230900 BUILDING AUTOMATION CONTROL SYSTEM GUIDELINES

Cornell's Design and Construction Standards provide mandatory design constraints and acceptable or required products for all construction at Cornell University. These standards are provided to aid the design professional in the development of contract documents and are not intended to be used verbatim as a contract specification nor replace the work and best judgement of the design professional. Any deviation from the Design and Construction standards shall only be permitted with approval of the University Engineer.

PART 1: GENERAL

1.01 RELATED SECTIONS

A. Section 221500 – Compressed Air

B. Section 230000 – Basic HVAC Requirements

C. Section 230540 – Laboratories

D. Section 230510 – Chilled Water System

E. Section 230520 – Heat Generation

F. Section 230901 – Building Automation and Control System Communications and Interoperability

G. Section 260923 – Lighting Controls

H. Section 262923 – Variable Frequency Drives

1.02 RELATED STANDARD DETAILS

A. A comprehensive package of temperature control schematics, points and alarms list, and sequences of operation have been developed to aid consultants in the design and installation of a building temperature control system that meets Cornell requirements. Where a detail has been generated for a specific zone or system, a reference to the detail is included.

B. These control diagrams reflect functional systems that have the capability of operating in a stand-alone fashion in the event of a network failure. They are intended to be used as templates, and are to be revised to suit the particulars of the project.

C. In addition, these details represent the minimum level of information expected and required for a comprehensive control diagram meeting Cornell Standards.

D. The details are broken up into several sections of varying level of detail.

1. Detail Numbers 3.5.(x) consist of general automation system requirements that apply to all projects.
2. Detail Numbers 3.6.(x) consist of device building blocks. These building blocks are to be used to develop zone and system automation details.
3. Detail Numbers 3.7.(x) and 3.8.(x) represent typical zone and system automation details that use the building blocks in 3.6.(x), along with the addition of points and alarms lists and sequences of operation.

1.03 INTRODUCTION

A. The Building Automation and Control System (BACS) is configured as a network with control functions at multiple levels, and with multiple points of operator control and supervision. The BACS includes web-based access, the Energy Management and Control System (EMCS), data transmission systems, field panels and controllers, necessary interfacing controls, sensors and actuators. The controllers contain microprocessors and other supporting electronics that perform local control functions and execute application programs without requiring communications with the centralized head-end computers or workstations.

1.04 SCOPE

A. These guidelines apply to all new and major renovation projects for Cornell University that involve the automatic control of building systems. The Cornell University BACS monitors and controls predominantly building heating, ventilating, air conditioning, associated equipment and auxiliaries while monitoring key parameters and alarms from other systems. While several BACS vendors exist on campus, they are all covered by this standard.

1.05 INTENT

A. General: It is the intent of this guideline to require fully automated, reliable and cost-effective, distributed digital control (DDC) systems for all building systems provided under the scope of this standard. More specifically, it is the intent of this standard to:

1. Establish a level of quality for the control systems installed at Cornell University.
2. Promote and facilitate consistency among the numerous projects installed by the various entities.

3. Establish the extent of the control system that is required and cost-effective for Cornell University, synthesizing the requirements of the design, management, and operations of the facility.
4. Establish preferences relative to the HVAC controls.

B. Deviations from these guidelines must be submitted with a detailed justification for the deviation.

C. Functional Intent

1. Accessibility: As much as practical, design the system BACS equipment to remain out of (or above) user areas. The maintenance staff must have quick and direct access with sufficient room for operation and maintenance. Keep equipment out of elevated and/or enclosed spaces. Provide suitable access panels or doors only when this is not practical. The access panels or doors shall be a minimum size of 18 x18 inches.
2. Reliability: Cornell requires reliable control systems. Controls are integral to acceptable building conditions and shall be designed to be robust and reliable over time.
3. Cost-Effectiveness: This document prescribes a control system that is cost-effective from a life cycle cost perspective (including not only first cost but energy, maintenance, and operations).
4. Digital Terminal Unit Control - This intent of this standard is to require digital electronic control down to the terminal level. Terminal level controls will typically be cost-effective controllers designed for the specific application. Stand-alone local controls may only be used when specifically approved by Cornell.
5. Expandability - When specifying the BACS equipment, provision must be made for reasonably expected future expansion. Hardware and software required to implement expansion must be provided via system sizing, configuration, and appropriate license agreements.

D. When a portion of an existing building is to be renovated, the new control system should match and integrate seamlessly with the existing control system. It is generally preferred to extend the existing control system architecture rather than introduce a new system into the facility.

1.06 POINT TYPE DEFINITIONS

A. Point types used throughout this document are defined as follows:

1. Binary Input (BI): An on/off indication that has a maximum cycle rate of 1 Hz. This is typically sensing a contact closure.

2. Binary Output (BO): A contact closure on the controller that will cause an action in the system.
3. Binary Value (BV): A network-visible binary point whose value is determined by a controller computation.
4. Analog Input (AI): A continuously varying voltage or amperage signal that is varied by a sensor in relation to a sensed variable. This signal is processed in the controller after an analog-to-digital converter on the controller that converts the analog signal to a digital value.
5. Analog Output (AO): A continuously varying voltage or amperage signal that is generated from the controller after digital-to-analog conversion. The voltage or amperage signal will be used, for instance, to drive a modulating actuator or reset a hardwired setpoint on a packaged device.
6. Analog Value (AV): A network-visible analog point whose value is determined by a controller computation.

1.07 DOCUMENTATION

A. General:

1. Projects that involve BACS shall include a detailed control system design. The design shall be prepared by properly qualified personnel who are knowledgeable in the equipment to be controlled and the applicable control systems. The design professional shall include the following on their design documents:
   a. Floor Plans.
   b. Control System Architecture Diagram.
   c. Control Schematic Drawings.
   d. List of all points, including alarms and trends.
   e. Detailed written sequences of operation.
   f. Design specifications detailing the BACS requirements.
   g. Valve, damper, and laboratory airflow device schedules.

2. In addition, the design professional shall include the requirement for the BACS vendor to submit for approval the following BACS documentation:
   a. Floor Plans.
   b. Control System Architecture Diagram.
   c. Control Schematic Drawings.
   d. List of all points, including alarms and trends.

e. Detailed written sequences of operation.

f. Valve, damper, and laboratory airflow devices schedules.

g. Product Data.

h. Wiring Diagrams.

i. Record Documents.

B. Floor Plans: Floor plans shall include all controllers/control panels, sensors, interface devices, remote pressure transmitters, smoke detectors, control valves, control dampers, flow meters, UPS's, etc., located and identified and coordinated with the HVAC designer.

1. In addition, the BACS vendor shall indicate all network components (repeaters, routers, etc.). Network wiring shall be shown and identified on the floor plan drawings.

C. Control System Architecture Diagram: System architecture one-line diagrams shall indicate schematic location of all controllers, LAN switches and interface devices, gateways, etc.

1. In addition, the BACS vendor shall indicate address and type for each control unit; as well as physical media, protocol, communication speed, and type of each LAN.

D. Control Schematics: Control schematics shall be generated to graphically indicate each functional system, show the schematic configuration of the systems and location of control devices, define the point names and addresses (as applicable), and define the setpoints for control elements. The following information shall be included in the controls schematics at a minimum:

1. BACS legend and abbreviations.
2. BACS one-line Architecture diagram.
3. Point names and types.
4. Normal position of output devices.
5. Setpoints.
6. In addition, the BACS vendor shall include point addresses and device ranges per Cornell Standard Section 230901; and a complete bill of materials listing all devices and manufacturer numbers.

E. Points and Alarms List: A listing of all input/output (I/O) points shall include all physical and virtual points, organized by system/sub-system; names, descriptors, and point types; as well as the following:

1. Hardware Point type (AI, BI, AO, BO).

2. Software Point type (BV, AV).
3. Specific input points that must be able to be put in test mode to facilitate commissioning.
4. Listing of any associated alarms, as well as annunciation location (BACS, EMCS, etc). Control loops shall include an adjustable deviation from setpoint alarm based upon error and time. The alarm parameters shall be the state the point is in to cause a particular alarm, including whether the source system is also enabled. Examples of points in this list are as follows:
   a. Supply air temperature (AI) +/- 4 °F from setpoint for 30 minutes.
   b. Space air temperature (AI) +/- 4 °F from setpoint for 30 minutes, and the baseboard radiation heating system is enabled
5. Listing, for each point, of its trending and scheduling requirements.
6. Listing of whether the point is to be included on the BACS graphics.
7. In addition, the BACS vendor shall include point addresses.

F. Sequences of Operation: Detailed written sequences of operation for each system on a consolidated BACS drawing shall be included along with the control schematic and points/alarm list. All related equipment should be grouped together by areas served. Also, group all sequences into functional sections (i.e., start/stop, static pressure control, economizer, temperature control, humidity control, etc.). The sequences shall include, as a minimum, the following information:

1. Sequences in all modes of operation: on, off, occupied, unoccupied, warm-up, cool-down, night setback, summer, winter, economizer, etc.
2. Detailed steps during mode switches.
3. Details of operation during and after a power outage. Loss of status associated with power outages are not to be indicated as failures with a subsequent alarm or lock out.
4. Specific direction on failure scenarios for loss of proof and all safety device trips.
5. Setpoints, trip points, and ranges.
6. Fire/smoke control system interfaces.
7. Schedule of operation, including Cornell holidays and breaks.
8. Fire alarm panel interlocks and special operating modes.
9. Steam and chilled water load shed scenarios.

G. Specifications: The design professional shall develop control specifications detailing the requirements of the BACS hardware and software. At a minimum, the specifications shall include the following information:

1. The minimum quality on all hardware.
2. Define the control system submittal and as-built documentation required.
3. Specify all wiring and tubing requirements.
4. Clearly delineate limits of responsibility and/or dictate various requirements in the specific context of the system. Examples of this requirement include:
    a. Mounting of terminal controllers.
    b. Furnishing, installing, calibrating, and commissioning valves and dampers, standard and laboratory grade VAV terminals, sash sensors and hood monitors, general field devices, etc.
    c. Balancing/calibrating various BACS sensors (e.g., TAB versus Controls Contractor) and coordination with the TAB section of the specifications.
    d. Lighting control devices, emergency power relays for emergency light fixtures.
5. The quality and quantity of the graphic interfaces to be developed for the project.
6. The level of commissioning activities required.
7. The trending capabilities required of the BACS as well as the project specific requirements for setting up trends and archiving data.
8. Define the warranty period and maintenance requirements.
9. Define the training required. Training requirements must be applicable to the project and coordinated with Cornell.
10. Detail sequence of work for renovations in existing facilities to minimize disruption.
11. Define emergency notification and alarming requirements. Alarm thresholds should be dictated on applicable values and level/means of alarm notification must be specified.
12. Define direct digital control software functional requirements.
13. Detail and coordinate interfaces to third party control systems.

H. Valve Schedule: Control valve schedules shall be included on the BACS drawings, and coordinated with the HVAC design. Valve sizes shall be picked as close as possible to meet the design pressure drop. The schedule shall include the following:

1. Manufacturer and Model Number.

2. System/Zone Served.
3. Valve body size, type (2-way/3-way), CV rating, pipe connection size.
4. Actuator, model number, fail position.
5. Type (2-way/3-way, spring return/non spring return, etc.).
6. Flow and pressure drop at design maximum flow.
7. In addition, the BACS vendor shall include the controlled circuit pressure differential range.

I. Damper Schedule: Damper schedules shall be included on the BACS drawings, and coordinated with the HVAC design. The schedule shall include the following:

1. Manufacturer and Model Number.
2. System/Zone Served.
3. Size and Type (parallel blade/opposed blade, etc.).
4. Actuator and Model Number, Pilot (Y/N), Range and Mounting Position, fail position.
5. Design flow and pressure drop.
6. Leakage Class.

J. Laboratory Airflow Devices Schedule: These devices shall be included under the BACS responsibilities. Schedules shall be included on the BACS drawings. The schedule shall include the following:

1. Manufacturer and Model Number.
2. System/Zone Served.
3. Indicate supply or exhaust service.
4. Size.
5. Full Manufacturer's device range.
6. Minimum and Maximum airflow setpoints.
7. Minimum operational (differential) pressure.
8. Fail position.

K. Product Data: The BACS vendor shall submit manufacturer's technical product data for each control device, panel, controller, and accessory furnished indicating dimensions, capacities, performance and electrical characteristics, and material finishes. Also include installation, start-up, calibration, and maintenance instructions as well as all cable and tubing requirements.

L. Wiring Diagrams: The BACS vendor shall include detailed wiring. Indicate all required electrical wiring. Wiring diagrams shall include both ladder logic type diagrams for motor starter, control, and safety circuits and detailed digital interface panel point termination diagrams with all wire numbers and terminal block numbers identified. Provide panel termination drawings on separate drawings. Ladder diagrams shall appear on the system schematic. Clearly differentiate between portions of wiring that are factory-installed and portions to be field-installed. All wiring of related components that make up a system shall be grouped together in one diagram (e.g., all wiring diagrams for the components and devices on a particular AHU shall be shown on one drawing. The supply fan components and devices should not be shown separate from return fan components and devices, etc.).

M. Record Documents: Record documents shall be prepared reflecting the final installed condition of the BACS. These as-built documents shall be kept up to date throughout the construction and warranty period. Provide the following information for approval prior to project closeout:

1. Maintenance instructions and spare parts list for each type of control device, control unit, and accessory.
2. BACS User's Guides (Operating Manuals) for each controller type.
3. BACS Programming Manuals for each controller type.
4. All information provided during the submittal phase; updated with as-built information. As-built panel drawings shall also be included as part of the O&M manual process. The drawings that are located in each panel shall incorporate all the systems controlled from that particular panel. The drawings shall include the system schematic and detailed panel wiring diagram. Also included (typically noted on the system schematic diagrams) should be the specific locations of any remote devices such as remote static pressure sensors, differential pressure sensors, etc.
5. Each control panel on the project shall include an as-built hard copy of all drawings and documentation associated with that panel and its field devices. This documentation shall be provided in a plastic protective pocket mounted inside the panel door.
6. The final as-built controls drawings (PDF) shall also be accessible via the web based graphics.
7. As-Built Program: Databases with logic, graphics, trends, setpoints, and tuning parameters.

PART 2 PRODUCTS

2.01 GENERAL

A. This section defines requirements for the sensors, controllers, computers, and the components that make up the BACS.

2.02 CONTROLLERS

A. General: The control system shall consist of a network of controllers. It is intended to allow cost-effective application of manufacturers' standard products while maintaining the integrity and reliability of the control functions commensurate with their application.

B. Building and system level controllers (for example, air handling units, hydronic systems, laboratory zones) shall be capable of operating independently, in stand-alone fashion, with no communication to other devices on the network while performing their monitoring and control routines using programs and operating parameters stored in the controllers' memory. All points and functions that make up a functional system (typically that shown on one control schematic) shall be included in one controller to qualify for this stand-alone functionality.

C. Where control sequences depend on global variables such as outside air temperature, the controller shall have the capability of either using the last value or a default value. ***The design professional shall specifically indicate point groupings for stand-alone capability.*** Examples of required functional point groupings are as follows:

1. Air Systems: All points and functions required to control an air handler with all directly associated supply fans, return fans, exhaust fans, airflows, heat recovery, coils and downstream static pressure sensors. This excludes the terminals that may be associated with that air handler.
2. Hydronic Systems: All points and functions associated with the supply side of a hydronic system such as pumps, flow meters, temperature sensors, differential pressure sensors, proof indications, valves etc. This excludes the terminals on that hydronic system.
3. Terminals: All points and functions required to control one terminal system including variable airflow devices, control dampers, valves, temperature and humidity sensors, etc. This does not include the scheduling period or any outside air that may be necessary for control.

D. Values that may be received across the network are as follows:

1. Air Systems: Outside air temperature and humidity, emergency power source indications, terminal based reset parameters, VAV box commands, smoke modes.
2. Hydronic Systems: Outside air temperature and humidity, emergency power source indication, and terminal based reset parameters, control valve commands.

E. Controllers must include sufficient memory for all required operation and all required trending, when trending is buffered in the controller. Where control system operation is hindered by the shortage of memory, contractor shall, at no cost to the Owner, either upgrade the memory or provide multiple controllers. The mix of points for multiple controllers shall not violate the stand-alone requirements.

F. Controllers storing their configuration in volatile memory shall not be used. Software stored in non-volatile memory will not have to be downloaded from the central server after an interruption of power occurs.

G. Controllers used for time-scheduled operations must be equipped with a battery backed internal real-time clock function to provide a time base for implementing time-dependent programs. Provision shall be made for the automatic updating (such as a NTP - Network Time Protocol server or PTP Precise Time Protocol server) of the controllers' clocks via a time master.

H. Resumption of power after an outage shall cause the controllers to automatically restart and establish communications as needed by their applications. Controller shutdown based on a self-diagnosed failure in the power supply, hardware, or software must set each piece of controlled equipment to a predetermined failure mode.

I. Controllers shall be powered from the most reliable source that powers any of the systems it serves. In the situation where a controller will be required to continuously collect data, or where it monitors critical recovery information such as the presence of emergency power, it may be necessary to provide a UPS for the controller as well as any critical sensors. Where panels are provided with a UPS, the panel shall be provided with a means of monitoring the power source status to the controlled equipment to enable special emergency power logic. This can be a dedicated power monitor or a value coming from transfer switch contacts.

2.03 SENSORS

A. General: All sensors and transmitters shall be located in accessible locations that do not require system shutdown for calibration. Locate all remote transmitters in control panels 5-ft above the finished floor.

B. Temperature Sensors/Transmitters

1. Sensor Resolution: When matched with A/D converter of the controller, sensor range shall provide a resolution of no less than 0.4 °F (unless noted otherwise).
2. Sensor Accuracy: +/- 0.4 °F accuracy at calibration point. When used in combination with a humidity and/or CO2 sensor, an accuracy of +/- 0.5 °F is acceptable.
3. Sensing Element: RTD or thermistor. For outside air temperature and liquid immersion sensors, use of an integrated circuit element is also acceptable.
4. Room Temperature Sensor: These shall be an element contained within a ventilated cover, suitable for wall mounting. Provide an insulated base.
   a. Setpoint Adjustment: Provide where indicated. Public spaces shall not have setpoint adjustment. The setpoint adjustment shall be a warmer/cooler indication that shall be scalable via the BACS.
   b. Occupancy Override: Generally, the preferred method of occupancy override is with occupancy and vacancy sensors; which in most cases should eliminate the need for a manual override button. Where spaces do not have occupancy/vacancy sensors, provide a button on the room sensor enclosure where indicated. Public spaces shall not have occupancy overrides. This shall be a momentary contact closure.
   c. Display: Alphanumeric.
5. Single Point Duct Temperature Sensor: These shall consist of a sensing element, junction box for wiring connections, and a gasket to prevent air leakage or vibration noise. The sensor probe shall be stainless steel.
6. Averaging Duct Temperature Sensor: These shall consist of an averaging element, junction box for wiring connections, and gasket to prevent air leakage. Provide sensor lengths and quantities to result in one foot of sensing element for each, two square feet of coil/duct face area.
7. Liquid Immersion Temperature Sensor: These shall include brass or stainless steel thermowell, sensor and connection head for wiring connections.

8. Outside Air Temperature Sensor: These shall consist of a sensor, sun shield, utility box, and watertight gasket to prevent water seepage. Materials shall be non-corroding and be resistant to UV exposure.

C. Humidity Sensors

1. Device shall be suitable for duct, wall, or outdoor mounting, and shall be combined with the temperature sensor in the same device. Sensors shall be two-wire transmitters utilizing bulk polymer resistance change or thin film capacitance change. Units shall produce linear continuous output of 4-20 mA for % RH.
2. Shall be combined into one device with temperature/CO2 sensors, as applicable.
3. Sensors shall have the following minimum performance and application criteria:
   a. Input Range: 10 to 100% RH.
   b. Operating Range: As required by the application.
   c. Long Term Stability: Less than 1% drift per year.
4. Accuracy:
   a. General Duty, monitoring: +/- 3% RH between 20-90% RH at 77 °F, including hysteresis, linearity, and repeatability.
   b. High Accuracy control, enthalpy calculation, dewpoint calculation, humidification and dehumidification control: +/- 2% RH between 20-90% RH at 77 °F, including hysteresis, linearity, and repeatability.

D. CO_2 Sensors

1. Application: Demand controlled ventilation of high density occupancy spaces, such as auditoriums, classrooms, lecture rooms, and conference rooms.
2. Shall be combined into one device with temperature/humidity sensors, as applicable.

E. Dewpoint Sensors

1. Devices shall typically used for compressed air dewpoint monitoring service.
2. Acceptable Manufacturers:
   a. Vaisala, Model DPT146 for air compressor applications

F. Air Differential Pressure Sensor / Transmitters

1. Applications: Duct static pressure, filter DP, etc.
2. Provide the smallest range feasible for the application, but no more than two times the working differential pressure of the system to allow the highest possible resolution. Provide zero and span adjustments.
3. Accuracy: ± 1% of full scale.
4. Acceptable Manufacturers:
   a. Dwyer
   b. Mamac
   c. Setra
   d. Veris Industries

G. Liquid Differential Pressure Sensors

1. Pressure transmitters shall gauge pressure in the form of a linear 4 to 20 mA or 0-10 VDC signal.
2. Sensor shall be provided with a three-valve manifold for venting, draining and calibration; and shall have pressure/temperature test ports in lieu of pressure gauges.
3. Wetted parts shall be stainless steel with a silicone fluid-filled diaphragm.
4. Provide external span and zero adjustments.
5. Span shall be no greater than 2 times the working differential pressure of the system to allow the highest possible resolution.
6. Pressure rating: 150 psig, static.
7. Accuracy: 1% accuracy over the entire span.
8. Repeatability: Plus or minus 0.5% at maximum span.
9. Transmitters shall have a three-valve manifold for venting, draining, and calibration.
10. Acceptable Manufacturers:
    a. Mamac
    b. Setra
    c. Veris Industries.
11. Particular attention needs to be paid to proper installation of these devices. See Cornell Standard Detail 3.4.3 – Differential Pressure Transmitter Detail.

H. Air Differential and Static Pressure Switches:

1. Span shall be no greater than 2 times the measured value to allow the highest possible resolution. The switches shall be installed in accordance

with the manufacturer's installation instructions. All switches shall be mounted in accessible and, to the extent possible, vibration-free locations (i.e., not on duct work).

I. Liquid Differential Pressure Switches:

1. Barksdale Model EPD1HAA40 or Penn P74 differential pressure switches shall be provided when pressure sensing is required to determine status. All switches shall be mounted in accessible and, to the extent possible, vibration-free locations.
2. Do not use differential pressure switches for run status on pumps. Current switches shall be used on constant volume pumps and drive contacts shall be used for pumps with VFDs.

J. Water Flow Sensors/Transmitters

1. These devices are to be used for sub-metering applications. Full building utility meters needed for billing purposes will be furnished by Cornell Utilities for Contractor installation.
2. Flow sensors shall be carefully placed to ensure flow profiles that are required for accurate flow sensing. Designs shall specifically indicate the location of the sensors and indicate the length of unobstructed duct or pipe upstream and downstream from the sensor.
3. Water flow sensors shall meet the requirements necessary for use for test and balance duty as defined in the BACS specifications.
4. Magnetic flow meters shall be used. Turbine and annubar meters are not allowed.
5. Acceptable Manufacturers:
   a. Siemens
   b. Yokogawa

K. Airflow Sensors/Transmitters

1. Flow sensors shall be carefully placed to ensure flow profiles that are required for accurate flow sensing. Designs shall specifically indicate the location of the sensors and indicate the length of unobstructed duct or pipe upstream and downstream from the sensor.
2. A pitot-tube averaging grid of a material compatible with the environment is to be used. The use of fan inlet grids are preferable where possible to measure fan flow. Fan inlet grids shall be provided by the fan vendor and shall not block or affect fan efficiency.
3. The use of combination control damper/flow measurement devices is not acceptable.

4. Span shall be no greater than 2 times the measured value to allow the highest possible resolution.
5. Accuracy: +/- 0.25%.
6. Stability: +/- 0.5% of full scale per year or less.
7. The device shall have auto-zero capability by venting ports to atmosphere.
8. Acceptable Manufacturers:
   a. Air Monitor
   b. Paragon

L. Current Sensors

1. Application: Status indication on constant speed motors.
2. Sensor shall indicate loss of status when current falls below an adjustable trip point.
3. CS shall include LED indication of status.
4. Acceptable Manufacturer: Veris Industries.

M. Occupancy/Vacancy Sensors

1. HVAC and lighting control systems using occupancy/vacancy sensors shall be integrated. See Cornell Design and Construction Standard 260923.

N. Condensate Sensors

1. Application: Moisture sensing on chilled water supply systems to terminal chilled beam and radiant cooling devices.
2. Acceptable Manufacturers and Model Numbers:
   a. Siemens QXA 2000
   b. Sauter EGH 102
   c. Honeywell H7018A1003

2.04 CONTROL VALVES

A. General

1. Valves shall be suitable for the rated pressure and temperature service. Close off pressures must be determined in concert with the actuators and valves shall be provided to close off against extreme anticipated conditions. Valves shall be selected such that they are not oversized.
2. Modulating valves shall be carefully selected to control in a smooth and stable fashion across the range of anticipated conditions. Split ranging of heating and cooling valves controlled by the BACS is not acceptable. A

separate output from the BACS shall be provided for all control valves. Electric input shall be 4-20 mA or 0-10 VDC.

B. Pressure independent control valves shall not be used.

C. Actuators shall be electric, one motor only. Stacking of actuators is unacceptable.

1. Acceptable Manufacturer:
   a. Belimo

D. Steam

1. Steam control valves shall have a flanged or screw body with a rating of 400°F or higher, as appropriate. Trim shall be rated for 400°F.
2. High performance segmented V-ball control valves shall be used for all steam control applications. Since Cornell does not require 1/3-2/3 sizing, these valves are extremely cost-effective; the energy savings associated with the reduced pass-through leakage often pays for the higher cost premium. In addition, these valves require less packing maintenance and use much less vertical space than comparable valves. Steam valves shall have the following characteristics:
   a. Leakage Class: ANSI Class IV, minimum
   b. Flow Characteristic: Equal Percentage
   c. Rangeability: 300:1 turndown
3. On steam control valves with a normal differential pressure of 15 PSIG or greater, stainless steel noise reducing trim shall be used.
4. Acceptable Manufacturers:
   a. Fisher
   b. Neles
   c. Valve Solutions, Inc.
5. Fail positions shall generally be as follows:
   a. Heat Exchangers/Converters: Normally closed spring return (to protect for high temperature).
   b. Clean Steam: Normally closed spring return.
   c. Humidifiers: Normally closed spring return.

E. Chilled Water Recirculating Loop Valve (two-way)

1. Type: Rotary-segmented ball ported industrial control valve.
2. Body: Flanged carbon steel.
3. Seat: Composition or stainless/Teflon.

4. Leakage Class: ANSI Class IV, minimum.
5. Trim: 316 Stainless.
6. Flow Characteristic: Equal percentage or modified equal.
7. Fail Position: Fail Last.
8. Typically CV shall be selected to give a 2 PSIG drop @ maximum building flow with the valve at the 90% open CV. Verify the necessary pressure drop with Cornell. For buildings located at extremities, check with Cornell since requirements may not be typical.
9. Valve shall seat against 40 PSI differential pressure (typical values; check with Cornell for location-specific values).
10. Acceptable Manufacturers:
    a. Fisher
    b. Neles
    c. Valve Solutions, Inc.

F. Coil Valves, Water

1. Modulating water valves will generally be ball valves with an equal percentage characteristic. Modulating water valves shall typically be sized for 50-100% of the typical controlled circuit pressure drop at 70% wide open CV. The minimum design CV shall be no less than 1.9.
2. Water and glycol control valves shall be rated to remain closed (zero leakage) against 120% of the full shutoff head of the pumps, when the control signal is set to "fully closed".
3. Type: Two-way, V-port ball valve with characterizing disk, 1/4 turn.
4. Packing: EPDM O-rings, lubricated.
5. Ball & Stem: Stainless steel.
6. Seat: Fiberglass reinforced Teflon.
7. Flow Characteristic: Equal percentage.
8. Fail positions shall generally be as follows, contact Cornell for special circumstances requiring deviation from these requirements:
    a. Terminal hot water radiation: Fail Last
    b. Duct mounted re-heat coils serving animal rooms: Normally Closed, Spring Return
    c. Duct mounted re-heat coils serving laboratories: Fail Last
    d. Duct mounted re-heat coils serving offices: Fail Last
    e. Fan Coil Unit cooling coils: Normally Closed, Spring Return

f. Pre-heat coils in Air Handling Units: Normally Open, Spring Return

g. Chilled water coils in Air Handling Units: Normally Closed, Spring Return

h. Chilled Beam terminal cooling: Normally Closed, Spring Return

9. Acceptable Manufacturers:

a. Belimo
b. Valve Solutions, Inc.

2.05 CONTROL DAMPERS

A. Dampers shall be applicable for the rated pressure and velocity service. Damper structural rating shall exceed extreme anticipated conditions like fan deadhead.

B. Modulating dampers shall be carefully selected to control in a smooth and stable fashion across the range of anticipated conditions. Provide separate minimum outside air dampers from economizer dampers to ensure proper control performance.

C. Except where size dictates a single blade, dampers shall always be opposed blade.

D. When a large section of damper is to be connected to a single jackshaft, size limitations shall be followed. This will prevent excessive damper area or, more importantly, length from being connected to a single jackshaft. Typically, the manufacturer’s recommendation shall be sufficient for specifying a limit to the size of a damper bank that may have field fabricated jackshaft connections.

E. Whenever possible, dampers shall have external crankshafts to allow the connection of the damper actuator outside of the air stream. This will allow for easier access to the actuators for maintenance.

F. Outside air control dampers shall be low leakage dampers with damper seals.

G. Output to modulating control dampers shall be analog.

H. Actuators:

1. Size actuators and linkages to operate their appropriate dampers or valves with sufficient reserve torque or force to provide smooth modulating action or two-position action and adequate close off rating as required.

2. Actuators shall be electronic, one motor only. Stacking of actuators is unacceptable. Design for a minimum of 60,000 full cycles at full torque and listed to UL 873. Provide stroke indicator. Actuators shall have a positive positioning circuit and selectable inputs. Full stroke shall be within 90 seconds. Where fail positions are required, provide spring return on the actuator with adequate close off force.

3. Acceptable Manufacturer:

a. Belimo

2.06 LABORATORY AIRFLOW CONTROL DEVICES

A. Application: Laboratories and vivarium with fume hoods, cage racks and tracking supply / general exhaust air devices.

B. Air Flow for Fume Hood Laboratory and Vivarium Applications

1. Venturi Type Air Valves and Vortex Shedding Type Air Valves with fast acting electronic actuators shall be used on fume hoods and their associated tracking supply and general exhaust zone dampers.
2. Air Valves shall have pressure independent operation over a minimum of 0.3-in differential pressure and shall respond and maintain a specific airflow within three seconds of a change in duct static pressure.
3. Valve materials shall be suitable for the conveyed atmosphere; either having a 304 stainless steel body or an interior corrosion resistant coating.
4. Actuators shall move full stroke in less than one second.
5. Output to modulating actuators shall be analog.
6. The valves shall be calibrated / characterized for full manufacturer range. Actual airflows shall be set by software; allowing easy field modifications.
7. Venturi type air valves shall be provided with a fan static reset kit that allows static pressure reset strategies to be employed.
8. Acceptable manufacturers and model numbers:
   a. Venturi Type: Phoenix Controls Corporation, Low Pressure Accel
   b. Vortex Shedding Type: Accutrol, AVC6000 Series

C. Air Flow for Non-Fume Hood Laboratory Applications

1. The use of Venturi Type, Vortex Shedding or Conventional Type VAV Boxes are all acceptable.

D. Proximity sensors shall not be used on fume hoods.

E. Each airflow control device shall be specified with the option for shut-off.

F. Fume Hood Monitors/Controllers: All fume hoods shall be equipped with a fume hood monitor/controller. The monitor/controller shall include indication of safe airflow, re-settable audible and visual alarms when face velocity is out of range, and an emergency ventilation switch or button. Monitor shall also be capable of receiving inputs from the BACS to permit change of the hood face velocity setpoints for occupied/unoccupied/vacancy control strategy.

G. Sash Position Indicators: All fume hoods shall be fitted with a sash position indicator.

H. Fail Positions shall be as follows:

1. Fume Hood Exhaust: Normally Open.
2. Supply Air: Normally Open.
3. General Exhaust: Normally Closed.

2.07 COMPRESSED AIR SYSTEMS

A. Compressed air systems shall not be used on new installations. For information on replacement control air compressors see Cornell Standard Section 221500 – Compressed Air:

PART 3 BACS CONFIGURATION AND INSTALLATION

3.01 GENERAL

A. This section defines requirements for configuration and installation of the BACS.

B. Devices (i.e., sensors, meters, instruments, etc.) that are resettable must be installed in a readily accessible location (e.g., the device must be accessible at floor level without the use of a ladder). No device shall require shutting down a building system for calibration.

C. Devices that are installed in an exposed location (i.e., not mounted within a cabinet) must be suitable for such installations (e.g., do not install a device that is intended to be installed in a cabinet in an exposed location).

3.02 INSTRUMENTATION TUBING

A. General:

1. All instrumentation tubing in mechanical equipment rooms shall be hard-drawn type L copper.
2. It is extremely important that pneumatic tubing be properly terminated. Tubing shall be completely removed back to the main. Copper tubing shall be terminated with a soldered end cap; poly tubing shall be terminated using brass plugs. Bending over copper tubing, pinching/brazing, and the use of sheetmetal screws to make terminations are not acceptable.

3.03 CONTROL WIRING

A. General

1. Unless specifically required otherwise by the BACS equipment manufacturer, all I/O wiring shall be twisted shielded cable. For

communications, the BACS equipment manufacturer's installation guidelines and recommendations shall apply.

2. All control wiring in mechanical equipment rooms or other spaces in which it is readily accessible shall be installed in electrical metal tubing (EMT) with compression fittings.
3. All control wiring run in interstitial spaces shall either be run in EMT or a cable tray or raceway.
4. All control wiring installed outdoors or any area subject to moisture shall be installed per code.
5. All control wiring installed in vertical chases shall be installed in EMT.
6. All control wiring above non-accessible ceilings shall be installed in EMT.
7. All control wiring installed above accessible ceiling spaces which are not laboratories or AHU's shall be plenum type, not installed in conduit, but neatly run with generous use of rings or ties.
8. Wire shall be un-spliced from the controller to the sensor or device.
9. Control wiring shall not be routed in the same raceway as power wiring.
10. For sensors with twisted shielded pair cable, the shield shall be grounded at the panel and taped back at the sensor.
11. Control wiring shall have green jacketing, and be color coded and labeled at all points of termination.
12. Remove and properly dispose of all abandoned control wiring, conduit, tubing, boxes, enclosures, components, and other controls-related work.
13. All conduit containing control wiring shall be green.

3.04 BACS CONFIGURATION

A. Vendors providing controls for Cornell University shall maintain site-wide configuration documentation. Whenever the BACS is extended, the documentation required in this section shall be provided/updated per configuration management requirements to reflect the entire installation on the campus. Device naming and addressing must conform to Cornell's specific conventions as detailed in Section 230901. No device will be connected to a Cornell network until these conventions have been understood and met.

B. Acceptable Manufacturers

1. Automated Logic Corporation
2. Alerton

3.05 CONTROL PANELS

A. Control panels and enclosures housing the controllers shall be coordinated to the extent possible, to share vertical and horizontal wire-ways to facilitate and minimize the cost of home-runs to terminal equipment.

B. Cornell must have quick, direct access to all control panels to maintain building integrity similar to that provided for fire emergencies without going through user spaces. Panels should be located outside of user areas where practical. If panels must be located in user areas, they shall be in areas with easy access. Protection and separation for user activities will be provided.

C. Fabrication

1. All BACS mechanical room control panels shall be installed in metal enclosures containing the controller, I/O modules, power supplies, termination strips, battery (if not integral to the controller or I/O module) and a spare AC outlet. The Contractor shall size the panel such that no more than 80% of the surface of the enclosure back plate is used.
2. Locate control panels in equipment rooms, where practicable, and in locations maintaining ambient conditions between 50 and 90°F and 10 to 85% relative humidity. Control panels located in areas where conditions are outside of these ranges shall have enclosures outfitted with heating or cooling devices to provide the proper environmental conditions.
3. Network level boards shall be installed inside a protective enclosure.
4. All terminal controllers shall be installed in a protective sheetmetal enclosure. Coordinate with the terminal unit vendor.
5. All penetrations of the BACS or outboard gear panels in mechanical rooms shall be from the bottom of the enclosure with wireway and conduit stubs from the wireway up to the panel.
6. Enclosures shall be mounted on walls or free-standing supports.
7. Enclosures shall be Hoffman style with removable back plates and keyed, hinged covers.
8. Plastic wire way (e.g., Panduit) shall be used to organize all wiring in the panel.
9. Sufficient wire way shall be provided in the panel such that it is filled no more than 80% capacity.
10. Panel layout and construction shall be neat and professional.
11. All controllers, wiring, and components in the panels shall be labeled. All labeling shall match the reference numbers on the cabinet drawings that shall be provided for each panel.

12. All transformers and power supplies shall be mounted outside of the central panel enclosure.
13. Enclosures located in mechanical rooms shall be NEMA 4.
14. Enclosures located in occupied spaces, labs and other relatively dust free and dry spaces may be NEMA 1.

D. Low Voltage Power Supplies

1. The Contractor shall provide a regulated, protected low voltage power supply as required with the ability to produce at least 33% more current than required by the transmitters and controls being installed. Output regulation shall be less than 0.5mV. There shall be no overshoot on turn on or off. Operating temperature shall be -20 to +70ºC.
2. The BACS Contractor shall certify, in writing, at the time of shop drawing submittal that the DDC equipment provided will not cause, as a result of its operation, either directly or indirectly, electrical interference to be induced into the building's electrical power systems.
3. Class II transformers shall be used.

E. Line Voltage Power Source:

1. Controllers shall be powered from emergency power sources whenever the controlled equipment is connected.
2. Careful consideration must be given to the propagation of information across controllers as they wake up from a power interruption. This may require certain critical controllers to be powered from uninterruptible power to ensure rapid propagation of the emergency status.
3. An un-interruptible power source (UPS) shall be provided on Ethernet network gateways (headends) and switches.
4. Line voltage power sources to controls shall be labelled with its source panel and circuit number.

3.06 CONTROLLERS

A. The controllers provided shall meet the performance requirements for throughput, response time, point capacity, trend log capacity, etc., as stated in this section and Section 230901. The controllers shall also be configured and programmed to carry out the sequences of operation contained in the project documents. While Standard 230901 contains several constraints on the controller system architecture, it is recognized that a variety of configurations may be equally acceptable. For example, it may be possible to meet the project requirements with a single large controller or several smaller ones. Therefore, this guideline does not generally prescribe controllers' system architecture or controllers' detailed characteristics, such as processor speed, amount of memory, amount of I/O, power supply details, etc.

B. Since these guidelines with respect to controllers are performance oriented, rather than prescriptive, they will generally refer simply to "controllers", meaning computers capable of direct digital control. In those cases where distinguishing between controllers with differing capabilities is needed, the following nomenclature will be used (and is also defined in Section 230901):

1. Building-level controller: These are controllers that are connected to the campus backbone network and communicate over Ethernet using BACnet/IP. They will typically be used to control and monitor one or more large systems or be applied to other building-wide functions. They shall, at a minimum, meet the requirements of a BACnet Building Controller (B-BC).
2. System-level controller. These controllers may, or may not, be directly connected to the campus backbone network. They will typically be dedicated to the control of a single large piece of equipment such as an air handler or chiller and a lab environment with fume hoods. They shall, at a minimum, meet the requirements of a BACnet Advanced Application Controller (B-AAC).
3. Field-level controller. These controllers will be on a lower performance BACnet LAN such as MS/TP or ARCNET. They will typically be used for control of "unitary" devices such as VAV boxes, fan coil units, etc. They shall, at a minimum, meet the requirements of a BACnet Application Specific Controller (B-ASC).

C. Controllers shall be provided with a real-time operating system resident in ROM. It shall support all specified functions. It shall provide a command prioritization scheme to allow functional override of control functions. At a minimum, the following shall be provided:

1. Real-time operating system software.
2. Real-time clock/calendar and network time synchronization (with the exception of field-level controllers).
3. Controller diagnostic software.
4. DDC software.
5. Alarm processing and buffering software.
6. Energy management software.
7. Data trending, reporting, and buffering software.

8. I/O (physical and virtual) database. Inputs and outputs shall have the capability to be overridden for emergency modes and testing. If the design documentation does not specifically indicate for which points this is required, control vendor shall request in writing a list of such points. If this has not been requested, the vendor shall reprogram or reconfigure the systems as required during testing.

D. Programming: The programming shall be logically segmented, documented, and titled, and expand on the specified sequence of operations. Each segment shall contain control logic for a specific controlled component of a system. This is to improve the ability of the end user to understand and interpret the logic easily.

E. Trending: To support commissioning and building data mining, the BACS shall be capable of trending and archiving all points on building-level and system-level controllers at a minimum of 15 minute intervals. The BACS shall also have the capability of trending at least five points on each field-level controller at an interval of 15 minutes. The trend data shall be uploaded to a central database as needed to prevent buffer overflow in the controller. Controller memory capability, network architecture, and communications bandwidth shall be designed to account for this trending. The BACS vendor shall provide control trends during start up and prior to functional performance testing of the systems. Reports shall be scheduled to output the data to a common format such as comma separated text, Microsoft formats such as Excel and Access, and portable database format. Trended data will be archived in an Owner-accessible SQL database for a minimum period of 2-years.

F. Trend Graphs: Web-based software shall provide for displaying graphic plots of the trended values. The software shall support multiple scales, points and point types simultaneously. The BACS vendor shall configure these graphs in a logical manner for each system. Consult with the commissioning team members and project manager for required configuration. Provide a trend for every analog control loop that includes the setpoint, process variable, and control output.

G. Real-time Plotting: Software shall be provided for real time plotting/graphing of multiple values in user-defined time intervals. These graphs will typically be used in commissioning to observe loop responses and system reactions. The BACS vendor shall configure these graphs in a logical manner for each system. Consult with the commissioning team members and project manager for required configuration.

H. Web-based Graphics: The following screens shall be provided:

1. Floor Plan Screens

   a. Provide floor plan screens for each floor and/or section of the building. Indicate the location of all equipment that is not located on the equipment room screens. Indicate the location of temperature sensors and VAV boxes associated with each temperature-controlled zone (i.e., VAV terminals, fan-coils, single-zone AHU's, etc.) on the floor plan screens. Each floor plan screen shall show thermographic space temperatures and lighting on/off status.

b. Display the space temperature point adjacent to each temperature sensor symbol. Indicate room numbers as provided by Cornell University. Provide a graphic link from each zone and/or equipment symbol shown on the graphic floor plan screens to each corresponding equipment schematic graphic screen.

c. Provide floor plan screens for each mechanical equipment room and, if mechanical equipment is situated there, the roof. Indicate the location of each item of mechanical equipment. Provide a link from each equipment symbol shown on the plan view screen to each corresponding mechanical system schematic graphic.

d. If multiple floor plans are necessary to show all areas, provide a graphic building key plan. Use elevation views and/or plan views as necessary to graphically indicate the location of all of the larger scale floor plans. Link the graphic building key plan to larger scale partial floor plans. Provide links from each larger scale floor plan graphic to the building key plan and to each of the other graphic floor plan screens.

e. Provide a graphic site plan with links to and from each building graphic.

f. Locate central system static and differential pressure sensors, linkable from the floor plan drawings.

2. System Schematic Screens

a. Provide graphics for each air handling system. Indicate OA temperature and relative humidity, and mode of operation as applicable (i.e., occupied, unoccupied, warm-up, cool-down, etc.). Link screens for air handlers to the heating system and cooling system graphics Link screens for supply and exhaust systems, if they are not available in a single graphic.

b. Each I/O point in the project shall appear in at least one graphic. System graphics shall include flow diagrams with status, setpoints, current analog input and output values, operator commands, etc., as applicable. General layout of the system shall be schematically correct. I/O devices shall be shown in their schematically correct locations. Include appropriate engineering units for each displayed point value. Verbose names (English language descriptors) shall be included for each point on all graphics; this may be accomplished by the use of a pop-up window accessed by selecting the displayed point with the cursor. Indicate all adjustable setpoints on the applicable system schematic graphic or, if space does not allow, on a supplemental linked setpoint screen. All outputs shall be represented in terms of percent open and include a pop-up link or pull down to the control logic.

c. Provide a system schematic graphic for each HVAC subsystem controlled.

d. Provide a graphic for each hydronic system.

e. Link screens for heating and cooling system graphics to utility history reports showing current and monthly energy usage, demands, peak values, etc.

f. Link screens to all schedules and setpoints

3. Zone Schematic Screens, HVAC

a. Provide a graphic for each zone, including all terminal units such as fan coil units, chilled beams and VAVs shown on the graphic even if provided with different terminal level controllers.

b. In addition to points associated with the unit, indicate mode of operation as applicable (i.e., normal occupied, unoccupied, warm-up, maximum heating, maximum cooling, etc.). Provide links between the applicable floor plan screen and this screen.

c. Provide links to the graphics representing the parent systems.

4. Zone Schematic Screens, Lighting Controls: See Section 260923 – Lighting Controls

I. Alarm Programming: Alarms shall be intelligent based upon the algorithms in this section.

1. Alarm programming related to DDC controlled equipment should reside at the controller level along with the functional programming for equipment control.

a. Intrinsic alarming associated with AI, AV, BI or BV objects (or any of the other BACnet objects that support intrinsic alarming) shall only be used where the alarm is valid regardless of the state of the associated equipment or where there is a ready means for automatically suppressing alarm generation when the associated equipment is operationally secured.

b. Alarm points shall be separate BACnet objects actuated by associated alarm programming.

c. Alarm objects shall have descriptive BACnet object names. BACnet alarm object names shall end in “Alarm”. For detailed information on proper point naming conventions, see Section 230901 Building Automation and Control System Communications and Interoperability.

d. If it is necessary for the alarm to have latching functionality, the user shall be provided easy unlatching capability from within the DDC system if appropriate, taking into account equipment safety concerns. This is in addition to any local alarm reset.

e. Alarms designated for monitoring by EMCS shall be set up in the DDC system to report to the EMCS alarm server.

f. Generally, only central system alarms should annunciate at EMCS. Zone and or equipment alarms shall be considered on a case by case basis.

2. Analog Deviation Alarms: Analog deviation alarms shall be based upon the comparison between the controlled variable and the controlled variable setpoint (whether calculated or fixed).

a. When controlled variable deviates from setpoint above or below user adjustable high or low alarm thresholds, the alarm shall be activated.

b. High and low alarm threshold values shall have associated adjustable deadbands (hysteresis values) for alarm clearing conditions as the controlled variable falls below the high alarm threshold or rises above the low alarm threshold.

c. Alarm programming shall include user adjustable alarm delays for active equipment operation.

d. Alarm programming shall include startup delays to prevent nuisance alarms during equipment startup.

e. Analog deviation alarms shall be disabled if the associated equipment is operationally secured.

3. Analog High Limit Alarms: Analog high limit alarms shall be based upon the comparison between the controlled variable and a user adjustable high limit alarm value.

a. When controlled variable rises above the user adjustable high limit, the alarm shall be activated.

b. High alarm limit value shall have associated adjustable deadband (hysteresis value) for alarm clearing condition as the controlled variable falls below the high alarm limit.

c. Alarm programming shall include user adjustable alarm delays.

d. High limit alarms shall be disabled if the associated equipment is operationally secured, unless needed due to equipment safety considerations.

4. Analog Low Limit Alarms: Analog low limit alarms shall be based upon the comparison between the controlled variable and a user adjustable low limit alarm value.

a. When controlled variable falls below the user adjustable low limit, the alarm shall be activated.

b. Low alarm limit value shall have associated adjustable deadband (hysteresis value) for alarm clearing condition as the controlled variable rises above the low alarm limit.

c. Alarm programming shall include user adjustable alarm delays.

d. Low limit alarms shall be disabled if the associated equipment is operationally secured, unless needed due to equipment safety considerations.

5. Binary Run Status Alarms: Status alarms shall be based upon the comparison between run status and equipment command where applicable.

a. Alarm Status programming shall include user adjustable alarm delays.

6. Binary Alarming: Alarms shall be triggered upon associated BI changing state to the non-normal or alarm state.

a. Alarm Status programming shall include user adjustable alarm delays.

b. Binary alarms shall be disabled if the associated equipment is operationally secured, unless needed due to equipment safety considerations.

3.07 OPERATOR INTERFACES

A. All interface to the BACS shall be web-based. Operator's Workstations should not be provided.

B. During construction, the DDC shall be hosted on a construction server and transferred to the Owner's central server at the earliest convenience.

C. The project shall be responsible to upgrading the campus central server location.

3.08 COMMISSIONING

A. Commissioning (Cx) is the process of ensuring that all building systems are installed and perform interactively according to the design intent; that systems meet the Owner's operational needs; that the installation is adequately documented; and that the Operators are adequately trained. It serves as a tool to minimize post-occupancy operational problems. It establishes testing and communication protocols in an effort to advance the building systems from installation to full dynamic operation and optimization.

B. All new BACS installations and expansions of existing shall be fully commissioned. All acceptance testing, documentation, and training shall be required.

C. The BACS contractor's responsibilities for commissioning and check-out include the following:

1. Ensure that start-up, testing, adjusting, and balancing of systems and equipment has been completed prior to field commissioning.
2. Provide all logic, graphics, and trends for review prior to the start of field commissioning activities.
3. Provide a complete calibration and operational check for each individual point and function contained within the BACS.
4. Conduct the checkout with the use of point/function log sheets. The Owner shall approve the log sheet format.
5. Submit log sheets to the Owner prior to the commencement of any final acceptance testing.
6. Certify, in writing, to the Owner prior to the commencement of final acceptance testing that all components of the BACS system are functioning as per the requirements of the contract documents.
7. Provide to the Owner as-built drawings and documentation at least four (4) weeks prior to the commencement of any final BACS acceptance testing. Ensure all trends and graphics are complete and approved by Cornell.
8. The BACS contractor shall issue a report upon project completion stating that the system is complete, has been adjusted; and has had all hardware, software functions, trends and graphics verified, that all analog control loops are tuned, and is operating in accordance with the specifications. Any deviations from specified settings or operations necessitated during system adjustment shall be specifically noted.
9. The BACS contractor shall check out the installation with a representative from Cornell's Energy Conservation Control Team. The checkout shall consist of verifying the ability of the BACS to communicate with the central EMCS system, verifying the calibration of each sensor and/or transmitter, and verifying the operation of each control point.
10. All software processes shall be thoroughly demonstrated to Cornell. Alarm conditions shall be simulated for conformance. Analog control points shall be exercised through their entire range. All control interlocks and sequences shall be completely verified. The checkout shall be a thorough and exhaustive review of the installation to assure proper operation of the total system.

3.09 TRAINING

A. Upon completion of the work and acceptance by the Owner, factory representatives of the control manufacturer shall provide instruction to the Owner's operating personnel who have responsibility for the mechanical systems and controls installed by the contractor. The amount of training that shall be provided shall match the size of the project (e.g., no less than two hours for small projects and up to 80 hours for larger projects).

B. The contractor shall make available to the Owner regular, scheduled training courses for ongoing training of the Owner's operating personnel. Programs shall include hardware and software oriented courses as well as energy conservation and management courses.

C. In addition to the normal training listed above, on projects with a controls cost exceeding $500K, vendors will be required to provide one week of training at the BACS manufacturer's training facility for four people.

3.10 WARRANTY

A. Except as otherwise specified, the Contractor shall warrant and guarantee all work against defects in materials, equipment, and workmanship for a period of one (1) year from the date of acceptance of the work as evidenced by a resolution to that effect by the Owner, and for that period of time noted in special or extended warranties.

B. The period of one (1) year shall be extended with respect to portions of the work first performed after substantial completion by the period of time between substantial completion and the actual performance of the work.

C. The Contractor shall provide all recommended preventative maintenance of the materials, equipment, and workmanship as necessary and as described in the operating and maintenance manuals during the warranty period. In addition, the Contractor shall provide two (2) semi-annual service visits (i.e., one visit during the peak cooling season and one visit during the peak heating season) to test and evaluate the performance of the equipment. The Contractor shall provide a written report of the test and evaluation results. The service visits shall include, but not be limited to:

1. Checking and, if necessary, correcting the calibration of the sensors, transducers, and transmitters for airflow, liquid flow, pressure, temperature, and humidity.
2. Checking and, if necessary, correcting the operation of the dampers and damper actuators.

3. Checking and, if necessary, correcting the operation (i.e., monitoring and command) of the system points.

D. Software and Hardware Updates: At the end of the first six months after acceptance, and during the subsequent six month period, the BACS contractor shall update the equipment and any controllers, servers, workstations, and HMI web servers with the latest modification and improvements in software, firmware, and hardware that the manufacturer may have incorporated in the furnished equipment.

PART 4: BACS FOR SUB-SYSTEMS AND MONITORING

4.01 GENERAL

A. This section of the guideline defines general physical Input/Output (I/O) requirements, system architecture, sequences, and by inference some degree of system requirements related to how the BACS is applied to the building areas and sub-systems.

B. A comprehensive package of sub-system control drawings, including control schematics, points and alarms list, and sequences of operation have been developed for the typical terminal types used on the Cornell campus. These drawings exist to aid the consultant in designing control systems to meet Cornell preferences; it is expected that the Consultant will customize these details for project specifics. Where a drawing exists, a reference will be included. Consult Cornell for deviation from these standards, and zone control systems not covered by these drawings

C. The University has instituted procedures to shed heat and cooling system loads during emergencies. The intent is to shed less critical HVAC systems from the central distribution systems in order to allow critical spaces to remain under control. The consultant shall conduct a separate load shed meeting early in the design process for the primary purpose of making load shed decisions. Criticality of spaces will be determined on a case-by-case basis. Please refer to Standard Detail 3.5.3 for typical load shed matrices to use as a starting point in developing the project specific matrices.

D. In the event of a power outage, upon restoration of normal power, the building systems shall be restarted in priority of criticality with a slight timing delay between starts to minimize the power inrush.

E. Standard Details
3.5.1 – BACS Legend and Abbreviations
3.5.2 – BACS Architectural Diagram

3.5.3 – BACS Steam and Chilled Water Load Shed Matrices

4.02 BUILDING LEVEL

A. Outside Environment

1. On major/critical systems, one outside air temperature sensor shall be provided for each system; and one sensor shall be provided per mechanical room, or building-level controller. Generally, these shall be located on a north wall of the building and installed with stand-offs.
2. On 100% outside air systems, locate the sensor in the outside air plenum.
3. Points required for monitoring the outside environment include the dry bulb temperature and relative humidity, with calculated values of dewpoint temperature and enthalpy.
4. Standard Detail:
   3.6.1 – Outside Environment Monitoring Points

B. Building Chilled Water Connections

1. Facility cooling needs will typically be supplied from the campus chilled water distribution system. The control of the chilled water connection for new facilities must be carefully coordinated with the design professional and the project manager. The connection and controls shall be designed to maximize the facility's temperature differential and to maximize reliability. The design will include a recirculating loop bridge (with a check valve) and a building control valve.
2. Standard Detail:
   3.6.2 – Chilled Water Service Monitoring Points

C. Building Connection to Central Heating System

1. Facility heating needs may be supplied by central steam or central hot water (refer to Standards Section 230520 – Heat Generation). Prior to beginning control design work, confirm current and planned future heating supply and design basis for the work. Controls may be required to accommodate both immediate source and future source.
2. For controls design based on connection to the campus steam, design the mechanical system design to allow proper condensate drainage. Condensate returned from a modulating steam heat transfer device shall not be lifted. Control loops should be tuned at light load and checked under heavy load. For steam connections see Standard Detail 3.6.3 – Steam and Condensate Monitoring Points

D. Electrical Power Systems

1. Monitoring shall include status monitoring of the emergency generator and transfer switch position; as well as monitoring of the building electrical consumption.
2. Standard Detail:
   3.6.4 – Electric Service Monitoring Points

E. Compressed Air Systems

1. Compressed air systems shall include a pressure sensor to monitor supplied air pressure. Alarms shall be established for low-pressure conditions.
2. The dewpoint temperature of the compressed air system shall be monitored as well as the status of the air dryer.
3. Standard Detail:
   3.6.5 – Compressed Air Service Monitoring Points

F. Sanitary Service

1. Pumped drainage and waste systems shall include level switches to monitor high sump/basin levels. Alarms shall be established for high level conditions.
2. Standard Detail:
   3.6.6 – Sanitary Service Monitoring Points

G. Quality Water Systems

1. As a minimum, gallons per day use and conductivity should be monitored.
2. Standard Detail:
   3.6.7 – Quality Water System Monitoring Points

H. Laboratory Gas Systems

1. The status of laboratory gas detection systems shall be monitored, and used to initiate purge airflow strategies when required.
2. Manual ventilation system shutdown switches are typically provided in labs that store and use cylinder gases. The status of the switch is monitored, and when deployed closes all the ventilation airflow devices in the lab.
3. Alarming of laboratory gas detection systems is accomplished directly through the fire alarm system.

I. Vacuum Systems

1. Vacuum systems shall include a pressure sensor to monitor vacuum pressure. Alarms shall be established for low vacuum pressure conditions.

J. Laboratory Equipment

1. Special approval is required to connect laboratory equipment alarms (such as growth chambers, ultra-low refrigeration/freezers) to EMCS.

4.03 VARIABLE SPEED MOTORS

A. Variable Frequency Drives: The BACS shall provide for seamless integration with the control of the VFDs and associated systems. The interface shall be hardwired (point-by-point wiring to applicable terminations on the drives interface board) for start/stop, status and speed signals.

1. System status shall be determined via contacts on the drive, and the BACS shall prove operation. The drive specification must be coordinated to ensure that the status contacts are available and are a true feedback indication that the motor is running. The speed signal shall be 0-10VDC. The BACS shall annunciate an alarm whenever the fan is commanded to run and status is not proven within an adjustable de-bounce time; and when the fan is commanded off and on status is indicated.

2. Digital communications via a controller LAN shall be used to gather all other available diagnostic information.

3. An HOA switch shall be provided with the VFD. In the hand position the fan shall start and run continuously at a speed manually set on the drive unless a safety device trips; in the off position the fan shall stop; in the auto position the BACS shall start at minimum speed and ramp up under a controlled rate per described sequences of operation.

B. EC Motors: For single phase motors 2-hp and below, the use of EC Motors is preferred when available.

C. A loss of status coincident with a loss in power shall not be alarmed as a failure.

D. Standard Detail:
3.6.8 – Variable Frequency Drive Control Points

4.04 MOTOR STARTERS

A. For motors intended to operate at constant volume, it is preferred to use a VFD or an EC Motor in lieu of motor starter.

B. If a motor starter is the only available option, please include the following:

1. An HOA switch shall be provided with the starter. In the hand position the motor shall start and run continuously unless a safety device trips; in the off

position the motor shall stop; in the auto position the BACS shall control the motor per described sequences of operation.

2. Status shall be monitored by the BACS, preferably with a current sensor. Motor status shall be monitored via an adjustable de-bounce time. The BACS shall annunciate an alarm whenever the motor is commanded to run and status is not proved within an adjustable de-bounce time.

3. A loss of status coincident with a loss in power shall not be alarmed as a failure.

4.05 COILS

A. General

1. Coils shall generally be controlled by a modulating valve and include a temperature sensor immediately downstream of the coil before any other coil or heat transfer element. Coil selection must be coordinated with the control design and valve selection to ensure stable control particularly at light loading conditions.

2. When heating and cooling coils are included in one supply system, programming shall prohibit simultaneous heating and cooling operation (unless required for dehumidification) and smoothly sequence the coils as loading changes. All control valves shall have dedicated analog outputs. Coil control programming shall be coordinated with all other elements that affect the temperature of the supply air to minimize the energy use.

3. Generally, sensors within an air-handler shall be averaging unless they are after a well-mixed condition such as downstream of a fan.

4. Provide an alarm if there is an air temperature difference across the coil when the control valve is commanded closed.

5. Generally, the discharge air temperature shall be reset as follows:

OA Tdp 55 °F & above	=>	DAT = 55 °F
OA Tdb 75 °F & above	=>	DAT = 55 °F
OA Tdb 55 °F & below	=>	DAT = 65 °F

B. Preheat Coils

1. All preheat coils shall be controlled from the air handling unit discharge air temperature sensor.

2. The preheat control shall remain active when the unit is de-energized.

3. Preheat coil control valves shall open 100% whenever a freezestat trips.

4. Glycol pre-heat coils shall be included in air handling systems with heat recovery systems. A single coil strategy that combines heat recovery and

preheat into one coil is not preferred. The glycol pre-heat coil shall be sized to accommodate failure of the heat recovery system under a design day condition.

5. A glycol preheating coil shall be used for 100% OA preheat. There shall be sufficient design and control system consideration for low load control. Valves shall be sized for good control across the range. To prevent air stratification and nuisance freezestat trips, a coil pump shall be provided that will maintain flow in the turbulent region at low loads.

6. Standard Details:
3.6.10 – Preheat Coil in 100% Outside Air Handling Systems
3.6.11 – Preheat Coil in Recirculating Air Handling Systems

C. Chilled Water Coils

1. Coil selection shall be coordinated with the control design to ensure smooth operation and stable control at low load, particularly with 100% OA units.

2. Chilled water coil control valves on 100% outside air units shall open on freezestat trips. For larger coils requiring multiple freezestats, the freezestats shall be automatic reset with a remote manual reset located in an accessible location.

3. Chilled water coils shall be controlled from the air handling unit discharge air temperature sensor.

4. Standard Detail:
3.6.12 – Chilled Water Coils in Central Air Handling Units

D. Heating Coils

1. Heating coil control valves shall be sized for smooth and stable control.

2. Control valves on heating coils provided with a supply air handler shall close when the system is off.

3. Standard Details:
3.6.13 – Heating Coils in Central Air Handling Units
3.6.14 – Duct Mounted Heating Coils

4.06 AIR HANDLING UNIT MIXED AIR SECTION

A. The mixed air section of air handling units shall be designed for thorough mixing of the outside air and return air streams. Opposed blade dampers shall always be used for modulating dampers.

B. Mixed air sections for occupied spaces shall include controls to maintain adequate ventilation across all ranges of operation. The mixed-air section shall include an averaging temperature sensor and dedicated outputs to control the opposing outdoor air, relief air, and return air dampers.

C. If special humidity conditions are required or if energy savings on reheat are substantial (e.g., large differences in interior versus exterior space loads), the engineer shall utilize dedicated treatment of ventilation outside airflows, before they are mixed with return air.

D. Ventilation Control: Special attention shall be given to designing the outside air duct for the full range of airflow expected (minimum ventilation to economizer operation). If the outside air flow velocity would result in a flow that falls below 100 feet per minute velocity, a dedicated minimum OA duct and control damper shall be provided with an air flow measuring station to control and validate the ventilation flow rate.

E. Economizer control logic shall be used whenever feasible and cost-effective for the life cycle unless the merits are offset by humidity loads that result.

1. Integrated Economizer: Generally selects the stream with lower dry bulb temperature and initiate the economizer control when the OA is less. The economizer should not be enabled if the outside air dewpoint exceeds 55 °F, regardless of dry bulb temperature conditions (OA & RA). The outside air and relief air dampers shall be open, the return air damper shall be closed, and supplemental mechanical cooling may be required to maintain the system discharge air temperature setpoint.
2. Mixed Air Control: Depending on the loads connected to the system, it may be advantageous to provide mixed air control. When enabled, the OA and RA dampers shall modulate to maintain the mixed air temperature at the cooling setpoint to make it the first stage of cooling.
3. During unoccupied periods, the economizer controls shall remain enabled.

F. Standard Detail:
3.6.15 – Air Handling Unit Mixed Air Section

4.07 100% OUTSIDE AIR HANDLING UNIT INTAKES

A. Provide an OA temperature/humidity sensor (with calculations for dewpoint and enthalpy) and a flow station on each air handling unit outside air intake. A flow station is not required on 100% outside air units if one is provided at the supply air fan.

B. Standard Detail:
3.6.16 – 100% Outside Air Handling Unit Intakes

4.08 FILTER RACKS

A. The BACS shall monitor the differential pressure of the filter bank. A magnehelic indicating transmitter shall be used and the BACS shall annunciate an alarm when the differential pressure across each bank of filters exceeds the recommended loaded condition.

B. It is not necessary to measure across both the pre and final filters individually. One pressure reading across the entire filter bank is sufficient.

C. Standard Detail:
3.6.17 – Filter Rack Monitoring Points

4.09 HUMIDIFIERS

A. Due to the high energy use and control issues associated with humidification equipment, the consultant must obtain Cornell approval prior to using on a project. Typically, humidifiers should only be used in critical environments and vivarium applications.

B. Using manufacturer's packaged humidifier controls or the BACS system to control humidifiers are both allowed. BACnet cards shall be supplied with the humidifier to enable alarming to EMCS for equipment fault and service notifications.

C. Humidifiers shall be controlled to maintain the space or exhaust/return duct dewpoint temperature with a maximum supply duct relative humidity of 85%. A combination temperature/humidity sensor that calculates dewpoint should be used in lieu of a dewpoint sensor. Trending of zone humidity conditions shall be set up based on relative humidity.

D. A single trend summary screen shall be generated for each humidification system that includes the following information:

1. Zone relative humidity with min/max setpoints.
2. Zone dry bulb temperature with min/max setpoints.
3. Chilled water coil valve, reheat coil valve, humidifier control valve commands.
4. Space occupancy.
5. Supply air pressure switch status.

Having this single trend screen allows for easier diagnosing of zone humidity issues without having to index between multiple trend screens.

E. Exercise care in placing sensors and other components downstream of humidifiers to make sure they are well past the absorption distance and in a well-mixed air stream.

F. Standard Detail:
3.6.18 – Humidifier Control Points

4.10 RETURN AIR DUCTS

A. Standard Detail:
3.6.19 – Return Air Duct Monitoring Points

4.11 FANS CONTROLLED BY MOTOR STARTERS

A. Do not use. Contact Cornell for special applications.

4.12 FANS CONTROLLED BY VARIABLE FREQUENCY DRIVES

A. VFDs without Bypass: The standard is to provide bypasses only on critical systems that have no redundancy. This section covers applications with drives where bypasses are not provided, the most typical installation.

1. The starting and ramp up must be coordinated with the opening of any isolation dampers when there is a potential for damage or a pressure safety trip. This coordination shall be either one of the following:

a. Only energize the fan when the damper end switch indicates that the damper is open far enough to not cause physical damage or trip a pressure safety. If at any time during the operation of the fan the damper open indication is lost, the fan shall stop immediately (not at the controlled rate). This approach should be used when the fan is stand-alone.

b. Energize the fan to a preset minimum speed that will not do any damage to the system. Upon indication that the damper is open far enough not to do damage, the fan shall be allowed to accelerate to required speed. If at any time during fan operation the damper open status indication is lost, the fan shall decelerate and stop. This approach will typically be used for headered fans.

2. The BACS shall modulate the capacity device in response to the system static pressure sensed at a location(s) remote from the fan. The location of the remote sensing device shall be indicated and physically located by the design professional on the design documents and the final location shall be identified on the as-built control drawings. The setpoint shall be reset based on terminal requirements. Programming shall be in place to avoid one terminal device driving the entire system unless it is critical.

3. In failure mode, the run command shall remain, except on headered systems for which the run command will be removed requiring manual acknowledgement. Drives must have automatic restart programmed.

B. VFDs with Bypass:

1. All requirements indicated above apply; however, the application with the bypass must include appropriate consideration of operation in the bypass mode (ductwork pressurization, noise). If a bypass is used, it can only be operated locally in hand at the VFD. All VFD safeties shall remain fully functional.

C. Standard Detail:
3.6.21 – Fans with Variable Speed Control

4.13 AIRFLOW CONTROL TERMINALS

A. VAV/CV Terminals: Pressure independent terminals with digital control shall be used. Field-level controllers shall be installed in an enclosure mounted on the device. Typical control strategies are as follows:

1. The BACS shall modulate the terminal unit damper to maintain an airflow or room temperature setpoint. Setpoint will depend on the application. Examples are as follows:

a. Modulating temperature control: Damper modulates between minimum and maximum limits as the space temperature rises above the cooling setpoint. Damper command is typically at a fixed minimum when in heating mode.

b. Two-position ventilation control: Damper is either open or closed based on space occupancy.

c. Demand controlled ventilation: Damper modulates to maintain space carbon dioxide setpoint.

2. Standard Details:
3.6.22 – Variable Air Volume Terminals
3.6.23 – Constant Air Volume Terminals

B. Tracking Laboratory Terminals

1. The control of the terminals must be integral with the overall zone flow tracking logic.

2. On Venturi type air valves where airflow is not measured and it is inferred from valve (voltage) feedback, the BACS shall monitor and alarm the condition where the pressure in the duct is inadequate to maintain the correlation. A differential pressure transmitter shall be installed that

measures the static pressure drop across the valve, providing feedback to allow pressure reset control strategies.

3. A minimum of two occupancy sensors shall be used per zone, with one-week no-change-of-state alarms connected to the BACS that excludes the Christmas to New Year's break each year. Different minimum airflows shall be used for occupied and unoccupied periods as sensed by the occupancy sensors.

4. Fume Hoods: The BACS shall monitor sash position and initiate unoccupied mode. Alarm condition and the emergency ventilation position shall also be monitored.

   a. VAV fume hoods shall be controlled by the BACS. This will generally require a full and stable (flow at setpoint +/- 5%) response to a full sash movement within 3 seconds. The controller for the fume hood shall use sash sensors on the horizontal and/or vertical sashes to determine the face area. Based on the sash position the controller shall control the VAV terminal to the calculated airflow.

   b. The face velocity setpoint shall be 80-100 FPM occupied, and 65 FPM unoccupied. The 80 fpm setpoint shall be determined during final commissioning. Alarm setpoints shall change based on whether the hood is in the occupied or unoccupied mode as determined by the lab occupancy sensors. The controller shall include an energy waste alarm based upon sash height.

5. Ducted biosafety cabinets (BSCs) will generally be exhausted by house systems that shall be controlled by the BACS. The exhaust flow from the cabinet will be constant volume. The cabinet will typically be part of a flow-tracking zone. The system and BACS design shall provide an alternate means of exhaust flow when the BSC is isolated for decontamination. An occupied and unoccupied mode shall be utilized and the flow-tracking zone shall adjust accordingly.

6. Standard Details:
   3.6.24 – Tracking Laboratory Supply Air Terminals
   3.6.25 – Tracking Laboratory Fume Hood Exhaust Terminals
   3.6.26 – Tracking Laboratory General Exhaust Terminals
   3.6.27 – Tracking Laboratory Biosafety Cabinet Terminals

4.14 ENERGY RECOVERY WHEELS

A. The BACS shall fully control heat and energy recovery wheels including sensing the temperature and relative humidity of all four airstreams around the wheel and the speed of the wheel via the VFD furnished with the wheel. The BACS shall also monitor the rotation sensor and alarm when rotation is expected and not proven. The heat recovery sequence shall be coordinated with all other thermal loops in the air systems.

B. Averaging temperature sensors shall be used downstream of the wheel unless adequate mixing distance is provided before the sensor to ensure thorough mixing.

C. Where space permits, provision for wheel bypass shall be provided.

D. The BACS shall calculate and trend the heat recovery effectiveness. For energy wheels, the total effectiveness shall be calculated using enthalpy derived from the temperature and relative humidity sensors. Air stream flow shall be derived from the supply and return air fan flow stations, typically provided external to the heat recovery system.

E. Incorporation of a frost control mode is only required on systems that serve humidified zones.

F. Standard Detail:
3.6.28 – Energy Recovery Wheels

4.15 GLYCOL RUN AROUND HEAT RECOVERY COILS

A. The BACS shall fully control the glycol heat recovery coil system. The BACS shall control the start/stop of the circulating pump and monitor the status of the pump and alarm upon failure. In addition, the BACS shall monitor the temperature and humidity of all four airstreams around the coils.

B. The heat recovery sequence shall be coordinated with all other thermal loops in the air systems. Averaging temperature sensors shall be used downstream of the coils unless adequate mixing distance is provided before the sensor to ensure thorough mixing.

C. Where space permits, provision for coil bypass shall be provided.

D. The BACS shall calculate and trend the heat recovery effectiveness. For glycol run around heat recovery systems, the total effectiveness shall be calculated using enthalpy derived from the temperature and relative humidity sensors. Air stream flow shall be derived from the supply and return air fan flow stations, typically provided external to the heat recovery system.

E. Incorporation of a frost control mode is only required on systems that serve humidified zones.

F. The glycol loop system pressure shall be monitored, and alarmed in the event of a leak.

G. Standard Detail:
3.6.29 – Glycol Run Around Heat Recovery

4.16 HEAT PIPE HEAT RECOVERY

A. BACS shall fully control the heat pipe system. The system shall employ a face and bypass damper arrangement (in both the exhaust and supply air streams) and duct-mounted temperature sensor in the exhaust air stream for anti-frost. Provide dual face and bypass dampers (supply and exhaust) only if isolation of the AHU is a requirement. In addition, the BACS shall monitor the temperature of all four airstreams around the coils.

B. The heat recovery sequence shall be coordinated with all other thermal, flow, and humidity loops in the air systems. Averaging temperature sensors shall be used downstream of the coils unless adequate mixing distance is provided before the sensor to ensure thorough mixing.

C. The BACS shall calculate and trend the heat recovery effectiveness. Air stream flow shall be derived from the supply and return air fan flow stations, typically provided external to the heat recovery system.

D. Incorporation of a frost control mode is only required on systems that serve humidified zones.

E. Standard Detail:
3.6.30 – Heat Pipe Heat Recovery

4.17 DESICCANT DEHUMIDIFICATION SYSTEMS

A. Desiccant dehumidifiers will typically be supplied with a factory control package. The BACS shall enable the desiccant unit, send applicable setpoints to the unit, and fully monitor the system.

B. Monitoring points shall include, as a minimum, entering and leaving process air temperature, entering and leaving process air humidity, entering and leaving process air dewpoint (calculated).

C. Input energy for reactivation air heating can be high pressure steam, natural gas or electricity; and shall be chosen based on project specifics and available energy source.

D. Alarming shall be configured for discharge and space dewpoint.

E. Standard Detail:
3.6.31 – Desiccant Dehumidification Systems

4.18 CONVERTERS

A. A properly sized steam valve shall control steam converters. Steam valves shall be of an industrial type.

B. Generally, redundancy will not be provided in the heating source component (i.e., converter). If it is provided, controls shall facilitate automatically isolating flow from the converters(s) that are not needed for capacity, such that the control loop gain is reduced and therefore easier to tune. This shall mean a single two-position valve shall be provided on the HW circuit to each converter. Automatic sequencing of the backup component, as well as rotation of the lead and maintenance lockout shall be included in the sequence.

C. Control shall be based on leaving water temperature, generally reset when feasible with systems served as indicated for hydronic systems.

1. Primary Loop:

   The supply water temperature setpoint shall be 130 °F.

2. Perimeter Loop:

   OAT 10 °F & below => SWT = 130 °F
   OAT 55 °F & above => SWT = 90 °F

3. Glycol Heating Loop:

   OAT 10 °F & below => SWT = 125 °F
   OAT 55 °F & above => SWT = 90 °F

4. Reheat Loop:

   The supply water temperature setpoint shall be 130 °F.

D. Steam shell and tube heat exchangers shall have two temperature alarms associated with them.

1. Operational Supply Temperature Deviation Alarm when heat exchanger is in operation.
2. High Supply Temperature Alarm that is always enabled whether or not the heat exchanger is operational or not, so as to monitor for steam control valve leak by.

E. Standard Details:
3.6.32 – Steam to Hot Water Converters

3.6.33 – Redundant Steam to Hot Water Converters

4.19 HEAT EXCHANGERS (FLUID TO FLUID)

A. Heat exchangers shall generally include modulating control via a properly sized valve.

B. Control of heat exchangers shall maintain system supply temperature.

C. Standard Detail:
3.6.34 – Liquid to Liquid Heat Exchangers

4.20 PUMPS CONTROLLED BY MOTOR STARTERS

A. Do not use. Contact Cornell for special applications.

4.21 PUMPS CONTROLLED BY VARIABLE FREQUENCY DRIVES

A. The BACS shall modulate the drive in response to the system differential pressure sensed at a location(s) remote from the pump. The location of the remote sensing device shall be indicated by the design professional on the design documents and the final location shall be identified on the as-built control drawings. The setpoint shall be reset based on terminal requirements. Programming shall be in place to avoid one terminal device driving the entire system unless it is a critical zone.

B. Standard Detail:
3.6.36 – Pumps with Variable Speed Control

4.22 FAN COIL UNITS

A. Fan coil units shall be digitally controlled by the BACS. Controller shall control for room temperature by modulating the heating and cooling control valves.

B. Where a fan coil unit serves an area that is also served by central air (VAV box, MAU, etc.) the fan coil unit shall be the primary device for space temperature control.

C. All fan coils shall have interlocks to close the cooling coil control valve when the fan is off.

D. All fan coils shall be supplied with EC Motors, and should be locked out from operating above 50% of the unit fan speed.

E. Standard Details:
3.6.37 – Four Pipe Fan Coil Units
3.6.38 – Cooling Only Fan Coil Units
3.6.39 – Heating Only Fan Coil Units

4.23 RADIANT HEATING/COOLING ZONES

A. Radiant heating and cooling zones shall be digitally controlled by the BACS and coordinated with other thermal loops associated with the devices.

B. Recording of feed flow temperature, return flow temperature, heat amount, and flow rate for radiant floor heating zones shall be accomplished using a Resol WMZ-M1 V40 flow meter.

C. Standard Details:
3.6.40 – Active Chilled Beam Cooling
3.6.41 – Passive Chilled Beam Cooling
3.6.42 – Radiant Heating Panels
3.6.43 – Baseboard Radiation
3.6.44 – Radiant Floor Heating

PART 5: BACS FOR ZONES

5.01 GENERAL

A. This section of the guideline defines general physical Input/Output (I/O) requirements, sequences, and by inference some degree of system requirements related to how the BACS is applied to zone level control.

B. A comprehensive package of zone control drawings, including control schematics, points and alarms list, and sequences of operation have been developed for the typical zone types used on the Cornell campus. These drawings exist to aid the consultant in designing building control systems to meet Cornell preferences; ***it is expected that the Consultant to customize these details for project specifics.*** Where a drawing exists, a reference will be included. Consult Cornell for deviation from these standards, and zone control systems not covered by these drawings.

C. As a minimum, all zones of control will require a combination temperature/humidity sensor. Control shall include maintaining space temperature in the comfort range as defined by ASHRAE.

D. Generally, it is preferred that zone ventilation be provided by a dedicated outside air system, with air conditions sufficiently conditioned (dehumidified) to offset the expected space latent gains due to space occupancy.

E. Without exception, sensors and terminal ventilation devices must correlate with the controlled zone. In zones where both heating and cooling systems are designed, it is especially important to coordinate the heating and cooling control zones.

F. Generally, it is preferred that occupancy sensors be utilized to control occupancy modes. If override buttons are provided with sensors, they shall as a minimum perform the following functions:

1. Return the zone to occupied mode and enable the equipment that serves the zone (e.g., the central air handling unit and the zone VAV box). All other zones that are not occupied shall remain at unoccupied flow setpoints, as applicable.
2. For single zone units, the AHU (or other terminal system) serving the zone shall start and run in the occupied mode.

G. Unless otherwise indicated, zone temperature control shall include a 5 °F deadband between heating and cooling setpoints.

H. Occupied, occupied setback, and unoccupied temperature setpoints shall be designated on the design control drawings. Occupied setback mode is used where a defined building occupancy schedule is used in conjunction with occupancy sensors. A typical Cornell space temperature setpoint reset schedule is as follows:

1. Space Cooling Temperature Setpoints:

Occupied:	75 °F ± 1.5 °F
Occupied Setback:	75 °F + 3.0 °F
Unoccupied:	75 °F + 6.0 °F

2. Space Heating Temperature Setpoints:

Occupied:	70 °F ± 1.5 °F
Occupied Setback:	70 °F – 3.0 °F
Unoccupied:	70 °F – 6.0 °F

I. For residence halls, the students have made a request to allow the heating temperature setpoint to be reset lower than the typical Cornell schedule. The controls shall be programmed to allow the temperature setpoint to be manually reset to a minimum of 60 °F across all heating modes.

J. Ventilation airflows shall be reduced during the occupied setback mode. The consultant shall schedule the airflow setpoints across all modes on their drawings.

K. Standard Details:
3.7.6 – Zone Control, Four Pipe Fan Coil Unit
3.7.10 – Zone Control, VAV with Reheat

5.02 LABORATORIES

A. Laboratory zones will generally be controlled first to flow tracking, followed by temperature. Space controllers shall be networked to the building's system-level or building-level controllers.

B. Laboratories shall most often consist of flow-controlled zones using variable air volume terminals controlled by actively maintaining an airflow offset between the total supply and exhaust flow to the room. Rarely will constant volume systems using passive flow control achieved by balancing be allowed.

C. On VAV zones that are required to be negative, the supply flow should track the total exhaust flow. On VAV zones required to be positive, the exhaust should track the supply.

D. Specific consideration must be considered for the redundancy of the systems for laboratories. In either a failure mode or an emergency power mode, and when the flow is actively controlled at the zone level, reset of the terminal flow setpoints is required to maintain the required room pressurization in a prioritized fashion. When this is the case, design professional shall dictate the priorities.

E. Monitoring of space pressure with local indication is generally only required when the potential threat to human well-being or the research program from air-borne contamination is significant. This shall be discussed on a case-by-case basis with Cornell to establish this need.

F. In all laboratories, a minimum of two occupancy sensors shall be provided to determine occupancy, in turn allowing reset of the ventilation rates and temperature deadband for the room.

G. Special caution should be taken to ensure that the reset flow rate is not below the controllable range of the given terminal and accuracy of the flow measuring device. For this reason, the consultant shall include a schedule indicating the airflow setpoints across all expected modes. Examples of these schedules are included on the Standard Details.

H. Standard Details:
3.7.1 – Low Hood Density Tracking Laboratory
3.7.2 – High Hood Density Tracking Laboratory
3.7.3 – Low Hood Density Cooling Tracking Laboratory

5.03 CONFERENCE/MEETING/CLASSROOM/AUDITORIUM ZONES

A. All zones expected to have a high occupancy density, as well the potential for variability of density, shall be provided with combination temperature/humidity/CO2 sensors.

B. Control for meeting areas must be closely coordinated with the system design, but shall include temperature and ventilation control. Space control data shall be available on the BACS network.

C. Control shall include maintaining space conditions in the comfort range as defined by ASHRAE.

1. Adequate ventilation shall be ensured by active control of CO2, modulating ventilation rates to maintain space CO2 below 900 PPM.
2. Larger auditoriums and classrooms shall also include controlling to humidity setpoints.

D. Standard Details:
3.7.4 – Conference/Meeting/Auditorium Spaces without Economizer
3.7.5 – Conference/Meeting/Auditorium Spaces with Economizer

5.04 RADIANT HEATING/COOLING ZONES

A. For zones with passive radiant heating and cooling systems, the typical Cornell occupied, occupied setback, and unoccupied temperature setpoint reset schedule shall be modified. Experience shows that the following reset schedules are sufficient to maintain proper comfort levels given the slower response time associated with these systems:

1. Space Cooling Temperature Setpoints:
Occupied: 75 °F ± 1.5 °F
Occupied Setback: N/A
Unoccupied: 75 °F – 4.0 °F
2. Space Heating Temperature Setpoints:
Occupied: 68 °F ± 1.5 °F
Occupied Setback: N/A
Unoccupied: 68 °F – 4.0 °F

B. A condensate sensor shall be provided on the supply piping for each chilled beam zone. This sensor shall be wired as a binary input to the zone controller to shut the temperature control valve to the zone upon sensing any moisture.

C. Standard Details:
3.7.7 – Zone Control, Radiant Heating and Cooling

3.7.8 – Zone Control, Baseboard Heating, Passive Chilled Beam Cooling
3.7.9 – Zone Control, Baseboard Heating, Active Chilled Beam Cooling

5.05 COMPUTER ROOMS

A. Computer Rooms: The BACS shall control computer rooms to temperature. The use of proprietary controls packaged with the equipment is not acceptable.

B. Space controllers shall be networked with the system-level or building-level controllers and other space controllers. Provide coordinated control to prevent energy waste from humidification, dehumidification, and temperature control loop fighting.

C. Airflow to the room should be modulated using a hot aisle / cold aisle approach.

D. Liquid sensors shall be provided below the raised floor.

5.06 ENCLOSED GARAGES

A. Enclosed Garages: The BACS shall monitor and alarm high CO levels in enclosed garages. Space controllers shall be networked with the system-level or building-level controllers. The BACS may either interface with packaged controls that ventilate the garage to control the CO or the BACS may control the system entirely. When the BACS controls garage ventilation, it shall start/stop and sequence ventilation fans as necessary to maintain acceptable CO levels. Sensing shall be provided as required by Code. Sequence shall allow for scheduled fan operation during normally heavy traffic periods.

5.07 LOADING DOCKS/SHIPPING AND RECEIVING AREAS:

A. Loading Docks/Shipping and Receiving Areas: The BACS shall control the area to temperature as dictated by the system design. Space controllers shall be networked with the system-level or building-level controllers. The installation shall also include a CO sensor to alarm upon high levels of CO and initiate additional ventilation as permitted by the system design.

PART 6: BACS FOR CENTRAL SYSTEMS

6.01 GENERAL

A. This section of the guideline defines general physical Input/Output (I/O) requirements, sequences, and by inference some degree of system requirements related to how the BACS is applied to central system control. Systems are generally composed of the sub-components that are indicated with the systems.

B. A comprehensive package of central system control drawings, including control schematics, points and alarms list, and sequences of operation have been developed for the typical system types used on the Cornell campus. These drawings exist to aid the consultant in designing control systems to meet Cornell preferences; it is expected that the Consultant will customize these details for project specifics. Where a drawing exists, a reference will be included. Consult Cornell for deviation from these standards, and zone control systems not covered by these drawings

C. An outside air station incorporating measure values of temperature and humidity; as well as calculated values for enthalpy and dewpoint shall be provided for each mechanical room in the facility.

D. After equipment shutdown, equipment failure, and / or power outages, the BACS shall provide for smooth and orderly start up and staging of mechanical equipment.

E. A single controller with stand-alone capability shall control each central air system.

F. Where an engineered smoke control sequence is specified, the BACS may be used to execute the sequences only if the controller maintains an Underwriters Laboratory (UL) category 864 UUKL listing. Otherwise, the fire alarm system shall locally override all devices via addressable modules.

G. Supply air systems that work in concert with exhaust systems shall be carefully coordinated with that system. Supply and exhaust ramping rate on start-up for 100% outside air systems shall be coordinated to control space pressurization.

H. In headered systems where multiple fans feed a common duct plenum, the following shall be incorporated.

1. Systems shall be staged for the most efficient and effective operation. When the fans are controlled by variable frequency drives, fans shall be started into a closed damper. An end switch shall be provided on the associated isolation damper, which shall prove open prior to allowing the drive to accelerate the fan.
2. Lead fans shall be rotated every 1000 hours to equalize run time.
3. When a fan on a headered system indicates a failure, the BACS shall remove the run command and close the associated isolation damper. This system shall require manual acknowledgement before it is reset.

I. Systems shall be interfaced with the fire alarm system as required by the Building Codes of New York State and NFPA.

J. Standard Detail:
3.8.8 – Floor Pressurization

6.02 SUPPLY AIR SYSTEMS

A. As a minimum, all supply air systems will be controlled to a discharge air temperature.

1. Supply air systems serving multiple terminal units, particularly those that serve terminals that involve some sort of reheat, shall include a supply air reset algorithm.
2. Reset may be based on either outside air temperature or feedback from the terminals.
3. Where control is based on feedback from the terminals, logic shall prevent a single box from controlling the entire system unless it is critical.
4. Reset schedules shall prevent the discharge air temperature from resetting higher whenever the outside air dewpoint is greater than 55 °F.

B. Air systems that include additive humidity control shall include a high limit humidity sensor in the supply air duct separated by an adequate distance from the humidifier. If jackets are used on the dispersion tubes of the humidifier, provide an automatic means of isolating the jacket when the dewpoint of the outside air is above the applicable setpoint.

C. The starting of the fan and the opening of associated dampers shall be carefully coordinated. For VAV air handlers, the fans shall start at minimum capacity and ramp up to capacity at a controlled rate. On 100% outside air systems and systems with smoke dampers, end switches on the dampers shall prove damper status as open before allowing the fan capacity to ramp up at a controlled rate.

D. All air handling units shall have a DPDT freezestat with manual reset. One foot of capillary is required for every square foot of coil surface. The freezestat shall trip when any area of the preheat coil discharge drops below 38 °F. One pole shall be hard wired to the VFD, and the other shall be wired to the BACS panel. Additional requirements for freezestats are as follows:

1. When a freezestat trips, the supply fan shall stop and all associated dampers shall close (unless in fireman's override). The associated coil control valves shall remain under control.
2. The freezestat shall have a manual reset mounted external to the unit. For installations with coils that are large enough to require multiple freezestats,

they shall be auto reset and wired to a remote accessible manual reset station, ideally within the system control panel enclosure. The station shall have multiple contacts and shall function as stated above.

E. When the dead-head of the fan is capable of damaging the wall, component, or system ductwork upon closure of an isolation or fire damper, the air handler shall be protected with applicable high and/or low differential pressure safety switches.

F. Standard Details:
3.8.1 – Dedicated Outside Air System with Energy Recovery Wheel
3.8.2 – Dedicated Outside Air System with Glycol Heat Recovery
3.8.3 – Dedicated Outside Air System with Heat Pipe Recovery
3.8.4 – Central Variable Air Volume System with Reheat

6.03 STAIRWELL PRESSURIZATION

A. When required by NFPA 70, building systems shall include a stairwell pressurization system. These systems shall typically be initiated by the fire alarm system whenever an alarm condition occurs.

6.04 EXHAUST AIR SYSTEMS

A. All exhaust air systems, including toilet and general exhaust, shall be provided with airflow measurement; this information will be used to coordinate with the supply airflow to control building pressurization.

B. Exhaust systems shall be provided with automatic dampers to close and isolate the system when the system is off.

6.05 LABORATORY EXHAUST SYSTEMS

A. The velocity of the exhaust air in exhaust stacks must be controlled to maintain adequate dispersion and to prevent re-entrainment into fresh air intakes. Bypass air is generally used to maintain the stack(s) discharge at a constant velocity.

B. Sensors for laboratory exhaust systems must be selected for corrosion resistance and for the appropriate hazard expected in the duct.

C. Standard Detail:
3.8.5 – Central Laboratory Exhaust Systems

6.06 CLEAN STEAM (STEAM SOURCE) SYSTEMS

A. The BACS shall generally monitor the steam pressure produced by the boiler(s) or generator(s) and annunciate alarms (high and low) if an alarm condition occurs.

B. The steam boiler/generator is typically specified with packaged controls. The BACS shall interface with the packaged controls to monitor an overall alarm condition.

C. Make-up water to these systems shall be preheated. When the preheaters are controlled by the BACS, the status of flow to the system must be monitored to allow the BACS to enable/disable feed water control.

D. Clean steam systems shall contain automatic blow down systems. Ending of the blowdown cycle shall be based on time and conductivity using a conductivity controller.

6.07 HYDRONIC SYSTEMS

A. Most of the requirements of hydronic system components are covered separately. At least one key point of static pressure shall be monitored and a low alarm shall be set at the point when any point in the system is subject to going to a negative gauge pressure.

B. The supply and return temperatures shall be monitored on all hydronic systems.

C. The control sequence for hydronic loops shall control the source component(s) to maintain a supply temperature that is reset.

D. On steam source heating components, the minimum required heat exchange surface shall be active at all times.

E. When hydronic systems include redundant or staged pumps, the sequence shall provide for automatic start of the standby pump during the following conditions:

1. Failure of the lead pump, stopping the standby pump when it is no longer needed.
2. Rotation from standby to lead.
3. Maintenance lock-out.

F. Sensible Radiant Cooling System Requirements

1. At least two (2) temperature/humidity sensors that have dewpoint calculations shall be provided on each floor level; three (3) shall be provided on an entry level floor. The cooling loop supply water temperature shall be reset so that the loop temperature is above the dew point temperature of the worst case sensor, generally between 58 to 64 °F.

2. System shall be enabled as follows: The BACS shall poll the space temperatures associated with the system. If the 10% (adj.) of the zone valve commands are above zero, then the system shall be enabled.

G. Standard Details:
3.8.6 – Chilled Water Distribution Systems
3.8.7 – Heating Water Distribution Systems