

15900 – HVAC Instrumentation and Controls

PART 1 - GENERAL

1.1 SYSTEM FEATURES AND ARCHITECTURE

- A. The controls system shall be capable of integrating multiple building functions including equipment supervision and control, alarm management, energy management and historical data collection.

1.2 SUBMITTALS

- A. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
 - 1. Each control device labeled with setting or adjustable range of control.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 1. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
 - 2. Wiring Diagrams: Power, signal, and control wiring. Differentiate between manufacturer-installed and field-installed wiring.
 - 3. Details of control panel faces, including controls, instruments, and labeling.
 - 4. Written description of sequence of operation.
 - 5. Schedule of dampers including size, leakage, and flow characteristics.
 - 6. Schedule of valves including leakage and flow characteristics.
 - 7. Trunk cable schematic showing programmable control unit locations and trunk data conductors.
 - 8. Listing of connected data points, including connected control unit and input device.
 - 9. System graphics indicating monitored systems, data (connected and calculated) point addresses, and operator notations.
 - 10. System configuration showing peripheral devices, batteries, power supplies, diagrams, modems, and interconnections.
- C. Software and Firmware Operational Documentation: Include the following:
 - 1. Software operating and upgrade manuals.
 - 2. Program Software Backup: On a magnetic media or compact disc, complete with data files.
 - 3. Device address list.
 - 4. Printout of software application and graphic screens.
 - 5. Software license required by and installed for DDC workstations and control systems.
- D. Software Upgrade Kit: For Owner to use in modifying software to suit future power system revisions or monitoring and control revisions.
- E. Maintenance Data: For systems to include in maintenance manuals. Include the following:
 - 1. Maintenance instructions and lists of spare parts for each type of control device and compressed-air station.
 - 2. Interconnection wiring diagrams with identified and numbered system components and devices.
 - 3. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
 - 4. Calibration records and list of set points.

- F. Project Record Documents: Record actual locations of control components, including control units, thermostats, and sensors. Revise Shop Drawings to reflect actual installation and operating sequences.

1.3 QUALITY ASSURANCE

- A. Installer Qualifications: An experienced installer with at least 10 years of experience who is an approved installer of the automatic control system manufacturer for both installation and maintenance of units required for this Project.

1.4 WARRANTY and SERVICE

- A. The Contractor shall warrant the system to be free from defects in material and workmanship for a period of two (2) years from the date of completion and acceptance of the work by the owner. Any defects shall be repaired or replaced, including materials and labor at no cost to the owner.
- B. The Contractor shall provide one (1) year of maintenance service for the HVAC controls system to begin concurrently with the 1st year of warranty. Service shall include inspection and adjustment of all operating controls and components. The service shall be performed every 3 months and documentation of service shall be provided to Facilities Operations.

1.5 EXTRA MATERIALS

- A. Furnish the following extra materials to Facilities Operations at completion
 1. 1 sensor of each type (Hydronic, air supply, humidity)
 2. 2 zone thermostats
 3. 2 sets of filters for the compressed air system

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. HVAC controls system contractor shall provide a fully integrated system, UL listed, incorporating direct digital control for energy management, equipment monitoring and control as manufactured by:
 1. Invensys (Siebe)
 2. Controls System International
 3. Johnson Controls
- B. Alternates to base bid: Invensys (Siebe)

2.2 DDC EQUIPMENT (Workstations, laptops, printers, software, DDC control units)

- A. Building Control Unit
 1. The Building Control Unit (BCU) is the electronic link between the respective building and the campus network and shares information among all the DDC stand-alone panels within the respective building.
 2. The building BCU shall be a networking stand-alone energy management panel enclosed in a sturdy metal enclosure. The microcomputer shall be at the least 16 bit. The microcomputer shall utilize a multi - tasking, multi - user operating system. The BCU shall have peripheral ports for a

CRT, a printer, an auto answer / auto dial modem, and network communications. The BCU shall have a battery back - up for the clock.

3. The building BCU shall be placed on the control vendor's Local Area Network (LAN) configuration within the respective building via its BUS ports. Fault tolerant operation of the Local Area Network shall guarantee that failure in communication or operation of any DDC controllers on the LAN shall not interrupt the communication between remaining units. The BCU shall also be connected to the Campus Wide Area Network via Ethernet connection with communications based on TCP/IP protocol. This connection is via the communication port. The BCU shall be furnished with a built-in software library.
4. The Ethernet card shall reside in the BCU. It shall communicate with the network via a Mbps network adapter
5. The BCU shall have an operator interface that is an integral part of the BCU. The interface can be a display and keyboard, or a touch-sensitive screen. The interface shall provide visual indication of analog variables, binary (status) condition, adjustment values, automatic operation, trouble, alarm condition and value, manual or override condition.
6. Only one building control unit (BCU) per building shall be connected to the University network via the Ethernet connection. The BCU may not be located in University telecommunication rooms. A standard University voice/data outlet should be installed adjacent to the BCU.
7. A Laptop computer shall be provided and capable of communication with the controls network through the BCU connection

B. DDC Controllers

1. DDC Controllers (stand-alone) shall be microprocessor-based with a minimum word size of 16 bits. They shall also be multi-tasking, multi-user, real-time digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules. Controller size shall be sufficient to fully meet the requirements of this specification.
2. Control of the mechanical systems shall be performed by a field programmable microprocessor-based direct digital controller (DDC), which incorporates closed loop control algorithms, all necessary energy management functions, and provides for digital display and convenient local adjustments of desired variables at the controller cabinet. Systems which require the existing user-defined data base to be reentered through the operator's terminal after a failure or power interruption shall not be acceptable.
3. Each unit shall be capable of performing the following energy management functions:
 - a. Start/stop optimization
 - b. Time of day scheduling
 - c. Enthalpy economizer control
 - d. Supply air reset
 - e. Chilled water reset
 - f. Hot water reset
 - g. Event initiated programs
 - h. Night setback
 - i. Chiller sequencing
 - j. Chiller load monitoring
4. Each DDC shall be capable of performing all specified control functions in a completely independent manner. Additionally, DDCs shall be capable of being networked for single point pro-

gramming and for the sharing of information between panels, including, but not limited to, sensor values, calculated point values, control set-points, tuning parameters, and control instructions.

5. Each DDC controller shall include its own microcomputer controller, power supply, input/output modules, termination modules, battery, and spare AC outlet. The battery shall be continuously charged and be capable of supporting all memory for a minimum of 72 hours. Upon restoration of system power, the control unit shall resume full operation without operator intervention.
 6. Each DDC controller shall have at least two RS-232 communication ports
- C. Building Operator Workstation: Provide as a minimum an IBM-compatible microcomputer with minimum configuration as follows:
1. Processor: Intel Pentium MMX, 266 MHz., 32 MB RAM, 256 kB Cache
 2. Graphics: SVGA, minimum 1280 x 1024 pixels, 4.0-MB EDO video memory.
 3. Monitor: 17 inches , noninterlaced, color, with maximum 0.28-mm dot pitch.
 4. Standard keyboard, mouse and 1.44 MB floppy-disk drive.
 5. Hard-Disk Drive: 4.0 GB.
 6. CD-ROM Drive: 24x.
 7. Modem: Autodial, internal, minimum 56 kBaud.
 8. Ethernet card (if connected directly to the campus network)
 9. Backup: 250 Mb Zip Drive.
 10. Operating System: Microsoft Windows NT 4.0
 11. Prefer Gateway, Dell or Compaq
- D. Graphic Display Requirements
1. Provide a windows based software package for the preparation of system graphics. The package shall be designed to work on the University's computer monitors.
 2. Include with this software a library of HVAC symbols such as fans, pumps, chillers, etc.
 3. This section establishes standards for graphic displays as follows.
 - a. All operator workstations other than the Laptop shall be programmed to display graphical representations of the mechanical systems and floor areas for which this system has control. Systems to be displayed include the air handlers, air terminal units, chillers, heat converters, pumping systems and similar mechanical devices.
 - b. Floor plans displays are required and shall indicate the approximate positions of controlled mechanical system elements within the floor layout.
 - c. All displays shall show real time data to include temperatures and run status.
- E. Printer: Provide a dot-matrix type as follows:
1. Print Head: 24 pin, 360 x 360 dpi resolution.
 2. Carriage: Wide, 132 characters per line of paper.
 3. Paper Handling: Fan-fold paper, with 1carton containing minimum of 2500 sheets.
 4. Print Speed: Minimum of 120 characters per second.
 5. Prefer Panasonic, Okidata
- F. Application Software: Include the following:
1. Input/output capability from operator station.
 2. Operator system access levels via software password.
 3. Database creation and support.
 4. Dynamic color graphic displays.
 5. Alarm processing.

6. Event processing.
7. Automatic restart of field equipment on restoration of power.
8. Data collection.
9. Graphic development on workstation.
10. Maintenance management.

G. LAPTOP: Provide as a minimum an IBM-compatible Laptop with minimum configuration as follows:

1. Processor: Intel Pentium MMX, 233 MHz., 32 MB RAM, 128 kB Cache
2. Graphics: 2.0-MB video memory.
3. Screen: 12 to 13 " Active matrix, color
4. Floppy-Disk Drives: 1.44 MB.
5. Hard-Disk Drive: 2.0 GB.
6. CD-ROM Drive: 10x.
7. Operating System: Microsoft Windows NT 4.0.
8. Prefer Gateway, Dell or Compaq

2.3 CONTROL PANELS

- A. Panels shall have hinged doors and be marked with engraved labels. Panels used as a location for mounting control devices shall have a document holder located on the inside of the door.
- B. Provide common keying for all panels
- C. Entrance and exit wiring should be on the panel sides.
- D. All heat generating devices shall be located at the top of the panel.

2.4 SENSORS and TRANSMITTERS

- A. Humidity Sensors
 1. Accurate to +/- 3%
 2. Room sensors; 20 – 90 % RH. Cover to match room thermostat.
 3. Duct and outside air sensor; 0 – 100% RH
- B. Pressure Sensors
 1. Duct static pressure sensors shall have an accuracy of +/-1% of range
- C. Temperature Sensors
 1. Platinum or nickel RTD, 100 or 1000 ohm, accurate to +/-0.5%
 2. Outside air sensors shall be shielded from solar radiation.
 3. Temperature sensors used in BTU calculations shall be a matched pair with a differential accuracy of +/-0.15F over entire range and supplied by the BTU system manufacturer.
 4. Room space sensors may be thermistor type.
- D. Transducers
 1. Provide a minimum 1¼" pressure gauge at the output of each I/P and E/P transducer
- E. Current Sensors
 1. Proof of run for pumps and fans shall be by current sensed devices

2.5 METERS

- A. BTU Meter
 - 1. Meter shall be Onicon System-1, Model 100 or approved equal
 - 2. Meter shall have 6 digit electro-mechanical BTU totalizer with units dependent on anticipated energy usage.
 - 3. LCD for liquid flow rate.
 - 4. The meter shall output supply temperature, return temperature, flow rate and totalized BTU's to the DDC control system.
- B. Water Flow Meters
 - 1. Turbine Flow Meter
 - a. Dual turbine element w/ electronic sensing
 - b. Analog output: 4-20ma & 0-10vDC
 - c. Accurate to +/- 2% of reading from 0.4 – 20.0 ft/s
 - d. Shall have capability to remove meter without shutting down chilled water system

2.6 THERMOSTATS

- A. Space Thermostats
 - 1. All room thermostats in labs, classrooms and offices shall have exposed setpoint adjustment with internal stops or software stops for minimum and maximum setting initially set between 68 degrees and 72 degrees
 - 2. All room thermostats in public areas will have concealed setpoint adjustments with blank cover.
 - 3. Insulated mounting bases on exterior walls
 - 4. Accuracy to +/-0.5%
 - 5. Each thermostat shall be capable of reporting the space temperature and setpoint. In addition, each shall be capable of remote reset by the DDC system

2.7 CONTROL VALVES and ACTUATORS

- A. General
 - 1. All control valves for HVAC equipment within mechanical equipment rooms and central station units shall utilize pneumatic actuation. Butterfly valves for air handling unit coil control are unacceptable unless they are high performance type and only with approval from Facilities Planning and Design.
 - 2. Preheating and cooling valves shall be software interlocked so that both valves cannot be opened simultaneously except for override
 - 3. Operator bodies shall be metal
- B. Steam Valves
 - 1. A 1/3, 2/3 valve configuration will be utilized on all hot water converter applications. The 1/3 valve will be normally open and the 2/3 valve will be normally closed. A separate AO pneumatic output will be used for each valve. The use of a single AO and a reversing relay is not permitted
 - 2. Valves shall have stainless steel trim and seat.
- C. Hydronic Valves
 - 1. Valves shall be sized so that pressure drop across valve is at least 25% of the coil pressure drop at full design flow.
 - 2. Valves shall remain closed (zero leakage) against 100% of the full shutoff head of the pump.
 - 3. High performance butterfly valves shall have adjustable packing, EPDM seat with suitable metal back-up ring, upper and lower shaft thrust bearings, 316 SS one piece shaft and 316 SS disc with offset shaft/disc design. Valves shall be provide with pneumatic actuator and positioner. Valves and actuators shall be manufactured by the valve manufacturer.
 - 4. Valves shall be two-way and equal percentage.
 - 5. Two-position valves shall be line size.

6. Valve service rating shall be 125 psig. or greater except that valves in the campus chilled water piping shall be rated at 250 psig. or greater. The shaft to which the actuator(s) is coupled shall be square or hexagonal or round with one side flattened, to achieve secure coupling.
7. Terminal reheat valves shall be electric proportional, 4-20 ma or 0–10 VDC signal with positive positioning mechanism. Floating point or step control is not allowed. Prefer not to use ball valves.
8. Valves shall have stainless steel trim and seat.

2.8 DAMPERS and ACTUATORS

A. Dampers:

1. Maximum blade width of 8" with nylon blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.
2. Provide low leakage control dampers where not furnished with packaged units. Damper leakage rate shall not exceed 10 CFM/sq. ft. at 4" wg.. Dampers shall have blade seals and stops. The shaft to which the actuator(s) is coupled shall be square or hexagonal or round with one side flattened, to achieve secure coupling.
3. Provide pneumatic actuators for all automatic control dampers. Locate damper actuators outside of the air stream. Positioning relays will be provided for each damper section: one each for outside air, return air and relief air.
4. Control dampers used for outside air or exhaust shall be installed a minimum of 6" away from wall penetrations to allow for external mounting of actuators.
5. Throttling operation shall be opposed blade type.
6. Floating point or step control not allowed.

B. Actuators

1. Operator bodies shall be metal except for VAV box actuators
2. Damper and VAV box actuators shall directly couple around damper shaft

2.9 AIR SUPPLY

A. Compressor and Accessories

1. Duplex air compressor system with a maximum of 20 minutes of run time
2. Electrical alternation set with motor starters and disconnect to operate compressors alternately. Provide control that if single unit is unable to maintain pressure, the second unit will start automatically.
3. Provide a refrigerant or desiccant type dryer to reduce dew point to less than 10F @ 20psig. If desiccant dryer, provide the automatic heatless regenerative type with compressor sized for blow-down load.
4. Provide automatic moisture trap on drain of receiver. Connect trap to building drain.
5. All blowdowns shall be muffled.

B. Control and Instrumentation Tubing

1. Copper
 - a. Hard drawn Type M seamless copper tubing
 - b. Soft copper tubing may be used in maximum 2 foot lengths for connection to control devices only.
 - c. Fittings: Cast-bronze solder fittings or wrought-copper solder fittings. Use compression type fittings only for connections to control devices
2. Plastic
 - a. Black virgin polyethylene tubing
 - b. Fittings: Compression or push-on polyethylene

2.10 LABELS and TAGS

1. Provide labels for all field devices including sensors, meters, transmitters and relays. Labels shall be plastic laminate and located adjacent to the device.
2. Labels of field devices (both locally and software ID's) shall be associated with their respective air handler, boiler, chiller, ect.
3. Junction box covers shall be painted yellow and labeled "DDC"

2.11 CONTROL WIRING

1. All control wiring shall be a minimum of No. 18 gauge.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Control and Instrumentation Tubing

1. General
 - a. Purge tubing with dry, oil-free compressed air before connecting control instruments
 - b. Number-code or color-code control air piping for future identification and service of control system, except local individual room control tubing
 - c. Pressure Gages: Install on branch lines at each receiver controller and on signal lines at each transmitter, except individual room controllers.
2. Mechanical rooms
 - a. All tubing in mechanical rooms shall be either hard drawn copper or poly tubing in conduit.
3. Concealed and Accessible Locations
 - a. All tubing in accessible locations such as suspended ceilings can be either poly tubing in conduit or copper
4. Concealed and Inaccessible Locations
 - a. All tubing in inaccessible locations such as concrete slabs, furred walls or ceiling with no access shall be copper.

B. Control Wiring

1. All wiring shall be in conduit. Conduit shall be run parallel or perpendicular to walls and building lines. Junction box covers shall be painted yellow and labeled "DDC"
2. Wires shall be labeled with mechanically prepared labels at their connection point to each apparatus point of connection.
3. Wiring shall not use the voice/data wireway/conduit systems as pathways.

3.2 ON-SITE TESTING

A. When installation is complete, the controls contractor shall perform the following:

1. A 100% field calibration of all sensors and equipment.
2. Verification of each control point by comparing the control command and the field device.
3. Documentation of results shall be provided to the University prior to final acceptance.

3.3 DEMONSTRATION

- A. The controls contractor shall demonstrate that controls are installed, adjusted and operate as required by the drawings and specifications. This demonstration shall be documented and may be conducted in conjunction with the training of University personnel. The documentation shall identify the item, the per-

son performing the demonstration, date, and the signature of the University's representative. The University's Representative will select the items to be demonstrated. Items shall be demonstrated as follows:

Item Demonstrated	Controls Contractor (Name)	University's Representative (signature)	Date
1. Disconnect one DDC from the building network to demonstrate that a single device failure will not disrupt peer-to-peer communication			
2. Manually generate alarms at ____ points and demonstrate that the workstation(s) receive the alarms			
3. Calibration has been performed on at least ____ sensors			
4. Point-to-point verification of the greater of ____ points or (____) % of all points. Include labeling of points.			
5. Sequence of operation for the air handling units including economizer cycle, reset , start/stop,			
6. Sequence of operation for the chilled water system including chiller(s)			
7. Sequence of operation for the hot water system			
8. Sequence of operation for ____ VAV terminal units including min/max air, reset,			
9. Sequence of operation for the boiler and steam system			
10. Sequence of operation of the HVAC controls system during a fire alarm			
11. Fail safe operation of AHU, chilled water system, steam and boiler system, hot water system , and terminal units.			
12. Graphics system is functional and that the layout is consistent with field conditions.			
13. Response to upset conditions and change of setpoint for selected systems			

3.4 TRAINING

- A. The manufacturer and the controls contractor shall provide on-site training in the maintenance and operation of the installed system for up to six (6) personnel. The training shall be documented and a syllabus and O&M manuals shall be submitted and approved by Facilities Operations 2 weeks prior to the training. The training should include the following:
 - 1. HVAC systems layout including the locations of air handlers, DDC controllers, VAV boxes, pumps, chillers. This will include a walk-thru at the building.

2. Sequence of operations for each control loop.
 3. Accessing the control system including:
 - a. Logon procedure
 - b. Use of graphic and DDC pages
 - c. Password requirements
 4. Operation and troubleshooting including:
 - a. Modification of setpoints, schedules
 - b. Overview of graphics and text pages
 - c. Trending of points
 - d. Calibration and adjustment
 - e. Hands on training in the troubleshooting and replacement of components including sensors, transmitters, control valves and actuators. Contractor shall have examples of each component and demonstrate measurement of input and output signals, and any operator adjustments available.
 - f. DDC controller functions and operation
 5. Review of O&M manual and control system as-builts
- B. The controls contractor shall provide an additional on-site training session nine (9) months after project completion. The purpose of the session will be to review any operational problems that have developed. In addition, the contractor will lead Facilities Operations personnel through a comprehensive annual preventative maintenance of the controls system. This shall be scheduled at least one (1) month in advance
- C. The manufacturer and the controls contractor shall provide training for two (2) university employees at the manufacturer's training facility. Include all travel, lodging and expenses for the trainer or the university personnel. The training shall be documented and a syllabus must be submitted and approved by Facilities Operations prior to the training. The training should include the following:
1. Programming logic changes
 2. Expansion of the control system including hardware and software additions
 3. Graphics generation
 4. HVAC control systems

APPENDICES

- A. Sample I/O Summary
- B. Minimum Points – Display and programming requirements
- C. Campus and building control schematic
- D. Notes for Designers

Construction Guidelines

SAMPLE INPUT/OUTPUT SUMMARY

NOTES

APPENDIX B – Minimum Points - Display and programming requirements

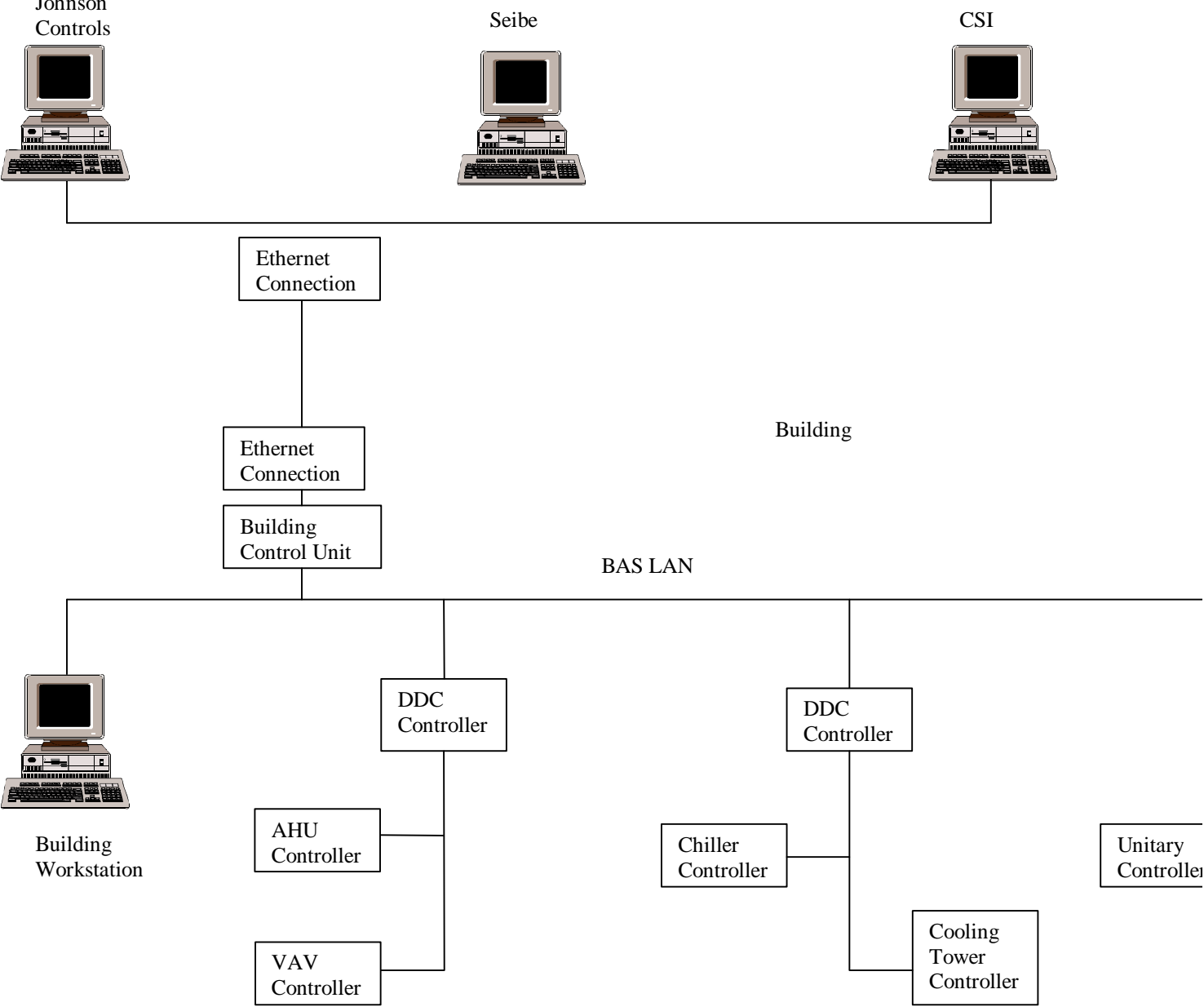
The following commands, displays and data shall be available at the operators terminal:

- A. Air Handling Unit:
 - 1. Outside air temperature
 - 2. Mixed air temperature
 - 3. Supply air temperature
 - 4. Supply air temperature reset
 - 5. Return air temperature
 - 6. Fan status
 - 7. Cooling/heating valve position (% of full open)
 - 8. The following points are only required if required by control strategy.
 - a. Calculated total outside air flow (cfm)
 - b. Damper positions (% of full open)
 - c. Duct static pressure
 - d. Fan speed (% of full speed)
 - e. Freeze protection status
 - f. Alarms (temperature, flow)
 - g. Outside air humidity
 - h. Humidity valve position (% of full open)
- B. Hot Water Steam Converters and Pumps:
 - 1. Pump status
 - 2. Supply and return temperature
 - 3. Valve positions (% of full open)
 - 4. Pump speed if variable speed drive (% of full speed)
- C. Chilled Water System:
 - 1. Supply and return temperature
 - 2. Condenser water supply and return temperature
 - 3. Supply temperature reset
 - 4. Chilled water pump status (current sensor)
 - 5. Condenser water pump status (current sensor)
 - 6. Cooling tower fan status
 - 7. Chiller status
 - 8. High/low temperature alarms
 - 9. The following points are only required if required by control strategy
 - a. Secondary/tertiary supply and return temperature
 - b. Secondary/tertiary flow (GPM)
 - c. Bridge flow (GPM)
 - d. Secondary/tertiary pump speed (% of full speed)
 - e. Return water temperature control valve (% of full open)
 - f. Secondary/tertiary loop differential pressure
- D. Boiler and Steam System
 - 1. Boiler status
 - 2. Common header pressure

- E. Air Terminals:
 - 1. Current space temperature
 - 2. Occupied setpoint
 - 3. Unoccupied setpoint
 - 4. Current status
 - 5. Minimum and Maximum air flow setting (CFM)
 - 6. Current air flow reading (CFM)
 - 7. Reheat valve position (% of full open)
 - 8. High/low temperature alarm

- F. Metering – Chilled Water, Power and Steam:
 - 1. Output from building kilowatt-hour meter (kw, kwh, phase voltage and current)
 - 2. Output from condensate or steam meter.
 - 3. Output from BTU meter

NC STATE University Construction Guidelines
APPENDIX C- Campus And Building Control Schematic



APPENDIX D - Notes For Designers

1. These design standards are to be used for all new construction and renovations. The designer should consult with Facilities Planning and Design if questions arise during the design.
2. This guideline provides requirements for NC State University. It is the responsibility of the designer to incorporate these requirements into the project specific controls specification. This guideline does not include all requirements for a complete controls design specification.
3. Designer should consult with Owner to establish project specific training requirements
4. The necessity and location of an operator workstation should be determined at schematic design
5. The following are required to be a part of the design for each project:
 - a. I/O Summary
 - b. Control schematic (can be identified on the mechanical schematic)
 - c. Sequence of Operation
6. Appendix B is provided to help the designer identify points. It is not intended for insertion into the design specification.