughout this project. Coordinate with the University and other trades. Provide communication and control wiring with proper identification and labeling. Clearly label and color code control wiring as follows:
   1. Orange: Local area network wiring.
   2. Blue: Analog and digital, input or output points.
   3. Green: Low voltage power wiring.
   4. White: Line voltage wiring, or per National Electric Codes.

K. Do not install low and line voltage wiring in the same conduit.

L. Provide and install wiring and conduit in connection with HVAC instrumentation and controls for complete operational system.

M. Install transformers inside NEMA rated control enclosures.

N. Program new construction systems into the existing campus central system.

O. Perform and document comprehensive testing for all control installation. Provide necessary instruments and equipment to document the results.
   1. Verify that circuits are continuous and free from short circuits and grounds.
   2. Verify that circuits are free from unspecified ground. The resistance to ground of all circuits shall be over 50 MegaOhms.
   3. Verify that circuits are free from induced voltage.
   4. Provide complete testing for all cables used under this contract. Provide all equipment, tools, and personnel as necessary to conduct these tests.
   5. Provide for complete grounding of all signal and communication cables, panels, and equipment so as to ensure system integrity of operation. Ground cabling and conduit at the panel terminations. Avoid grounding loops.

P. Installation Quality Requirements: In addition to the requirements of Division 16, manufacturer's recommendation and National Electric Codes, provide installation quality requirements specified here for a complete and operational control system.
   1. All conduits and raceways shall be installed level, plumb, at right angles to the building lines and shall follow the contours of the surface to which they are attached.
   2. Flexible Metal Conduit shall be used for vibration isolation and shall be limited to 3 feet in length when terminating to vibrating equipment. Flexible Metal Conduit may be used within partition walls. Flexible Metal Conduit shall be UL listed.
   3. Provide firestopping for all penetrations.
   4. All openings in fire proofed or fire stopped components shall be closed by using approved fire resistive sealant.
   5. All wiring passing through penetrations, including walls shall be in conduit or enclosed raceway.
   6. Penetrations of floor slabs shall be by core drilling. All penetrations shall be plumb, true, and square.

7. No penetrations in structural elements shall be made before receipt of written approval form the architect.

3.2 TRAINING

A. Field Training of Operators: Upon completion of work under this section and upon the University's acceptance provide a minimum of 16 hours of formal classroom training for the University's operators. The training shall be conducted by factory trained control engineers and technicians. This training shall be provided in 8 hour sessions at a time. A factory certified trainer shall be present during the training. Provide handouts and audio visual programs as required.

3.3 COMMISSIONING OF BUILDING AUTOMATION SYSTEM

A. Commissioning per ASHRAE Standards. Commissioning Report shall include the following:
   1. Trend Data.
   2. Installation Verification of Building Automation System.

B. Refer to Section 15980 "Mechanical Commissioning." Coordinate and provide the required expertise and services for a complete commissioning process. Coordinate with all other trades for a complete commissioned system. Coordinate with the commissioning authority.

C. Documents results in Standard Forms recommended by DDC manufacturer or other established organizations. Comply with the similar standards established by AABC, NEBB or ASHRAE. Obtain approval prior to commencement of the work.

D. Attend the monthly commissioning meeting. Coordinate with the commissioning authority of the project.

E. Coordinate installation interface with Campus Automation System.

F. Provide seasonal simulation to allow for a complete and operating system throughout the year or provide a comprehensive building automation re-commissioning within 6 months of installation for seasonal adjustment.

3.4 SEVENTY-TWO (72) HOUR TREND DATA

A. Upon completion after project provide a seventy-two (72) hour data indicating complete operation of DDC System. Final acceptance of the completion of the DDC shall be based upon the seventy-two (72) hour Trend Data. The Trend Data shall be in form of color Trend Graph. Provide Trend Data of all temperatures, air- and water- flow quantities, and equipment status points. This shall include room, outside air, chilled water, heating hot water, condensing water temperatures and set points. Trend data shall also include duct and pipe pressures and set points. The trend data shall also include variable frequency drive speed and frequency. It shall also include outside, return and supply air quantities and position of dampers. Provide trend data for kW meter and chiller operation. Submit specified list of points and graphic format of trending for approval prior to commencement of 72-hour trending. Coordinate with commissioning agent.

B. Provide additional (72) hour trend data as required until full compliance.

C. Upon completion submit the results indicating compliance in one complete package. Submit 6 sets.

3.5 OWNER WITNESSED TESTING

A. All parts of the testing described in this section are to be performed as point to point tests unless the University wishes them to defer. If such a deferment is made, the University will advise vendor of effected testing thru the normal submittal and review process. The complete Local Operators Station, including all controls programming, shall be available to support the point to point testing.

B. One copy of the preliminary as-builts (site drawings) shall be provided to support this testing. After receipt of all system documentation by the the University, notify the University ten working days before testing begins, then system testing shall be performed by the manufacturer or their local representative, witnessed by the the University, and include, as a minimum, the following:
   1. The test plan shall fully describe the procedure for the test; provide the format for documenting the results and space for comments. Provide a section to document vendor repair activity, vendor's initials and retest witnessing. Discrepancies shall be documented using form "Point to Point Discrepancies" provided in Part 7.

C. The local operator's station shall be installed and made available with adequate software and programming development to support the University Witnessed Testing.

D. Installation verification:
   1. Verify operation, location and identification of power sources, including circuit breakers and control power transformers.
   2. Start/Stop Points: Issue start and stop commands. Verify that controlled equipment responds appropriately and that the start/stop status is accurately reflected.
   3. Analog Points: Analog inputs and outputs shall be verified at both extremes of their ranges and at the midpoint. Verify tight shutoff and full opening of dampers and valves.
   4. Binary Points: Verify that both state conditions are accurately reflected.
   5. Verify fan and pump failure alarms by turning off the motor at the HOA switch and observing the run state indication at the operator station.
   6. Temperature Points: Verify calibration of sensors by comparing displayed temperature with the reading of an independent measuring device located in the same flow stream. Test liquid temperature sensors installed piping thermowells in site to verify effectiveness of heat conducting compound.
   7. Pressure Points: Verify calibration of sensors by comparing displayed pressure with the reading of an independent measuring device located in the same flow stream.
   8. Control Valves: Verify tight shutoff by comparing water or air temperatures entering and leaving the heat transfer device.
   9. Operator Response and Sequencing: Demonstrate that sequenced or modulated valves and dampers position accurately in response to positioning signals. (e.g. no overlap and correct ranging between 1/3 and 2/3 operators, multiple operators positioning accurately to provide simultaneous modulation of parallel dampers or valve assemblies.)
   10. Control signal stability, general: Demonstrate that control loops are tuned so that the output does not change until the controlled system has had time to respond to the last output signal.
   11. Control signal stability, response to step input: Demonstrate that control loops are tuned so that they are stable without excessive hunting following a step input of not less than 20% of the operating range of the controlled variable.

12. Control signal stability, floating point devices: Verify that minimum pulse output duration is no greater than 0.5 seconds.

E. Local Operator Station Operation:
1. Point Test:
   a. Check that terminal operates devices and receives information from sensors.
   b. Verify calibration of each sensor.
   c. Verify manual override capability for start/stop and modulated point types.
2. Control Logic:
   a. Exercise all control logic packages.
   b. Check response to upset, change in set point.
   c. Check full and partial load operation.
3. Supervisory Function:
   a. Verify content of time clock schedules.
   b. Verify alarms reporting.
4. Failure Modes:
   a. Verify all stand alone operation by disconnecting communication lines between stand alone control units and verifying proper operation.
   b. Disconnect and reapply 120 VAC Local Operator Station (LOS) power to confirm proper recovery from power failure.
   c. Disconnect and reapply 24 VAC controller power to confirm proper recovery from power failure.

F. Remote Operator Station Operation:
1. Verify communication with each field device installed.
2. Make end-to-end sensor and actuator checks.
3. Verify transmission and reporting of alarms.
4. Verify acquisition of data.
5. Duplicate local operator's station functions.

G. Test Other Software:
1. Trend Logging.
2. Report Generation.
3. Remote Access.
4. Ability of the control system to automatically restart all the connected systems which should be running, following a power restoration.

3.6 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect field-assembled components and equipment installation, including piping and electrical connections. Report results in writing.
1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove malfunctioning units, replace with new units, and retest.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment, and retest.
3. Calibration test electronic controllers by disconnecting input sensors and stimulating operation with compatible signal generator.

B. Engage a factory-authorized service representative to perform startup service.

C. Replace damaged or malfunctioning controls and equipment.

1. Start, test, and adjust control systems.
2. Demonstrate compliance with requirements, including calibration and testing, and control sequences.
3. Adjust, calibrate, and fine tune circuits and equipment to achieve sequence of operation specified.

D. Verify DDC as follows:
1. Verify software including automatic restart, control sequences, scheduling, reset controls, and occupied/unoccupied cycles.
2. Verify operation of operator workstation.
3. Verify local control units including self-diagnostics.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train the University's maintenance personnel to adjust, operate, and maintain control systems and components.
1. Train the University's maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment and schedules.
2. Provide operator training on data display, alarm and status descriptors, requesting data, executing commands, calibrating and adjusting devices, resetting default values, and requesting logs. In addition to training requirements specified elsewhere, include a minimum of 20 hours' dedicated factory instructor time on-site.
3. Review data in maintenance manuals. Refer to Division 1 Section "Operation and Maintenance Data."
4. Schedule training with the University, through Design/Builder, with at least seven days' advance notice.

3.8 ON-SITE ASSISTANCE

A. Occupancy Adjustments: Within one year of occupancy date based on the Notice of Completion, provide up to three Project site visits, when requested by the University, to adjust and calibrate components and to assist the University's personnel in making program changes and in adjusting sensors and controls to suit actual conditions.

END OF SECTION