Energy Resource Station

Technical Description

October 2015

iowa energy center

Energy Resource Station
Des Moines Area Community College
2006 S. Ankeny Boulevard
Ankeny, Iowa 50023
515.965.7055

TABLE OF CONTENTS

1 Introduction

1.1 Purpose

Energy Resource Station - Main Entrance

The Iowa Energy Center established the Energy Resource Station (ERS) for the purposes of examining various energy-efficiency measures and demonstrating innovative heating, ventilating, and air-conditioning (HVAC) concepts. The ERS is unique in that it allows for dynamic testing of an entire system within a controlled environment. The facility has laboratory-testing capabilities combined with real building characteristics and is capable of simultaneously testing two full-scale commercial building systems side-by-side with identical thermal loadings and control schemes.

The ERS is a demonstration, training and test facility built to compare different energy-efficiency measures, to record energy consumption, and to disseminate information concerning energy efficient design and operation of buildings. The ERS tests HVAC components in a building as a system, rather than simply testing individual pieces of equipment. This method of performance testing emphasizes the importance of the entire HVAC system and the interdependence of the individual building elements.

To achieve the unique ability to simultaneously test side-by-side, the building is equipped with two identical air handling units, each with its own dedicated and identical chiller. One air handling unit supplies the four test rooms designated as the A rooms and the other unit serves the four test rooms designated as the B rooms. The A test rooms and the B test rooms are arranged as mirrored pairs in a side-by-side design with each pair having a different cardinal exposure. There is a pair of test rooms that face south, east and west and an interior pair of test rooms with no exterior exposure. The rooms are unoccupied; however, there exists a capability to impose false thermal loads in the rooms. The false loads and room lighting can be scheduled to simulate various usage and occupancy patterns.

The A and B test rooms are individually controlled by a commercially available energy management and control system. The system has the option of off-site monitoring and control available. The control system is well instrumented with both research and commercial grade sensors installed.

The HVAC system for the occupied general service area of the facility is a separate air handling unit with a dedicated air cooled chiller, fan powered terminal air units and its own energy management and control system.

1.2 Site

The ERS is located on the campus of the Des Moines Area Community College (DMACC) in Ankeny, Iowa. Its latitude is 41.71 degrees North and longitude is 93.61 degrees West, with an elevation of 937.0 ft above sea level. The facility has a total floor area of 9,208 ft^2 and a building height of 15 ft.

An astronomical north base line was established prior to construction of the ERS and provides for a true north/south building alignment.

Energy Resource Station - South-East View

Construction details can be obtained from the building record and technical drawings available from the ERS.

1.3 Objective

The objective of this report is to present an overview of the design, equipment, control systems and research capabilities at the Energy Resource Station.

The building floor plan, exterior/interior envelope and overall building and roof construction details are discussed in Chapter 2. Chapter 3 outlines the mechanical systems and equipment used to condition the building air. The emphasis is placed on describing the ERS Test HVAC System. The lighting system capabilities and options are found in Chapter 4. The ERS Test Direct Digital Control (DDC) System is covered in Chapter 5.

1.4 Building Energy Research Capabilities

The ERS is unique as the only public facility in the United States able to simultaneously test and demonstrate multiple, full scale commercial building systems in an actual building environment. The distinct feature of four matched pairs of test rooms allow for side-by-side comparisons of systems in real time and in a controlled environment. Furthermore, the geographical location of the building provides annual outside air temperature and humidity extremes that represent the majority of potential climate zones. Testing equipment under high relative humidity or extreme cold temperatures is possible due to seasonality variability of Iowa's climate.

The ERS is equipped with three separate air handling units with three distinct hydronic piping circuits and allows a wide variety of possible performance testing configurations. Potential operational modes include:

- ***constant air volume***
- ***variable air volume***
- ***dual duct***
- ***ventilation air only***
- ***perimeter heating***
- ***fan powered variable air volume***
- ***low temperature air distribution***
- ***unit ventilator***
- ***fan coil unit***
- ***custom system configurations***

To aid in implementing and evaluating performance testing, the ERS has an extensive data acquisition system. The control system is capable of accurately controlling and monitoring operating conditions with over 800 data points. The ERS employs a rigorous calibration program to routinely calibrate and normalize key system instrumentation and maintains an in-house organizational system of all calibration documents.

With the extensive scope of research capabilities available at the Energy Research Station, multiple types of testing and research projects on building operations, energy efficiency and building controls have been conducted at the facility. Examples include:

- ***fault detection and diagnostics testing***
- ***reverse airflow testing***
- ***validation and optimization of building energy control systems***
- ***building energy simulation software***
- ***testing of an adaptive fuzzy logic controller for HVAC applications***
- ***day lighting research projects***
- ***effect of return air configuration on building energy and indoor air quality***
- ***testing of lighting circuit power reducers***
- ***special window energy performance***

The ERS has several components with the ability to simulate, replicate, measure and record specific conditions. The following sections are brief summaries of components, capabilities and available options.

1.4.1 Weather Station and Exterior Light Sensors

The building has a local weather station, solar instrumentation and exterior light sensors. The weather station measures ambient conditions and collect on-site weather data. Current weather conditions measured include:

- *outdoor air dry-bulb temperature and relative humidity*
- *wind speed& direction*
- *barometric pressure*
- *total normal incidence solar flux*
- *global horizontal solar flux*
- *longwave radiation*

Solar Station

Exterior Light Sensor

Weather Station

Exterior light sensors are located on the south, east and west sides of the ERS and measure the quarter sphere sky dome and ground reflectance. A global light sensor is on the roof and measures the half sky dome. The ERS also has a roof mounted net radiometer for broadband solar irradiance on a planar surface, and an equatorial mount pyrheliometer to measure direct beam solar irradiance.

1.4.2 False Thermal Loads

All eight test rooms are equipped with two stage electric baseboard heaters that can be utilized to introduce false internal thermal loads simulating various usage patterns. They provide 100% sensible heat loading and can be operated in three modes. See ***Table 1.1.***

Table 1.1 Stages of Baseboard Heat

Control Mode	Stage 1	Stage 2	Total Nominal Power Watts
1	Off	Off	0.0
2	On	Off	900
3	On	On	1800

Additional false loads can be introduced into the test rooms by activating the fan coil units and/or unit ventilators in either a heating or cooling mode of operation simultaneous along with the overhead air distribution system.

1.4.3 Occupancy Simulators

The capability to simulate people in the test rooms is available at The Energy Resource Station has the ability to simulate the sensible heat gain and respiration of people with sheet metal androids. Each test room has an android and these sheet metal cylinders are able provide a controlled and regulated CO2 production rate and internal incandescent lights generate occupant sensible heat for standard office work activity levels. A computer work station is also to simulate typical office equipment loads. The android systems are activated and deactivated as control points on the DAC system to follow any prescribed schedule. The level of CO2 and sensible heat can be modified as required and each android can simulate a maximum of two people and ***Table 1.2*** indicates the control modes available.

Android Set-up in Test Room

Table 1.2 Occupancy Simulators Control Modes

	Control Mode	Capacity per Person	People Activity Level	Operation Description
CO2	On	0.75 SCFH (0.35 liter/min)	Office Work	CO2 is produced at a controlled and regulated level
	Off	0 SCFH (0 liter/min)	Absent	The solenoid valve controlling CO2 flow to the android is closed
People	On	250 BTU/hr sensible 200 BTU/hr latent	Office Work	Heat is generated with a light bulb heat source, 75 watt/person (256 BTU/hr)
	Off	0 BTU/hr	Absent	Relay controlling the heat source is turned off
Equipment	On	42 Watts-Computer 46 Watts-Monitor	Office Work	Personal computer and monitor activated
	Off	4 Watts-Computer < 1Watt-Monitor	Absent	Relay controlling office equipment deactivated, equipment in standby mode

1.4.4 Test System Control Modes

The ERS test system has the flexibility to replicate and manipulate operating conditions to meet specific testing requirements. The test system has various modes of control of specific equipment items outlined below.

1.4.4.1 Air Handling Unit Control Modes

The test room air handling units have four separate control modes for greater flexibility in varying the fans and outside air damper to meet the specific testing goals. The four control modes are noted in ***Table 1.3.***

Table 1.3 Air Handling Unit Control Modes

Control Mode	Fan Operation	Test Room Temperature Mode	Outside Air Damper Operation	Control Mode Description
Off	Off	Unoccupied	Closed	AHU fans positively off, test room temperatures float, no heating / no cooling available
Setback	Cycles	Unoccupied	Closed	AHU fans cycle on signal for min or max test room temperature to prevent that temperature from exceeding the unoccupied setpoint, no outside air ventilation
Start-up	Continuous	Occupied	Closed	AHU fans operate continuously on 100% re-circulated air to transition the test room temperature from unoccupied to occupied setpoint, terminal heating coils activate for heat, VAV damper activate for cooling, no outside air ventilation

Occupied	Continuous	Occupied	Available	AHU fans operate continuously to maintain supply air temperature setpoint, outside air ventilation provided as selected by outside air mode control, VAV damper and terminal heating coil operate to maintain test room temperature setpoints

1.4.4.2 Outside Air Damper Control Modes
Both test room air handling units have outside air dampers that can be set to operate at a fixed damper position or a fixed CFM specification.

1.4.4.3 Economizer Control Modes
Three control modes are available for economizer control: fixed dry bulb, differential dry bulb and differential enthalpy.

1.4.4.4 Return Air Control Modes
The return air fans have three separate control modes: speed tracking, airflow tracking and fixed differential.

1.4.4.5 Chilled Water System Control Modes
The central building chilled water system has the option of operating on a chiller priority or an ice making mode that utilizes the onsite thermal energy.

1.4.4.6 Test Room Heating Modes
The reheat coils in the test room VAV boxes have two modes of heating operation: a hydronic reheat coil and a multi-stage electric resistive reheat coil.

1.4.4.7 Test Room Pressurization Mode
Test room differential pressure can be set at a positive, a negative or a neutral pressure differential setpoint. Sensors in the test room provide a differential pressure measurement between that room and the adjoining media center area.

1.4.5 Test Room Lighting Control Modes
There are several lighting options available in the test rooms used for to vary lighting conditions. Each test room has daylighting control with dimming electronic ballasts. Lighting control modes include two stages of lighting under manual or automatic scheduled control and two daylighting dimming control modes. Daylighting control through local stand alone light sensors is also available as well as a DDC control loop using any one of the other room sensors as the feedback input. Instrumentation includes photovoltaic sensors to measure the light levels and electric power transducers to monitor the lighting power.

1.4.6 Test Room Window Type Options
The window panes in the test rooms can be reasonably changed out for different window characteristics. The standard base window is a clear double pane window. Alternate window panes could have various shading coefficients and visible transmittance values.

1.5 Information Resources

The Energy Resource Station has detailed information on the facility construction and operations which includes:

- ***detailed technical drawings***
- ***as-built construction drawings***
- ***in-house set of systems manuals including submittals, technical data and operation and maintenance information on the facility and equipment***
- ***instrumentation calibration certificates and reports***
- ***instrumentation accuracy reports***
- ***building energy simulation software (Energy Plus and Design Builder) input files***
- ***extensive collection of construction and operational data available electronically***

2 Building Systems

2.1 Introduction

The general construction of the Energy Resource Station (ERS) is a structural steel frame building with pre-cast insulated concrete panels. The floor is slab-on-grade construction and all the rooms are finished. Partition walls are metal stud frame construction with gypsum wall board. The ceilings are suspended grids with lay-in acoustical tile in all rooms except the mechanical area which is open and exposed.

2.2 Floor Plan

The floor plan of the Energy Resource Station is comprised of three distinct and separate areas; the A test rooms, the B test rooms, and the general area. The A rooms are serviced by air handling unit A and the B rooms by air handling unit B. The exterior test rooms are mirrored side-by-side pairs of A and B with different cardinal exposures. The test rooms have identical in construction specifications. The general area consists mostly of office spaces and classrooms which are served by air handling unit AHU-1.

There are four test rooms in each set of A and B rooms for a total of eight.

- ***East A***
- ***South A***
- ***West A***
- ***Interior A***
- ***East B***
- ***South B***
- ***West B***
- ***Interior B***

The rooms in the general area consist of:

- ***Offices***
- ***Reception Space***
- ***West Vestibule***
- ***West Classroom***
- ***Mechanical Room***
- ***Communications Room***
- ***Display Room***
- ***Media Center***
- ***East Vestibule***
- ***East Classroom***
- ***Service Rooms***
- ***Electrical/Storage Rooms***

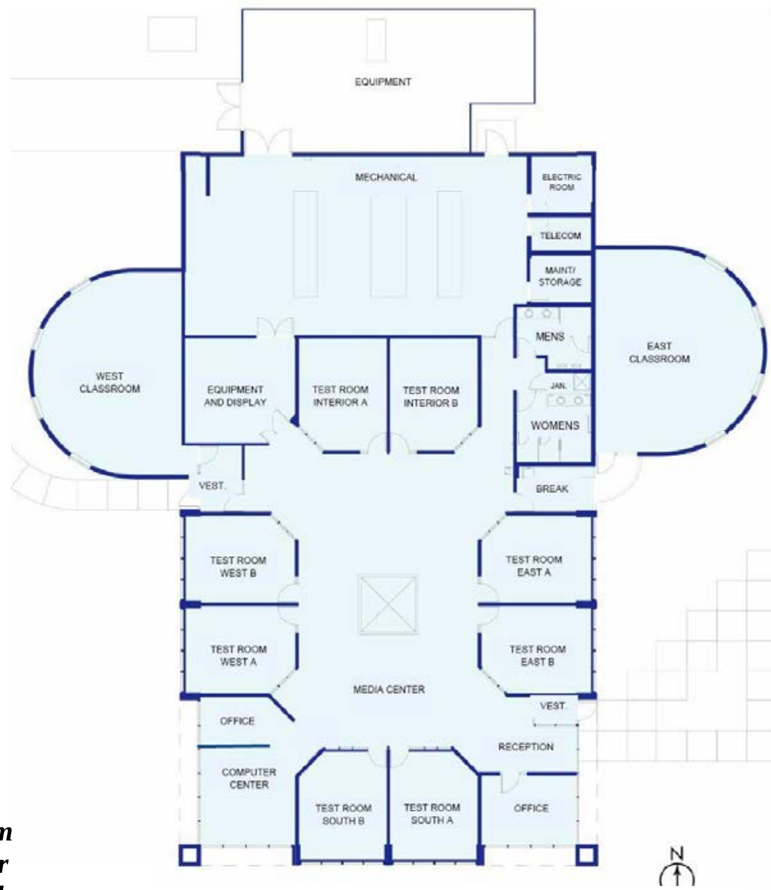


Figure 2.1 Energy Resource Station Floor Plan

A general floor plan of the Energy Resource Station is shown in ***Figure 2.1***. For detailed data on the individual rooms, see ***Table 2.1.***

Table 2.1 Room Data

Room Designation	Net floor area, ft^2	Ceiling height, ft	Plenum height, ft	Exterior wall, ft^2	Window area, ft^2
Test Rooms A and B:					
East	266	8.4	5.5	137	74
South	266	8.4	5.5	137	74
West	266	8.4	5.5	137	74
Interior	266	8.4	5.5	0	0
General Service Areas:					
Mechanical	1764	14.0	0.0	1080	0
Storage	90	14.0	0.0	294	0
Communications	66	14.0	0.0	88	0
Electrical	110	14.0	0.0	119	0
Service Rooms	390	8.0	6.0	499	0
Display Room	316	8.5	5.5	0	0
East Classroom	769	9.0	1.0	762	70
West Classroom	769	9.0	1.0	762	70
East Vestibule	36	8.5	5.5	33	30
West Vestibule	85	8.5	5.5	125	30
Media Center	1888	10.0	4.0	0	0
Reception Area	178	8.5	5.5	75	40
East Office	197	8.5	5.5	238	136
West Office and Computer Center	415	8.5	5.5	383	197

2.3 Exterior Envelope

2.3.1 General Description of ERS Exterior Envelope

The floor of the building is constructed of 4 inch concrete on a 4 inch layer of compacted sand. The exterior wall envelope is constructed of white, gray and buff colored architectural precast concrete panels. These panels are either 6 inches or 4 inches thick depending on location. The construction layers inward from the precast concrete panels generally consist of rigid insulation, air space, a vapor barrier, metal stud walls insulated with fiberglass and finished gypsum wall board. The percentages of window to exterior wall area are:

- ***East Elevation – 15%***
- ***West Elevation – 16%***
- ***South Elevation – 32%***
- ***North Elevation – 0%***

The building is surrounded by a grassy area, and an exterior enclosed equipment yard is on the north side. The outside equipment area has a concrete pad and concrete retaining walls. Approximately 80 yards southeast of the building is a small lake.

West Elevation of Energy Resource Station

2.3.2 Test Rooms Exterior Envelope

The exterior walls of the six test rooms are constructed of lower wall, window and upper wall sections.

The lower wall is 3 feet high; the center portion of the B test rooms houses the fan coil units while unit ventilators are in the A rooms. . The lower wall section also contains mechanical piping, electrical and building control systems with an interior access panel. The upper wall area construction layers are the same in all six exterior test rooms. For details of the construction layers, see ***Figure 2.2***.

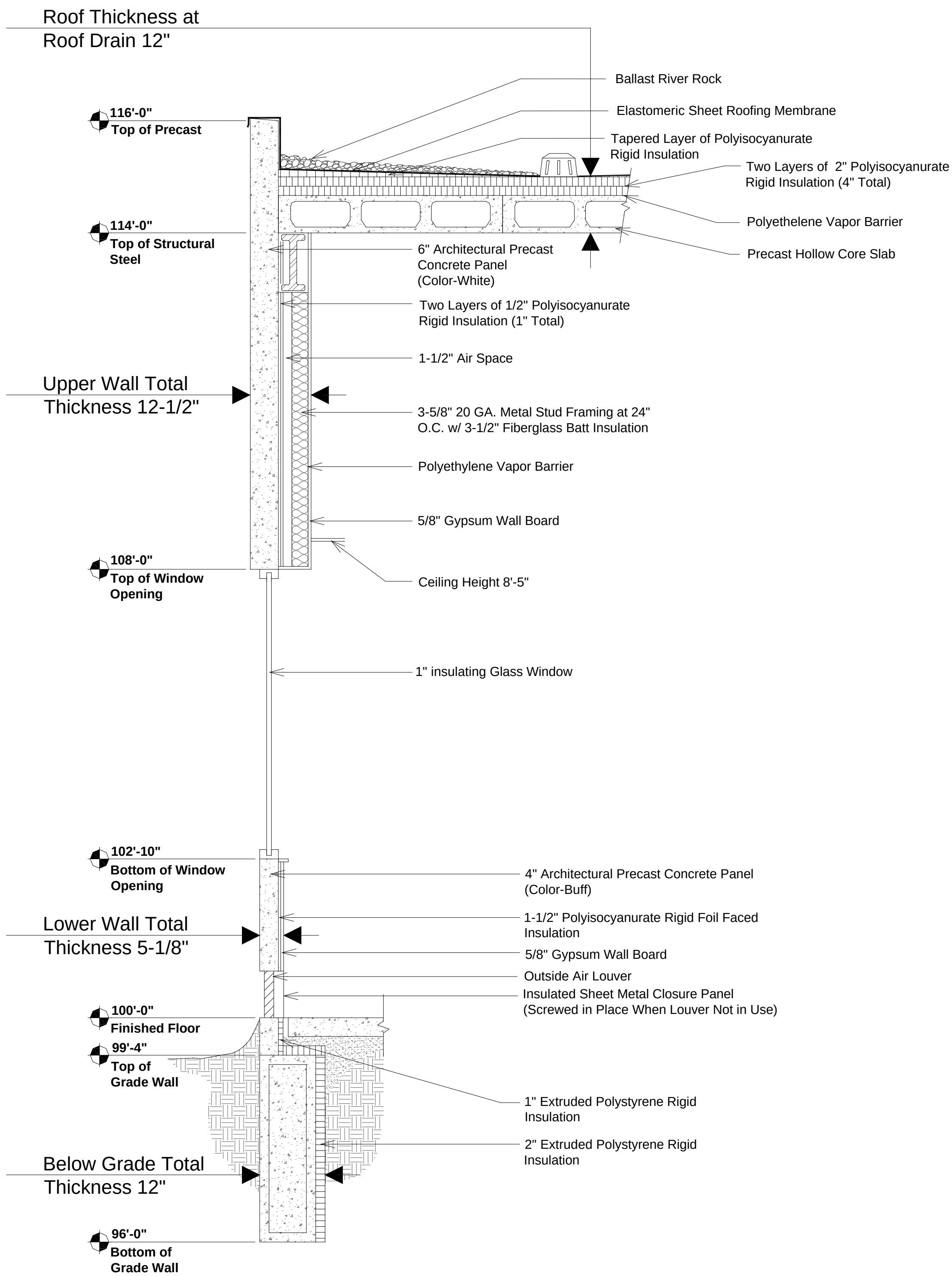


Figure 2.2 Typical Test Room Center Wall Section

The exterior windows in the test room are double-glazed ¼-inch clear insulating glass with a ½-inch air gap. The overall rough opening for the windows measures 5.0 feet high by 14.8 feet wide. The windows have 2" wide aluminum frames with 2" wide mullions. There are no exterior shading devices but there are interior aluminum blinds. The window panes in the ERS test rooms can also be easily replaced.

The interior test room partitions have clear window walls and a description of those windows is in Section 2.2. ***Table 2.2*** *shows the thermal and fenestration properties* for the test room windows.

South Test Room Exterior Windows

Table 2.2 Thermal Properties of Fenestration – Test Room Windows

Test Room	Type	Color	Height by Width ft x ft	Overall U Value Summer Btu/h·ft^2·°F	Overall U Value Winter Btu/h·ft^2·°F	Visible Transmittance	Shading Co-efficient
Base Clear Windows	Annealed Insulated	Clear	rough opening 5' x 14' window size (4 each) 55" x 39" (nominal)	0.55	0.48	81%	0.85

2.3.3 General Areas Exterior Envelope

The general and public areas of the ERS have varying exterior envelope construction layers. An overview of the exterior envelope of the rooms is outlined below. Detailed wall section drawings of the different wall construction types are available. The thermal properties for the windows located in the general areas are noted in ***Table 2.3***.

- ***Offices, Computer Center, and Reception Area***
  These rooms have an exterior 3' lower wall section covered on the outside with a black insulating glass spandrel panel. The envelope layers inward from the glass panel are, an air gap, rigid insulation, air space, standard metal stud framing with batt insulation, vapor barrier and finished gypsum wall board. The windows are double-glazed ¼-inch gray tinted, heat strengthened glass with a ½-inch air gap. The windows are 5' high with varying widths and have aluminum frames with thermal breaks. The exterior walls also have a 3' overhang and soffit. The exterior upper wall is 6" architectural precast concrete with rigid insulation, an air space, metal stud framing with batt insulation, a vapor barrier, and soffit.

- ***East and West Classroom***
  Both classrooms have exterior walls of gray 6" architectural precast concrete. The envelope layers inward are insulation, an air space, metal stud framing with batt insulation, a vapor barrier, and finished gypsum wall board. The only difference between two classrooms is the west classroom has polyisocyanurate rigid insulation, whereas the east classroom has high density spray-on polyurethane foam insulation. The windows are ¼-inch gray tinted, heat strengthened glass with a ½-inch air space. They are 5'x 3.8' and have aluminum frames with thermal breaks; there are no exterior shading devices but there are interior aluminum blinds.

Exterior View West Classroom

Interior View of West Classroom

- ***Mechanical Equipment Room***
  There are no windows in the mechanical equipment room and the outer wall layer is architectural precast concrete. The layers include rigid insulation, an air space, metal stud framing with batt insulation, a vapor barrier and finished gypsum wall board.

Table 2.3 Thermal Properties of Fenestration – General Service Area Windows

Room	Exposure	Type	Color	Height by Width ft x ft	Overall U Value Summer Btu/h·ft^2·°F	Overall U Value Winter Btu/h·ft^2·°F	Shading Coefficient
East Office	East South	Heat Strengthened	Gray Tinted	5.0 x 11.8 5.0 x 15.3	0.30 0.30	0.34 0.34	0.31 0.31
Computer Center	South West	Heat Strengthened	Gray Tinted	5.0 x 15.3 5.0 x 16.0	0.30 0.30	0.34 0.34	0.31 0.31
West Office	West	Heat Strengthened	Gray Tinted	5.0 x 8.0	0.30	0.34	0.31
East Classroom	East	Heat Strengthened	Gray Tinted	5.0 x 15.3	0.30	0.34	0.31
West Classroom	West	Heat Strengthened	Gray Tinted	5.0 x 15.3	0.30	0.34	0.31
Media Center	Roof	Skylight	Semi-Translucent	10.0 x 10.0	0.24	0.24	- - - -

2.4 Interior Envelope

The interior walls of each test rooms extend to the roof deck providing isolation from both the adjacent test room and the general public areas of the building. The typical interior partition walls are standard 3-5/8" metal stud walls with 5/8" finished gypsum board. Near structural columns the partitions are 6" metal stud walls with 5/8" finished gypsum board. The thicker walls are located at:

- ***West Wall – Interior A and South B***
- ***West Wall – West A and West B***
- ***East Wall – Interior B and South A***
- ***East Wall – East A and East B***

The insulation in the interior partitions varies and both 1/2 lb. open-celled polyicynene spray foam insulation and fiberglass batts are used.

The walls separating the test rooms from the media center include a partial glass section for inspection of test rooms and providing daylight into the center media area. The glass section is single glazed 1/4inch clear insulating safety glass. The overall the section is 7' x 6'and there are nine equal panels with aluminum frames and thermal breaks.

The test rooms have standard hollow-core metal doors and the ceiling is suspended grid with 2' x 2' acoustical tiles. There recessed fluorescent lights, two supply air diffusers, and one return grille in each room.

The general and public area interior partitions are standard construction 3-5/8" metal stud walls with 5/8" finished gypsum board.

Partial Glass Wall Section-Interior B Test Room

2.5 Roof Construction

The roof structure of the Energy Resource Station is flat with a tapered insulation system to allow for proper drainage. There is a semi-translucent skylight centered above the media center with a horizontal area of 100 ft^2.

The construction layers of the main portion of the roof, including the test rooms but not the classrooms, are composed of an 8" precast hollow core slab, a vapor barrier, 4" of rigid polyisocyanurate insulation, a tapered layer of insulation varying thickness of 0-5", an elastomeric roofing membrane secured with river rock ballast. The east and west classroom roofing layers are the same except the interior layer is a metal roof decking instead of the hollow core slab.

3 Mechanical Systems

3.1 Introduction

The primary mechanical system at the Energy Resource Station consists of a central heating and cooling plant servicing three air handling units provide conditioned air to the building.

A natural gas fired hydronic boiler and multiple circulating pumps make up the central heating plant. The central cooling plant has three air cooled liquid chillers, a thermal energy storage unit and numerous circulating pumps. These plants supply the chilled or heated water to the air handling units and test room level mechanical equipment.

AHU-1 is the biggest unit and serves the general areas of the building and due to the larger variation in thermal loading. The general office areas has fan powered variable-air-volume (VAV) electric reheat boxes for zone control and further condition the air supplied by AHU-1. AHU-A and AHU-B are identical and supply the A and B test rooms, respectively. These two air handling units have pressure independent VAV boxes located in each test room and have both electric and hydronic reheat capability.   The B test rooms have four pipe fan coil units installed and the A rooms have unit ventilators.

3.2 Central Heating Plant

3.2.1 Overview

The central heating plant utilizes a standalone gas fired hydronic boiler with several loop level circulating pumps that provide heating water, via a closed loop system, to the HVAC equipment in both the general areas and the test rooms.

Hot Water Boiler HWB-1

3.2.2 Central Heating Plant Description

The hydronic boiler, ***HWB-1,*** is the primary component of the heating plant and is a condensing type unit. There are five in-line circulating pumps for each of the five separate heating circuits. Three pumps provide water to the three air handling unit heating coils. The other two are loop level pumps serving the terminal heating equipment in the A and B test rooms. The loop A pump circulates heating water to the hydronic reheat coil in the VAV boxes and to the unit ventilators while the loop B serves the VAV reheat coils and the fan coil units.. A schematic of the heating water system is show in ***Figure 3.1.*** (Note: The loop A and loop B pumps are not shown in schematic)

3.2.3 Central Heating Plant Operation

A summary of the operation of the heating plant is:

- heated water leaves the boiler and goes to a common header supplying water to each of the five heating pumps
- three of the pumps are fixed speed and supply heating water to the test room air handling units and the general service unit
- two loop level pumps supply loop A and loop B and have variable frequency drives (VFD)

System instrumentation and sensors monitor the boiler operation and the heating system water flow, temperatures, power, and differential pressure.

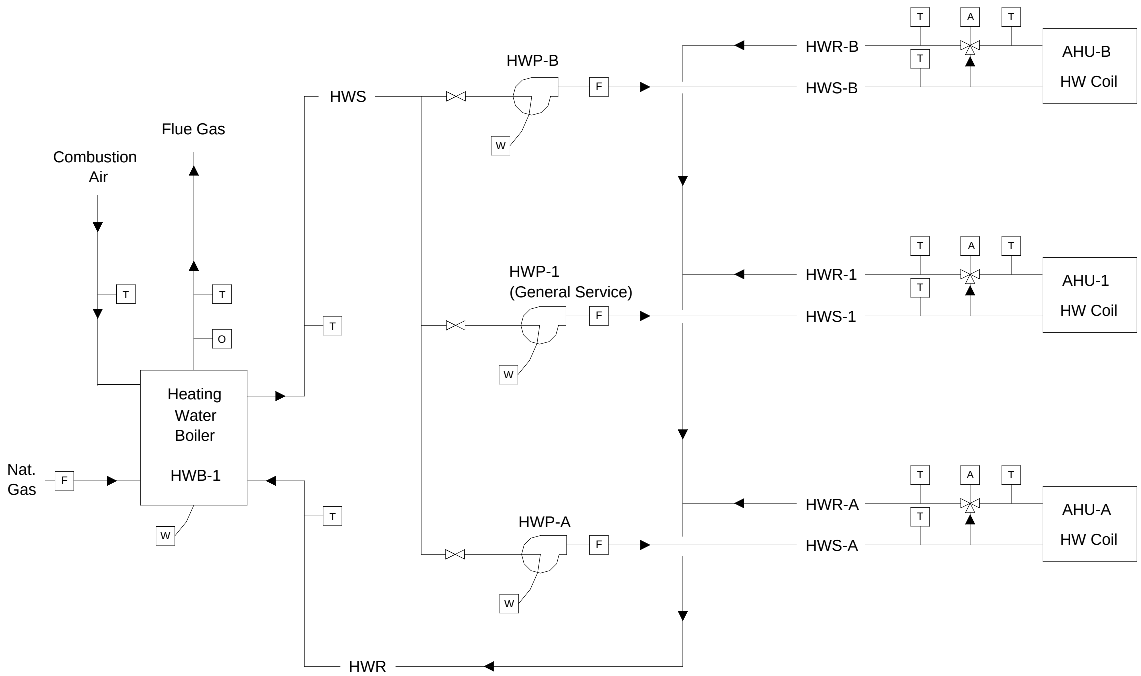


Figure 3.1 Heating Water Schematic

3.2.4 Central Heating Plant Equipment Specifications

The primary equipment specification items for the central heating plant are noted in ***Table 3.1 and 3.2.*** For additional information regarding this equipment contact the ERS..

Table 3.1 Heating Water Boiler Design Specifications

Design Item	Boiler HWB-1
Boiler Type	Natural Gas Fired Hot Water
Maximum Capacity	930,000 BTU/H
ASME Working Pressure	150 PSIG
Water Volume	23 Gallons
Control Range	50° to 220° F
Rated AFUE	92%

Table 3.2 Heating Water Pumps Design Specifications

Design Item	AHU Heating Coil Pumps	Loop A & Loop B Pumps
Pump Type	In-Line Centrifugal	In-Line Centrifugal
Pump Head Pressure	11.3 PSI	21.7 PSI
Water Flow	21.0 GPM (AHU-A & B) 40.0 GPM (AHU-1)	24.0 GPM
Motor Horsepower	0.50 HP (AHU-A & B) 0.75 HP (AHU-1)	1.00 HP
Motor Speed Control	Fixed	Variable

3.3 Central Cooling Plant

3.3.1 Overview
The ERS cooling plant is comprised of three air cooled liquid chillers, a thermal energy storage (TES) unit, and several circulating pumps and provides chilled water to the HVAC equipment. The chilled water system is quite flexible and has the ability to be isolated into individual circuits with a series of valves.

3.3.2 Central Cooling Plant Description
The chillers are located in the outside equipment area on the north side of the building. The common air cooled chiller ***ACCH-CH*** provides chilled water to the building air handler cooling coil and the test room fan coil units and unit ventilators. The two chillers, ***ACCH-A*** and ***ACCH-B*** are identical and can provide a dedicated chilled water circuit for each set of test room systems. The system can operate each circuit independently or simultaneously depending on the testing strategy. Identical chillers provide uniformity in design and performance useful in a comparison test.

Air Cooled Liquid Chillers

Chiller ACCH-CH can also provide chilled water to the test rooms when used with the thermal storage unit (TES) and via the ice priority control option.

There are seven in-line chilled water circulating pumps in the mechanical equipment room. Each of the three air handers has a dedicated cooling coil pump. There is also a general building level primary pump, a fan coil and unit ventilator pump and secondary chiller pumps for both A and B systems.

The thermal energy storage (TES) tank is located outside of the facility mechanical yard and is partially underground. The TES tank is an internal ice-on-tube type of unit with distributed piping and internal U-tube heat exchangers submerged in a water bath. The cooling plant is designed so chiller ACCH-CH can operate either in an ice priority or a chiller water priority by adjusting chiller setpoints and modulating 3-way valves.

A schematic of the chilled water system in chiller priority is shown in ***Figure 3.2.*** (Note: the schematic does not show the general service unit AHU-1 chilled water piping)

3.3.3 Central Cooling Plant Operation
The operation of the cooling plant is:

- chilled water is provided by the three air cooled chillers, the valve is closed if the option is to utilize in-house chillers for the source of chilled water for building
- chilled water is supplied to the air handler cooling coils in AHU-A, AHU- B and the general service AHU-1 by three individual circuit pumps
- chilled water is supplied to the fan coil units and unit ventilators in the test rooms by a single loop level pump
- overall the chilled water system is inherently flexible and can be easily reconfigured to isolate cooling circuits by a series of isolation valves
- the pumps serving the cooling coils for AHU-A and B are both fixed speed, all additional pumps have variable speed drives (VFD) allowing them to operate at varying flow rates

System instrumentation and sensors monitor the chiller operation, water flow rates, temperatures, power consumption, and differential pressure.

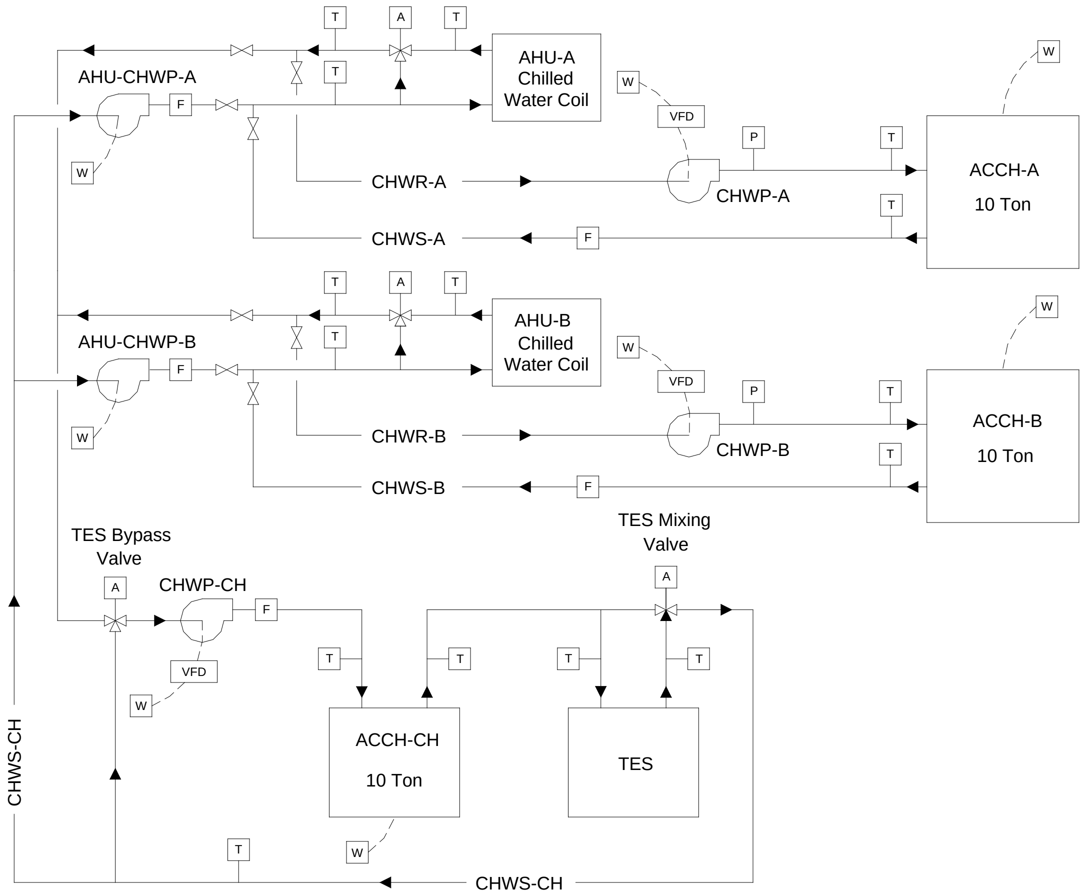


Figure 3.2 Chilled Water Schematic

3.3.4 Central Cooling Equipment Specifications

The key equipment design specifications for the central cooling plant are noted in ***Table 3.3, 3.4, and 3.5.*** For additional information regarding this equipment contact the ERS.

Table 3.3 Thermal Energy Storage Unit Design Specifications

Design Item	Thermal Energy Storage (TES) Unit
Unit Type	Internal Melt Ice on Tube
Unit Size (L x W x H)	96” x 66” x 82”
Maximum Latent Storage	125 Ton Hours
Number of Heat Exchangers	12 Each – U Shaped
Stored Cooling per Sq. Ft. Floor Space	3 Ton Hours

Thermal Energy Storage Unit

Table 3.4 Chiller Design Specifications

Design Item	Test Room Chillers ACCH-A & ACCH-B	General Service Chiller ACCH-CH
Chiller Type	Air Cooled Liquid	Air Cooled Liquid
Chiller Serves	System A / System B	General Service / System A / System B
Nominal Unit @ ARI Conditions	95°F Entering Air Temperature	95°F Entering Air Temperature
Capacity	9.8 Tons (34.3 KW)	9.6 Tons (33.8 KW)
Flow Rate	24.0 GPM	24.0 GPM
Leaving Water Temp	44.0°F	44.0°F
Full Load EER	9.7 BTU/H Per Watt	10.6 BTU/H Per Watt
Integrated Part Load EER	12.2 BTU/H Per Watt	10.5 BTU/H Per Watt
Refrigerant Type	HCFC -- 22	R-22
Refrigerant Circuits	1 Refrigerant Circuit	1 Refrigerant Circuit
Heat Transfer Fluid	25% Propylene Glycol	25% Propylene Glycol
Electrical Characteristics	460 Volt / 3 Phase / 60 Hertz	460 Volt / 3 Phase / 60 Hertz

Table 3.5 Chilled Water Pump Design Specifications

Design Item	AHU Cooling Coil Pumps	Air Cooled Chiller Pumps	Chilled Water Loop Pump
Pump Type	In-Line Centrifugal	In-Line Centrifugal	In-Line Centrifugal
Pump Head Pressure	11.3 PSI (AHU-A & B) 14.8 PSI (AHU-1)	21.7 PSI	21.7 PSI
Water Flow	28.0 GPM (AHU-A & B) 45.0 GPM (AHU-1)	24.0 GPM	24.0 GPM
Motor Horsepower	0.50 HP (AHU-A & B) 1.00 HP (AHU-1)	1.50 HP (ACCH-A & B) 1.00 HP (ACCH-CH)	1.00 HP
Motor Speed Control	Fixed (AHU-A & B) Variable (AHU-1)	Variable	Variable

Chilled Water Pumps

3.4 Test Room HVAC System

3.4.1 Overview

The HVAC system for the A test rooms is comprised of a central air handling unit and an overhead ducted air distribution that terminates with four room level variable air volume (VAV) terminal air unit mixing boxes.. There are two supply air diffusers downstream of the VAV box and one return air grille in each room. Each A test room also has a unit ventilator. The equipment and layout for the B test rooms is identical, except the test rooms include a fan coil unit. ***Figure 3.3*** provides an overview of the test system HVAC plan.

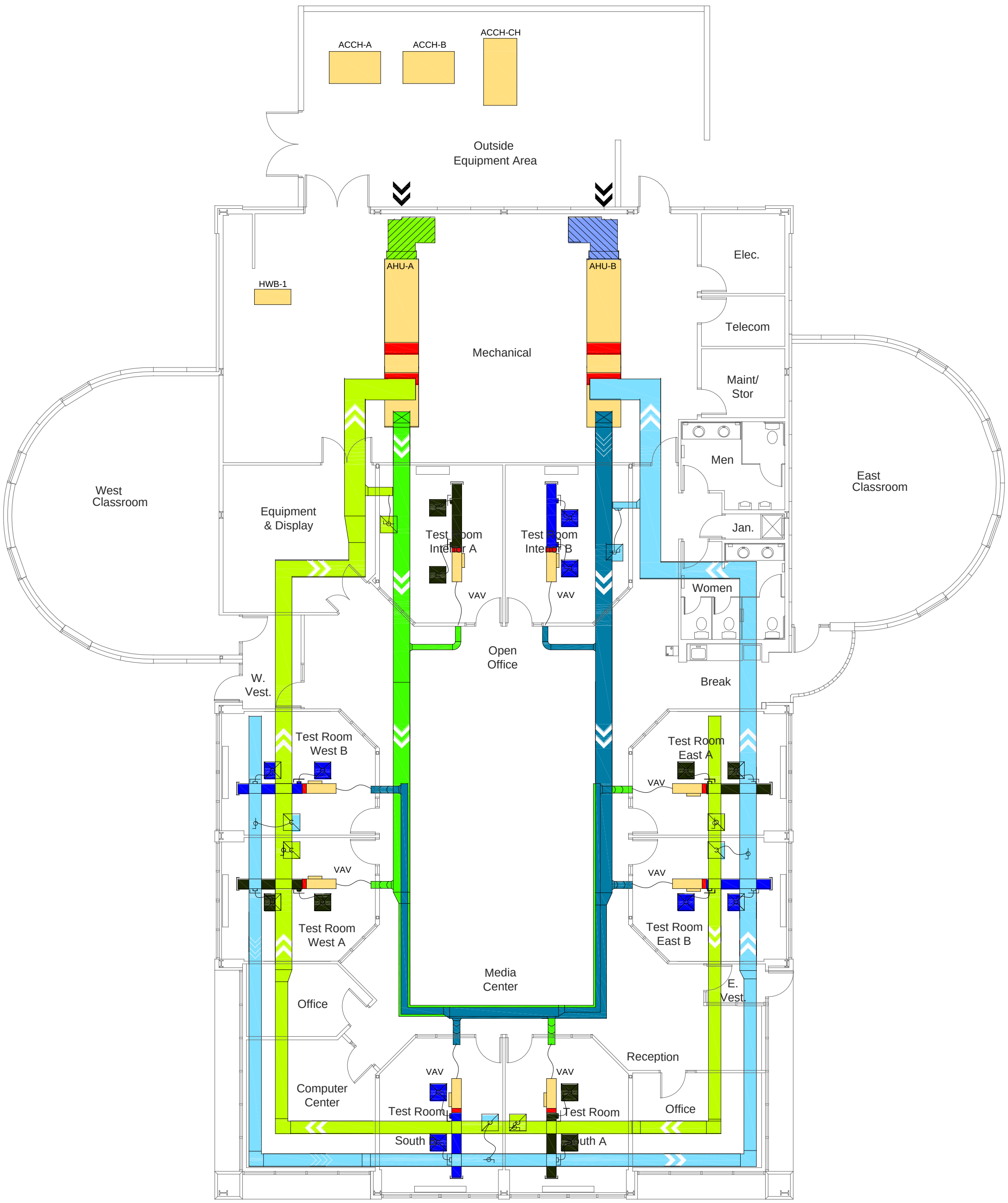


Figure 3.3 Test Room HVAC Plan

3.4.2 Air Handling Unit Description

The two central air handling units serving the test rooms are identical in design. ***AHU-A*** serves the four A test rooms and ***AHU-B*** the four B test rooms. The nature of the modular air handling units allows for ease of access, versatility and adaptability. See ***Figure 3.4***.

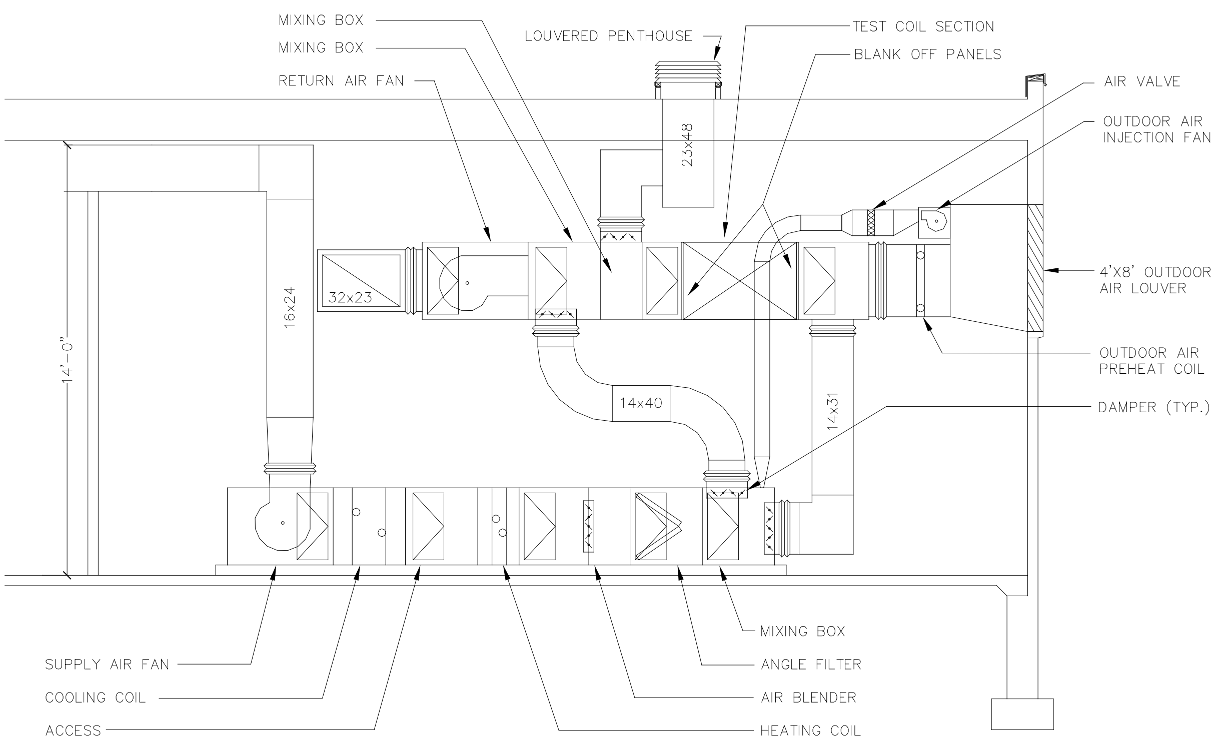


Figure 3.4 Test Room Air Handling Unit Section

3.4.2.1 Air Handling Unit Operation

A summary of the operation of the test room system air handling units:

- outside air enters the AHU through the outside air (OA) louver and duct
- the outside air, re-circulated air and exhaust air combine in amounts determined by damper settings for mixed air
- the mixed air passes through the heating coil
- the air then passes through the cooling/dehumidification coil
- the heating and cooling coils water flow rates are controlled by three way valves
- the draw through supply fan speed is controlled with a variable frequency drive (VFD)
- conditioned supply air is distributed through the supply air duct to the test room terminal air unit VAVs
- the return air in each test room can be configured for a ducted return system or a ceiling plenum return
- the AHUs also have an inlet preheat coil and independent air injection fan is also

Test Room AHU-B

System instrumentation and sensors monitor the air and water flows, temperatures, humidities, power consumption, pressures and carbon dioxide.

3.4.2.2 Air Handling Unit Equipment Specifications

The primary equipment specification items for the test room air handling units are noted in ***Table 3.6***. For additional information regarding this equipment, contact the ERS.

Table 3.6 Test Room Air Handling Unit Design Specifications

Design Item	AHU-A and AHU-B
Unit Configuration	Modular, Horizontal Draw Through
Total Design Supply Air Flow	3200 CFM
Preheat Coil - Outside Air	Heating Water 69 MBH 1 Row – 4.5 Sq. Ft. Face Area
Cooling Coil	Chilled Water 135 MBH 6 Row – 6.0 Sq. Ft. Face Area
Heating Coil	Heating Water 208 MBH 2 Row – 6.0 Sq. Ft. Face Area
Supply Air Fan	Centrifugal, Vertical Up Discharge 3.20 In. WG – Total Static Pressure
Return Air Fan	Centrifugal, Horizontal Discharge 1.25 In. WG – Total Static Pressure

3.4.2.3 Test Room Return Air Control
Each test room has an automatic return air damper controlling the volume of return air and this damper modulates to maintain a predetermined room pressurization requirement based on the specific test requirements.

3.4.3 Variable Air Volume Box Description
Each test room is equipped a pressure independent, single duct terminal air unit, variable air volume (VAV) box. . Each VAV box has both a hydronic and electric reheat coils.. The reheat coils option accommodates allows more flexibility in testing objectives including providing false thermal loads into the spaces. The overhead ductwork and terminal air units are easily accessible and can be reasonably reconfigured into a fan powered VAV type system.

Test Room Variable Air Volume Box

3.4.3.1 Variable Air Volume Box Operation
The following is summary of the operation of the variable air volume boxes:

- supply air from the air handling units enters the VAV box
- the airflow rate is determined from a velocity pressure difference measured using a flow ring and a differential pressure sensor at the inlet to the VAV unit
- the internal damper regulates the airflow rate
- the air then passes through a multiple stage electrical resistance reheat coil and then passes through the hydronic reheat coilair is discharged from the VAV boxthrough downstream ductwork to the supply air diffusers located in the test room

System instrumentation and sensors monitors the air and water flows, temperatures, pressures and power.

3.4.3.2 Variable Air Volume Box Specifications
The major specification items are noted in ***Table 3.7***. For additional information regarding this equipment contact the ERS.

Table 3.7 Variable Air Volume Box Design Specifications

Design Item	Exterior Test Rooms	Interior Test Rooms
Unit Type	Single Duct, Pressure Independent	Single Duct, Pressure Independent
Inlet Size	9 Inches	7 Inches
Air Flow – cooling design	1000 CFM	460 CFM
Hydronic Coil Flow Rate	3.0 GPM	2.0 GPM

Electric Coil Capacity	5.0 kW	2.0 kW
Electric Coil # of Stages / kW per Stage	3 Stages / 1.67 kW per Stage	2 Stages / 1.0 kW per Stage

3.4.4 Fan Coil Unit Description

The B test rooms are equipped with floor mounted, vertical cabinet dual temperature four pipe hydronic fan coil units (FCU) that are served independently by the central heating and cooling plants. The exterior B test rooms FCUs have an outside air opening on the back of the unit connected to a wall louver on the exterior of the building and interior test room unit has a separate ducted source for outside air.

3.4.4.1 Fan Coil Unit Operation

The fan coil unit operation is summarized as:

- the coils are single finned tube, multiple row with two headers, one each for heating and cooling
- for cooling operation, chilled water is supplied to the fan coil unit from the loop C circuit and for heating operation water is supplied by the loop B heating circuit.
- Pressure independent control valves modulate water flow rates to the FCUs
- the units have a mixed air damper to blend outside air and return air
- minimum outside air can be provided by indexing the mixed air damper to a fixed minimum position
- each FCU is capable of providing up to 100% outside air for economizer operation
- the FCU blowers have low, medium and high speeds, the capability exists to control the units at a predetermined fixed speed or to cycle the units in a staged fan speed mode

3.4.4.2 Fan Coil Units Equipment Specifications

The major specification items are noted in ***Table 3.8***. For additional information regarding this equipment contact the ERS.

Table 3.8 Fan Coil Units Design Specifications

Design Item	Exterior B Test Rooms	Interior B Test Room
Unit Configuration	Vertical Cabinet	Vertical Cabinet
Unit Size	1000 CFM	500 CFM
Inlet / Outlet Direction	Front / Top	Front / Top
Coil – Number of Rows	3 Row Cooling / 1 Row Heating	3 Row Cooling / 1 Row Heating
Number of Fans	Three	Two
Cooling Flow Rate	5.8 GPM	3.5 GPM
Heating Flow Rate	1.0 GPM (@ ≈ 114°F LWT)	1.0 GPM (@ ≈ 132°F LWT)

Test Room Fan Coil Unit

3.4.5 Unit Ventilator Description

The A test rooms are equipped with floor mounted, horizontal, flat top four pipe hydronic unit ventilators (UV) served independently by the central heating and cooling plants. The exterior A test room UVs have an outside air opening and wall sleeve connected to a wall louver and interior test room unit has a separate ducted source for outside air.

3.4.5.1 Unit Ventilator Operation

The unit ventilator operation is summarized as:

- the coils are finned tube, multiple row with two headers, one each for heating and cooling
- for cooling operation, chilled water is supplied to the fan coil unit from the loop C circuit and for heating operation water is supplied by the loop A heating circuit.
- Pressure independent control valves modulate water flow rates to the UVs
- the units have face and by-pass cooling control capability
- minimum outside air can be provided by indexing the mixed air damper to a fixed minimum position
- each UV is capable of providing up to 100% outside air for economizer operation
- the UV blowers have a low, medium and high speed setting

3.4.5.2 Unit Ventilator Specifications

The major specification items for the unit ventilators are noted in ***Table 3.9***. For additional information regarding this equipment contact the ERS.

Table 3.9 Unit Ventilator Design Specifications

Design Item	Exterior A Test Rooms	Interior A Test Room
Unit Configuration	Flat Top	Flat Top
Unit Size	1000 CFM	750 CFM
Inlet / Outlet Direction	Front Return / Top Discharge	Front Return / Top Discharge
Coil – Number of Rows	3 Row Cooling / 1 Row Heating	3 Row Cooling / 1 Row Heating
Number of Blowers	3	2
Cooling Flow Rate	6.0 GPM	6.0 GPM
Heating Flow Rate (Design)	6.0 (1.0) GPM	6.0 (1.0) GPM

Test Room Unit Ventilator

4 Lighting Systems

4.1 Introduction

Recessed troffers and down lights are the primary lighting fixtures in the test rooms, offices and classrooms. An acoustical lay-in ceiling grid runs throughout most of the ERS facility. The ceiling height is 8’5” in the test rooms, 8’-6” in the offices and 8’-8” in the classrooms. The media center ceiling height is 10’3” and utilizes indirect lighting arrangement with suspended linear pendants. The mechanical room has standard industrial utility strip lighting installed.

Detailed specifications of the various light fixtures are available from the ERS.

4.2 Test Room Lighting Fixtures

Each exterior test room has six 2’x2’ recessed grid troffers while the interior test rooms have four 2’x4’ recessed troffers. Each 2’x2’ fixture contains three U-shaped T8 fluorescent tube lamps each sized at 31 watts. The 2’x4’ troffers are 3 lamp fixtures and currently have lamps with varying Kelvin values. All the test room fixtures have dimmable ballasts and are set up for 2 stage lighting.

When all six fixtures and both stages are on 85 foot candles are provided at the work surface in each test room. When two fixtures are removed and the remaining four are relocated as shown in ***Figure 4.1*** 60 foot candles are provided at the work surface.

The test room ceilings can easily be re-configured to allow for installation of 2’ x 4’ recessed grid troffers if necessary.

4.3 Test Room Lighting Control Options

Day lighting controls are available in the test rooms and there are light sensors within the rooms that can control the fixture output with the dimmable electronic ballasts. Additional day lighting control is provided through the use of aluminum window blinds.

The test room lighting system has three modes:

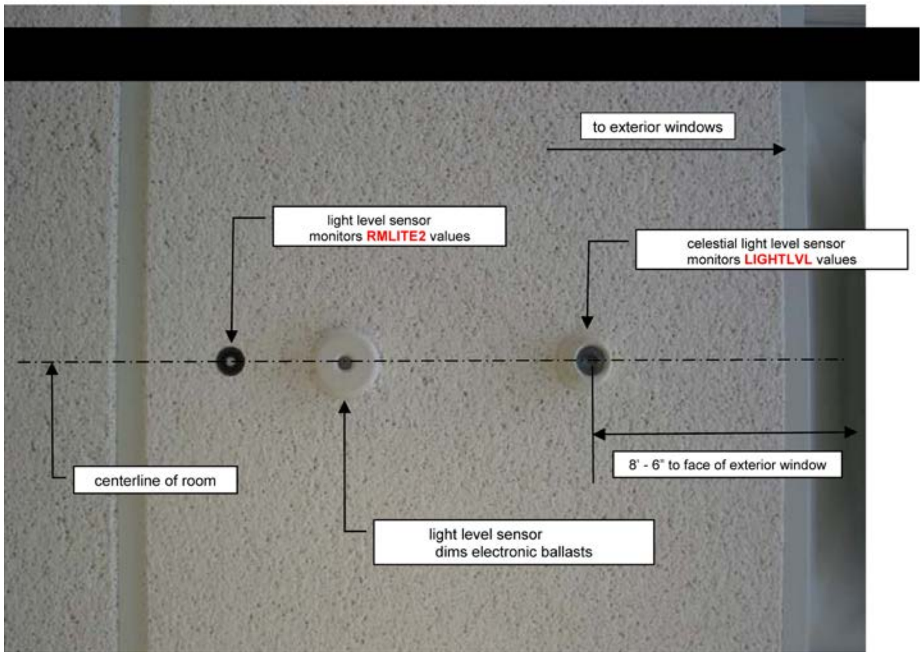
- local control –wall mounted switches located in each test room turn lights on or off, the light output is automatically controlled (dimmed) by a standalone local dimming photo sensor.
- DDC control – the building automation system controls test room lighting schedule, sequence and light output based on feedback from any of the light sensors.
- manual control – manually turn on/off test rooms lights at full power though building automation system

The staging function of the test room light fixtures can be utilized to allow for an exterior and an interior lighting zone in each room.

4.4 Test Room Lighting Instrumentation Devices

The test rooms have several sensors to monitor the light level in the room. There are three sensors mounted in the ceiling tile and two additional ones that can be used throughout the test room for other light level measurements.

Figure 4.1 is a reflected ceiling plan of a test room and shows the lighting fixture layout with four light fixtures and location of the ceiling mounted light sensors (see photograph). ***Figure 4.2*** is a section view drawing of a typical test room which demonstrates additional sensors measure the light level at the window. Several light sensors are installed on the exterior of the facility to measure total luminance and the ground reflectance.



Ceiling Mounted Lighting Sensors

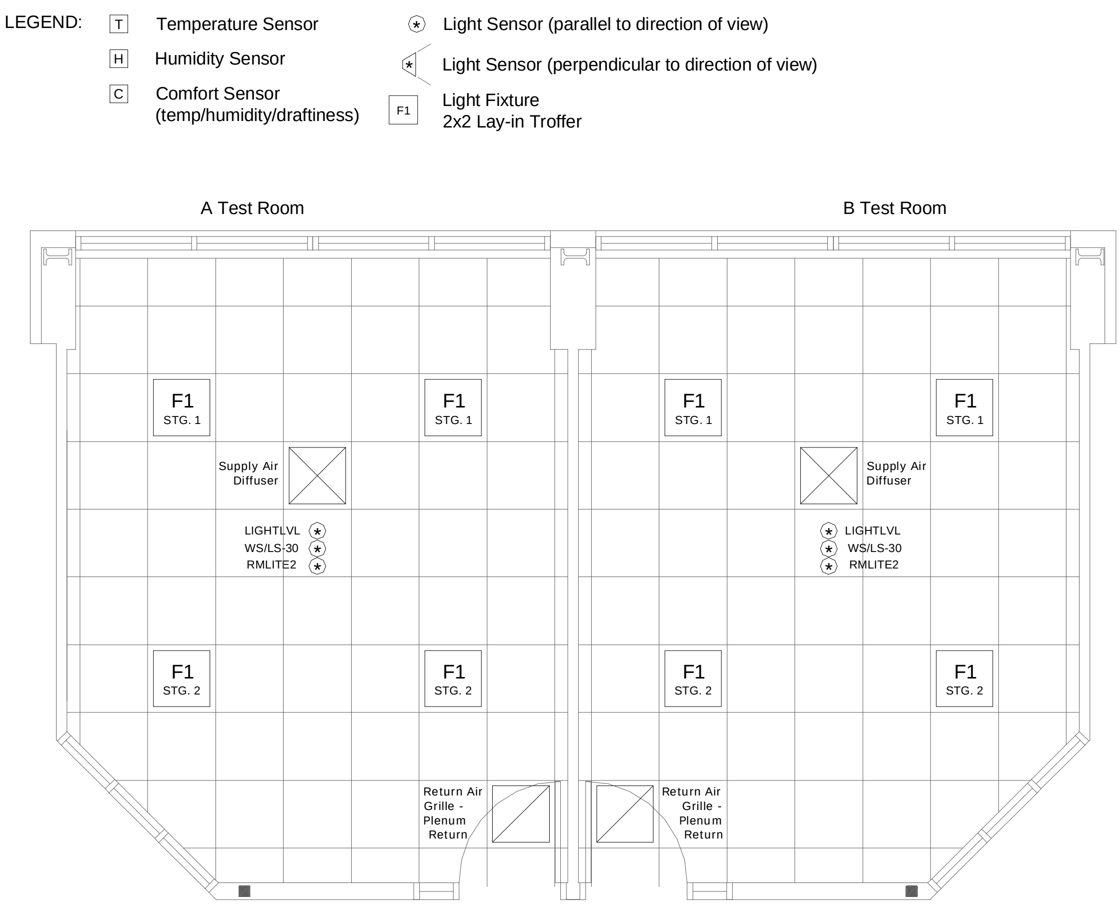


Figure 4.1 Test Room Reflected Ceiling Plan

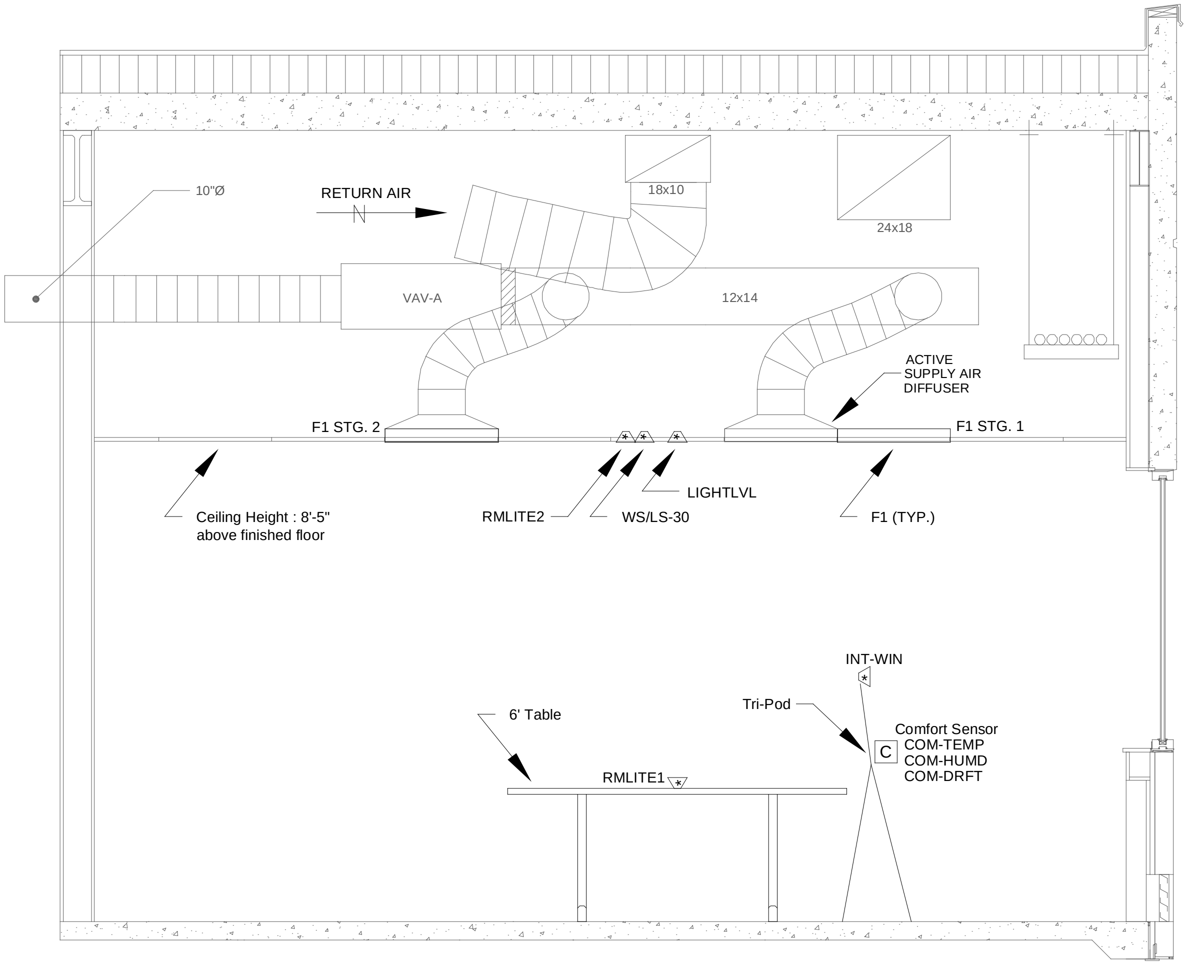


Figure 4.2 Test Room Section

5 Direct Digital Control Systems

5.1 Introduction

The two Direct Digital Control (DDC) systems at the ERS are both commercially available DDC systems. There is one system controls the ERS Test System, which includes AHU-A and AHU-B, eight test rooms, and the associated chilled water and heating water systems. The remainder of the building includes the general service area - media center, offices, classrooms, mechanical rooms, etc. is controlled by the general service DDC system.

5.2 ERS Test DDC System

5.2.1 Overview of ERS Test DDC System

The ERS Test DDC System is based on the modern, commercial-grade Distech Controls' EC-Net^{AX} Building Automation and Energy Management Platform. The system is a comprehensive web-based, multi-protocol platform powered by the Niagara^{AX} Framework®. The open structure creates a common development and management environment for the integration of LONWORKS®, Modbus™, and other control standards. It also provides seamless and intelligent integration of HVAC, Lighting, Access Control, CCTV, Energy Management, and additional building systems. A general EC-Net AX™ system architecture is shown in Figure 5.1.

The ERS Test DDC System has over 800 monitoring and control points trended at 1-minute sampling interval on a server with EC-Net^{AX} Supervisor software; the system has a flexible graphical user interface providing traditional building management functions such as scheduling, trending, alarming, historical data collection and advanced energy management applications.

The DDC system has remote monitoring capability which allows access, and control of the ERS Test System via the model EC-BOS-6 – a compact, embedded controller/server platform that combines integrated control, supervision, data logging, alarming, scheduling and network management functions with Internet connectivity and web serving capabilities.

The direct digital controllers utilized by the ERS Test DDC system are the ECB-650, 450, 350, 253, 203, and 103 microprocessor-based programmable controllers. These controllers are specifically designed to control various building automation applications such as air handling units, chillers, boilers, pumps, cooling towers, central plant, fan coil units, unit ventilator, heat pumps, etc. The controllers use the BACnet® MS/TP LAN communication protocol and are BTL®-Listed as BACnet Advanced Application Controllers (B-AAC) or Application Specific Controllers (B-ASC.) Additional features include large non-volatile flash memory for applications and data storage, built-in real-time clock with rechargeable battery, 16-bit analog / digital converter resolution for analog input channels and 12-bit digital / analog converter resolution for analog output channels.

The ECB series controllers can be custom programed using EC-gfx program as graphical programming interface; the program is free software and is compatible with Windows 7, 8, and 10 platforms. EC-gfx facilitates the configuration of the ECB controllers with a user-friendly, customizable interface and features a wide array of built-in basic and advanced programming blocs such as PID loops, time delay, schedules, real-time clock, optimum start, stage sequencing, logical gates, mathematical and comparator functions, psychometric functions, etc. The ECB controllers and EC-gfx software allows for creating custom program blocks and enables wireless communication.

All the sensors in the ERS Test System are systematically calibrated on a routine basis, either in the field or by the manufacturers. Recalibration schedules are rigorous but flexible to address project needs.

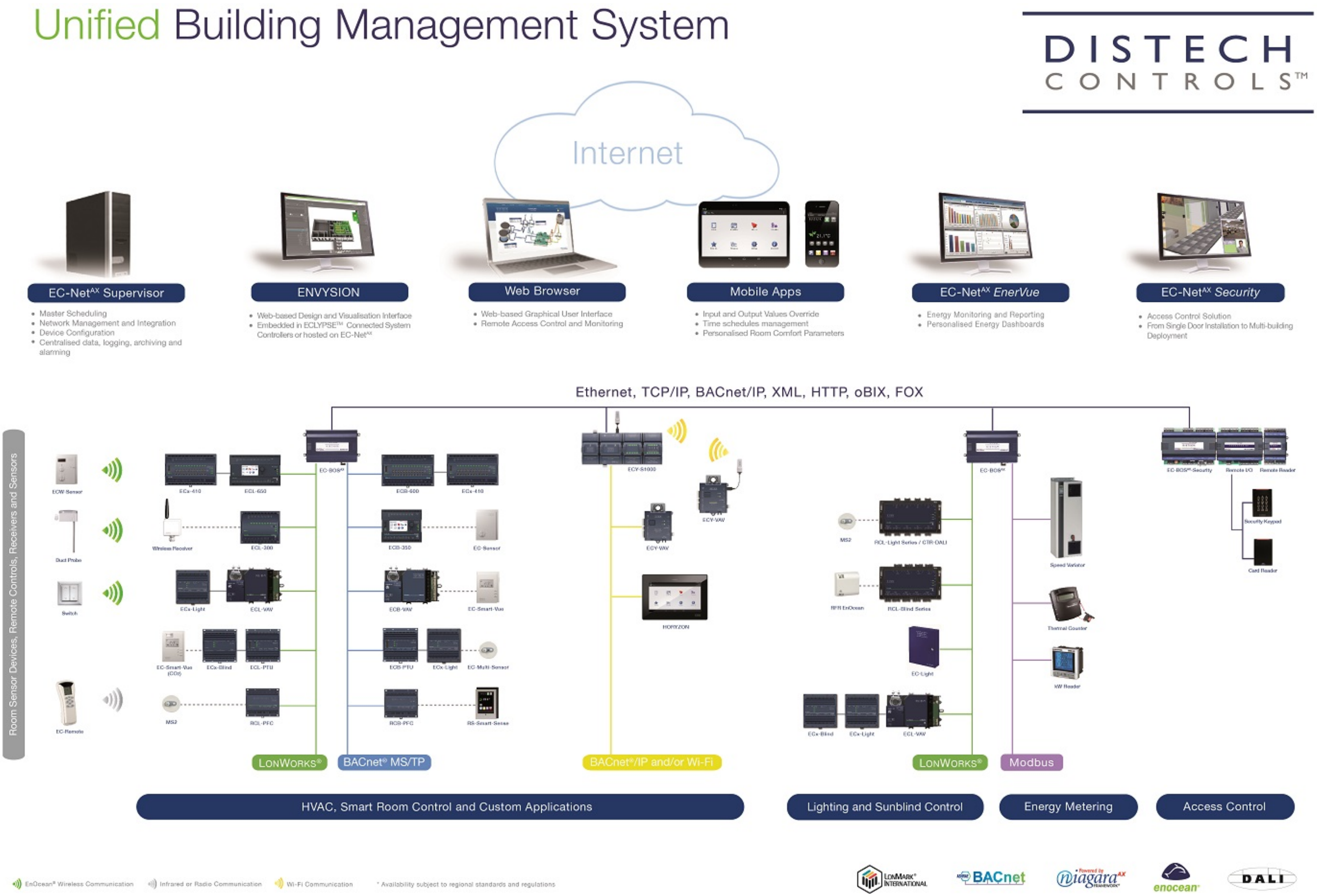


Figure 5.1 General EC-Net^AX System Architecture

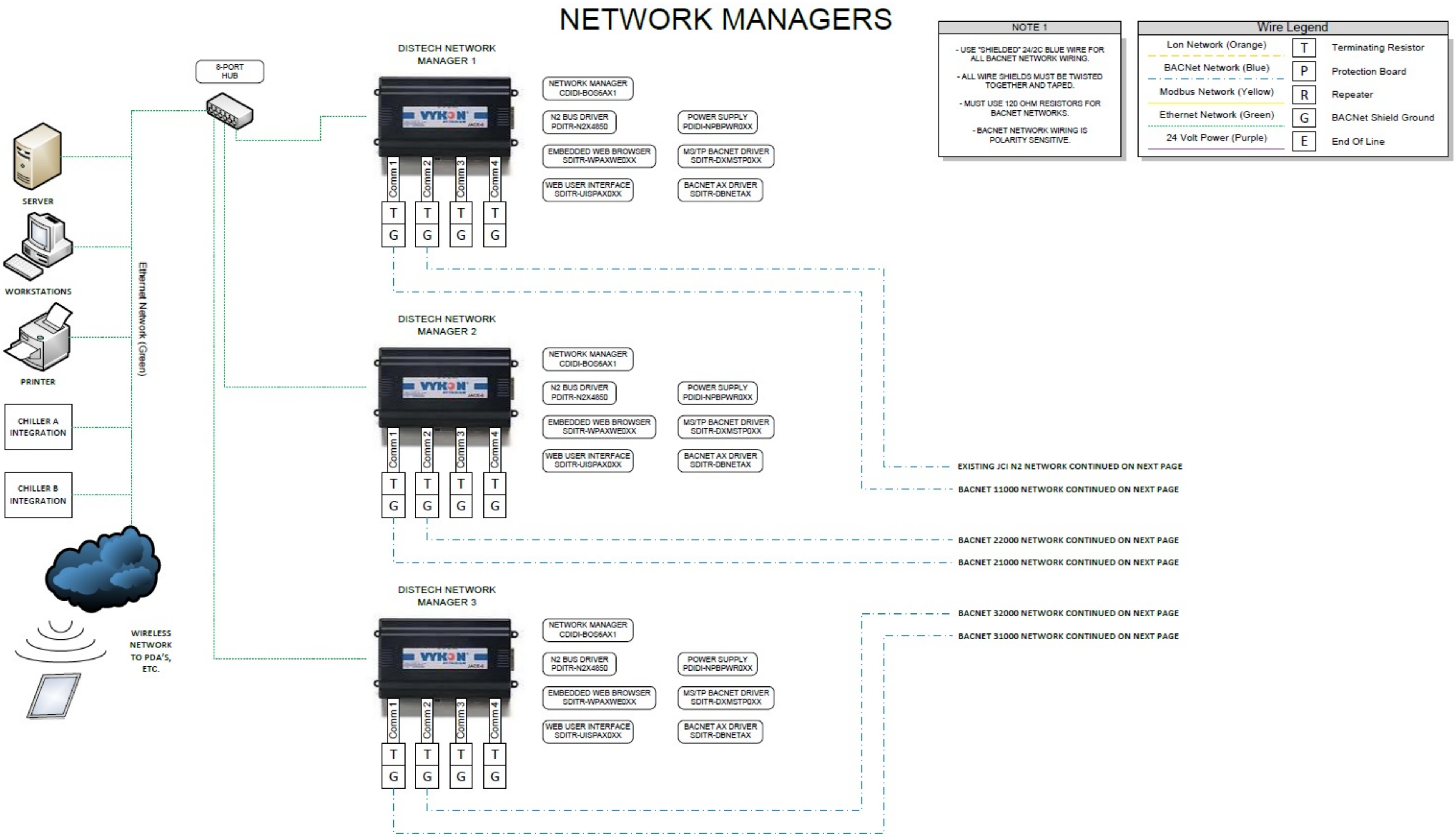


Figure 5.2 ERS Test DDC System Network Architecture 1

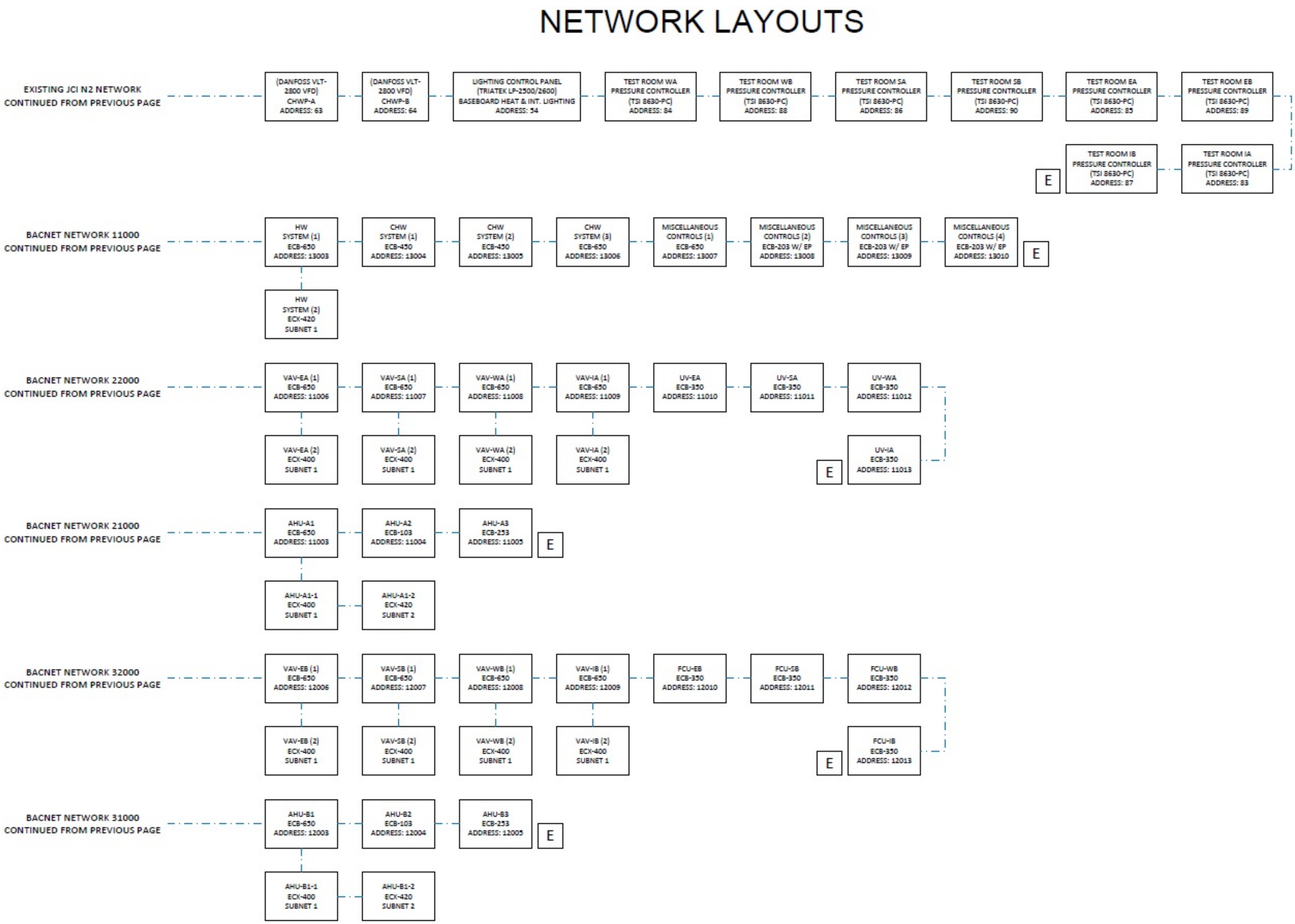


Figure 5.3 ERS Test DDC System Network Architecture 2

5.2.2 Network Architecture
The ERS Test DDC System is a fully native BACnet® system and the network architectural diagrams are illustrated in Figures 5.2 and 5.3.

The primary control network runs BACnet/IP protocol at 100Mbps and connects a server with the EC-Net^{AX} Supervisor, two workstations, one printer, three building network controllers (EC-BOS-6,) and two BACnet interfaces for Chiller-A and Chiller-B. The server with an EC-Net^{AX} Supervisor installed is for programming controllers with the EC-gfx programming tool, for long term data trending, system alarming, and also serves as DDC system user operator interface. Two workstations are located in the mechanical room and also used as local user operator interfaces. Three EC-BOS-6 controllers connect to the local controllers via secondary networks which run BACnet® MS/TP LAN communication protocol at 38.4 Kbps. The EC-BOS-6 controllers also serve web pages, short term data logging, alarming, scheduling, and data transfer to the server. Local field controllers are connected to one of these three building network controllers and provide local equipment and system control.

The ERS Test System utilizes some Johnson Controls N2-bus compatible instrumentation and equipment which is integrated into the primary building network controller #1 via the COM2 port.

5.2.3 Data Collection
Data marked for trending are collected from local field controllers and stored in the three building network controllers before they are uploaded to the server for long term storage. The frequency of data uploading to the server is approximately every 2 hours. The EC-Net^{AX} Supervisor on the server stores the data in an internal database. Daily ERS data sets are extracted from the database and automatically converted to Microsoft Excel spreadsheet format and uploaded to Iowa Energy Center FTP site.

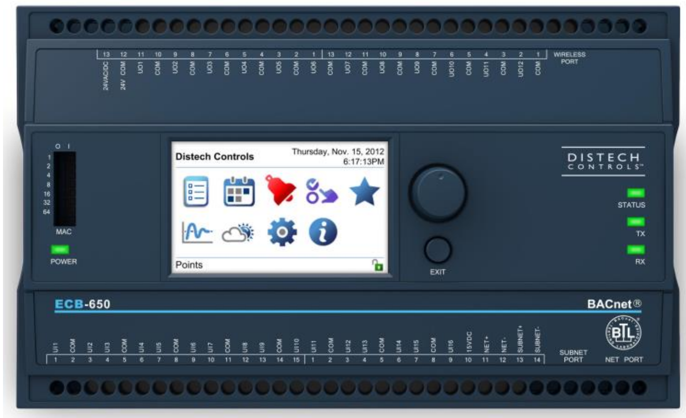
5.2.4 System Remote Access and Control
The ERS Test DDC System can be remotely accessed, monitored and even controlled in real-time via a standard web browser. Local control programs can also be accessed, controlled, modified, and debugged remotely via the EC-gfx programming tool and the three EC-BOS-6 web-enabled building network controllers. Contact the ERS for additional information concerning remote access privileges and restrictions.

5.2.5 Direct Digital Controllers
Network controller model EC-BOS-6: The EC-BOS-6 is a compact, embedded controller/server platform that combines integrated control, supervision, data logging, alarming, scheduling and network management functions with Internet connectivity and web serving capabilities. The EC-BOS-6 allows control of external devices over the Internet and presents real time information to users in web-based graphical views. It is BTL listed when BACnet driver is used and complies with B-BC, BACnet Building Controller, standard. The controller has an IBM PowerPC 440 524MHz processor, 256MB DDR RAM, 48MB Java heap and 128MB of serial flash memory.

Network Controller

Building controller model ECB-650: The ECB-600 Series controllers are microprocessor-based programmable controllers designed to control various building automation applications such as air handling units, chillers, boilers, pumps, cooling towers, and central plant applications. The controller uses the BACnet® MS/TP LAN communication protocol, has maximum 76.8 Kbps and is BTL®-Listed as BACnet Advanced Application

Controllers (B-AAC). The controllers are Open-to-Wireless™ ready, and when paired with the Wireless Receiver, work with a variety of wireless battery-less sensors and switches. The ECB-650 model has a full-color backlit-display and a jog dial for turn and select navigation to access a wide range of internal controller functions. The controller has 16 universal inputs (16-bit analog / digital converter,) 12 universal outputs (10-bit digital to analog converter,) and can connect up to 2 ECx-400 I/O extension modules. ECB-650 has a STM32 (ARM Cortex™ M3) MCU processor, 1 MB non-volatile flash memory for applications and 2 MB non-volatile flash memory for storage.

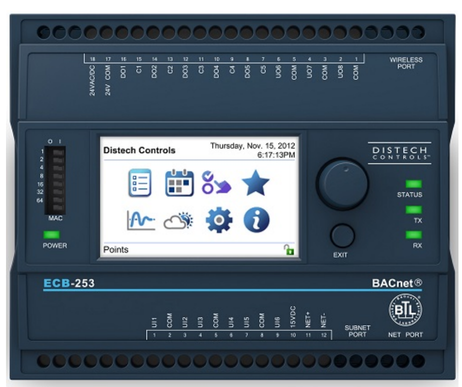


BACnet Advanced Application Controller (B-AAC)

Building controller models ECB-350 & 450: The ECB-350 and ECB 450 controllers are very similar in terms of capability and functionality to the ECB 650. The ECB-350 has 10 universal inputs and 8 universal outputs, and ECB-450 has 12 universal inputs and 12 universal outputs and both models cannot be expanded by connecting to additional I/O extension modules.

Building controller models ECB-103, 203 & 253: The 100 and 200 series controllers are microprocessor-based programmable controllers designed to control roof top units, fan coil units, unit ventilators, heat pumps, chilled beams and other small mechanical equipment. These controllers use BACnet® MS/TP protocol and are BTL®-Listed as BACnet Application Specific Controllers (B-ASC) and are also Open-to-Wireless™ ready when paired with the Wireless Receiver. The ECB-253 model has a full-color backlit-display while ECB-103 and 203 do not. The 203 and 253 models have 6 universal inputs, 3 universal outputs, and 5 digital (triac) outputs while the 103 model has 4 universal inputs, 2 universal outputs, and 4 digital (triac) outputs. All three models have a STM32 (ARM Cortex™ M3) MCU processor, 384 kB non-volatile flash memory for applications and 1 MB non-volatile flash memory for storage.

All these controllers can also be custom programmed using the free EC-gfx programming tool.



BACnet Application Specific Controller (B-ASC)

BACnet Application Specific Controller (B-ASC)

5.2.6 Controller Programming Tool

EC-gfx programming tool is a free Windows compatible software program that has a graphical programming interface and can be used with EC-Net^{AX} platform, or standalone with LNS, BACnet, ECLYPSE BACnet/IP. It provides an intuitive and customizable block-oriented programming environment. The tool has an extensive library of pre-engineered, energy-efficient HVAC application blocks and also includes more than 100 pre-defined functions for HVAC, Comparators, Logic, Math, Time, Input/Output, and others. EC-gfx enables troubleshooting in real-time through live-debugging and the ability to monitor specific process variables and detect errors as they occur.

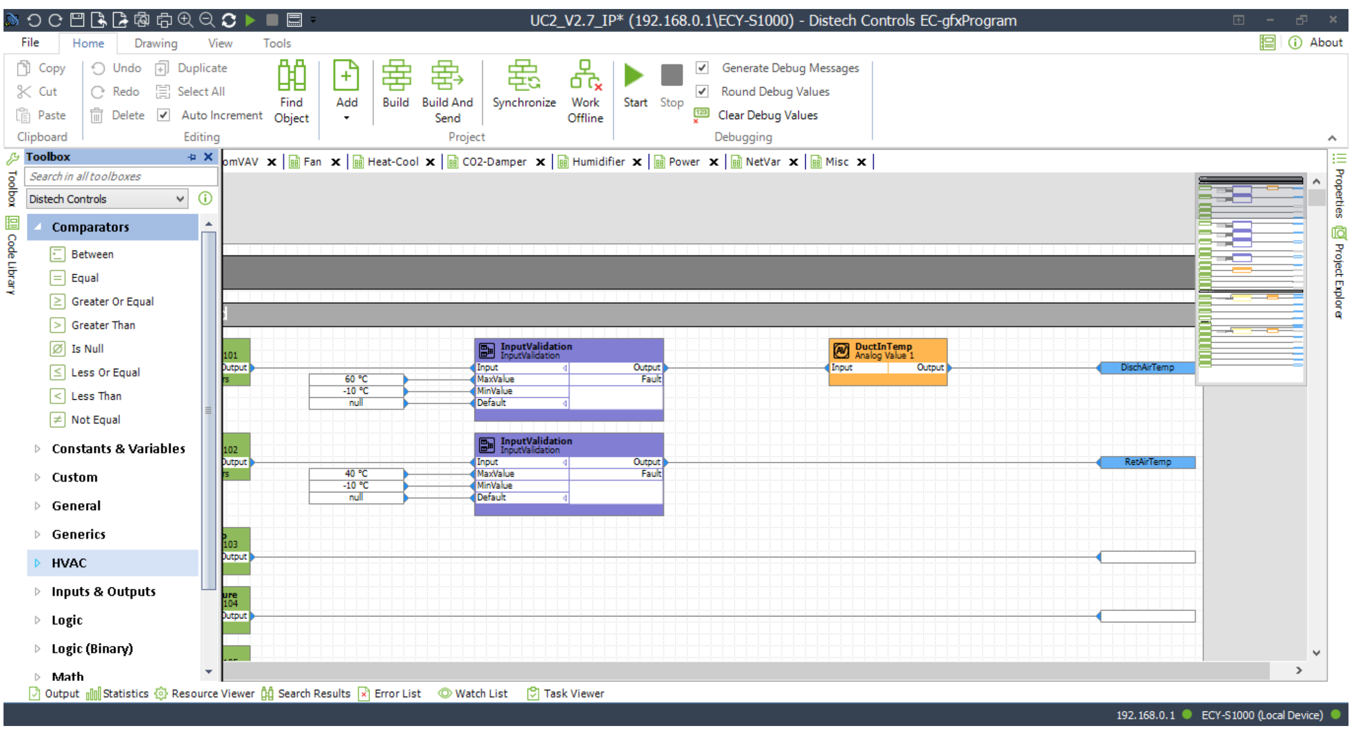


Figure 5.4 EC-gfx Programming Tool

5.2.7 Sensors

The ERS Test DDC system has approximately106 temperature sensors, 36 watt transducers, 18 water flow sensors, 14 air flow sensors, 32 air pressure sensors, 33 lighting sensors as well as additional miscellaneous sensing instruments. To provide a higher degree of accuracy and repeatability compared to conventional industry grade instrumentation, the majority of instrumentation and control devices utilized at the ERS are high laboratory grade precision sensors. Many instrumentation devices are certified to the National Institute of Standards and

Technology (NIST) standards. Critical sensors within the system undergo routine calibration at specific time intervals to ensure senor accuracy and quality data. Sensor calibration is performed by either professional ERS staff or original equipment manufacturers. The standard accuracies for major sensors are as follows:

- temperature: ± 0.25°F (± 0.14°C)
- watt transducers: ± 0.2 % reading
- water flow rate: ± 0.25 % reading: 0.61- 20.2 gpm (0.03 – 1.27 L/s)
- air flow rate: ± 2% of reading, ± 0.25% repeatability
- pressure: ± 0.25 % full scale

A reference temperature sensor with ± 0.019°F (± 0.011°C) NIST certified accuracy is used to field calibrate all the ERS temperature sensors. Additional measuring and control points can be added depending on project requirements.

5.2.8 ERS Test System Control and Monitoring Points

There are over 800 monitoring and control points in the ERS Test DDC System. These points are categorized by: air handling unit, test room, chilled water system, heating water system, and weather and exterior lighting points. For additional information concerning control points and specified accuracies contact the ERS.

5.2.8.1 Air Handling Unit System Points

The test room system air handling units, AHU-A and AHU-B, are identical in the control and instrumentation. This duplicity allows for side by side comparison and as well as testing of different equipment and control strategies.

The following is a summary of the major test room air handling unit control instrumentation devices:

- outside air, return, and exhaust dampers regulate the air flow in the AHU system via electronic actuators
- the airflow rate of the outside air (OA), supply air (SA) and return are (RA) are measured with thermal dispersion based airflow measuring stations with true average and independent multi-point sensing capabilities
- the humidity level of the supply and return air are measured by relative humidity sensors
- an array of four platinum 1000 Ohm Resistance temperature devices, RTDs, provide a single average 1000 Ohm RTD input reading for the supply, return, and mixed air temperatures and heating and cooling coil discharge air temperatures
- carbon dioxide sensors determine the outside, supply and return air CO_2 concentration and help ensure the proper ventilation levels
- the power of the fans is measured with an electric power transducer measures fan motor power while variable frequency drives control fan speeds.

See Appendix A for a typical AHU control schematic diagram.

5.2.8.2 Test Room Points

There are many different components of the test room system that allow for testing of a wide variety of control strategies. Each test room has an overhead air distribution system with a variable air volume terminal air unit, VAV, box. The VAV boxes have both a hydronic coil and a multiple stage electric resistance heater.

The A and B test rooms have floor mounted unit ventilators and fan coil units, respectively. False heating loads are introduced with two stage electric perimeter baseboard heaters located in the test rooms. There are monitoring and control points associated with the unit ventilators, fan coil units and baseboard heaters as well as wall-mounted sensors to measure the room temperature, humidity, and carbon dioxide concentration. A room level pressurization controller maintains the desired differential pressure between the test room and media center.

Test room lighting controls include light level sensors with two stage fluorescent light fixtures with dimmable electronic ballasts.

Room occupants are simulated by cylindrical sheet metal enclosures ”androids”, and are equipped with incandescent bulbs to mimic sensible heat gain as well as CO2 regulators to replicate human respiration ”. These androids can activate computer equipment and control the sensible heat gains and carbon dioxide to simulate typical occupied office conditions.

The following is a summary of the major test room instrumentation devices:

- arrays of four platinum 1000 Ohm RTD sensors provide a single average 1000 ohm RTD input reading of the VAV discharge air temperature.
- entering and leaving water temperatures for the hydronic heating coil and entering supply air temperature are measured with single point 1000 ohm RTD devices.
- power measurements monitor the multi-stage electric heating coil in the VAV box and the lighting.
- differential air pressure is measured at the inlet side of the VAV box to ensure proper air flow control and pressurization of the VAV supply air.
- room pressurization controllers mounted above the doors maintain a constant pressure differential of the room with respect to the adjoining media center.
- wall mounted sensors measure the temperature, humidity and carbon dioxide concentration in the rooms
- research grade light sensors measure the illuminance on specific surfaces in the test rooms.
- ambient light sensors monitor the light level in the test rooms.

See Appendix A for a typical VAV control schematic diagram.

5.2.8.3 Chilled Water and Heating Water System Points

The heating water and chilled water systems have multiple control devices available to monitor operational and performance characteristics. Typical system instrumentation includes flow meters, temperature probes, watt transducers, and pressure sensors.

The following is a summary of the heating and chilled water system instrumentation and control devices:

- electromagnetic flow meters record pump discharge water flow rates
- entering, leaving and mixed water temperatures are measured utilizing immersion resistance temperature devices, RTDs
- electric power transducers provide power measurements for the boiler, chillers and circulating pumps; select pumps have variable frequency drive capability
- water pressure sensors detect pump head and differential pressures
- the hydronic boiler system has additional sensors to track natural gas flow rate, flue gas temperature & oxygen levels and inlet combustion air temperature
- operating and performance parameters for the chillers are monitored via the chiller BACNet communication modules.

See Appendix B and C for the chilled water and heating water system control schematic diagrams

5.2.8.4 Weather and Exterior Lighting Points

Roof mounted weather instruments are used to measure general weather related conditions and exterior lighting sensors are also available to measure outside lighting levels.

The following is a summary description of weather and exterior lighting points:

- outside air temperature and humidity
- outside air carbon dioxide level
- wind velocity and direction
- barometric pressure
- solar beam intensity and solar normal flux
- infrared radiation
- global sky light level
- sky light levels on the east, south, and west facades

- ground light levels on the east, south, and west facades

5.2.9 Control Sequences

The ERS Test DDC System air handling unit and zone control sequences follow applicable control sequences recommended by ASHRAE research project RP-1455 "Advanced Control Sequences for HVAC System." The following logics in ASHRAE RP-1455 have been successfully implemented:

Multiple Zone VAV Air Handling Unit with Chilled Water Cooling Coil and Hot Water Heating Coil

1. AHU system modes
2. Supply Fan Control
   a. Supply fan start/stop
   b. Static Pressure Setpoint Reset
   c. Static Pressure Control
3. Supply Air Temperature Control
4. Minimum Outdoor Air Control - single common damper for minimum outdoor air and economizer functions, and airflow measurement
   a. zone minimum outdoor airflow
   b. outdoor airflow setpoint, for California Title 24 ventilation
   c. outdoor airflow setpoint, for ASHRAE Standard 62.1 ventilation
   d. minimum outdoor air control loop with airflow measuring station across entire intake
5. Economizer Lockout
   a. Fixed Dry Bulb
6. Return Fans with discharge static pressure control
7. Freeze Protection
8. Alarms
9. Automatic Fault Detection and Diagnostics
10. Hierarchical Alarm Suppression
11. Testing/Commissioning Override
12. Plant Requests

Single-Duct Multiple-Zone Variable Air Volume (VAV) System:

VAV Hot Water Reheat Terminal Unit

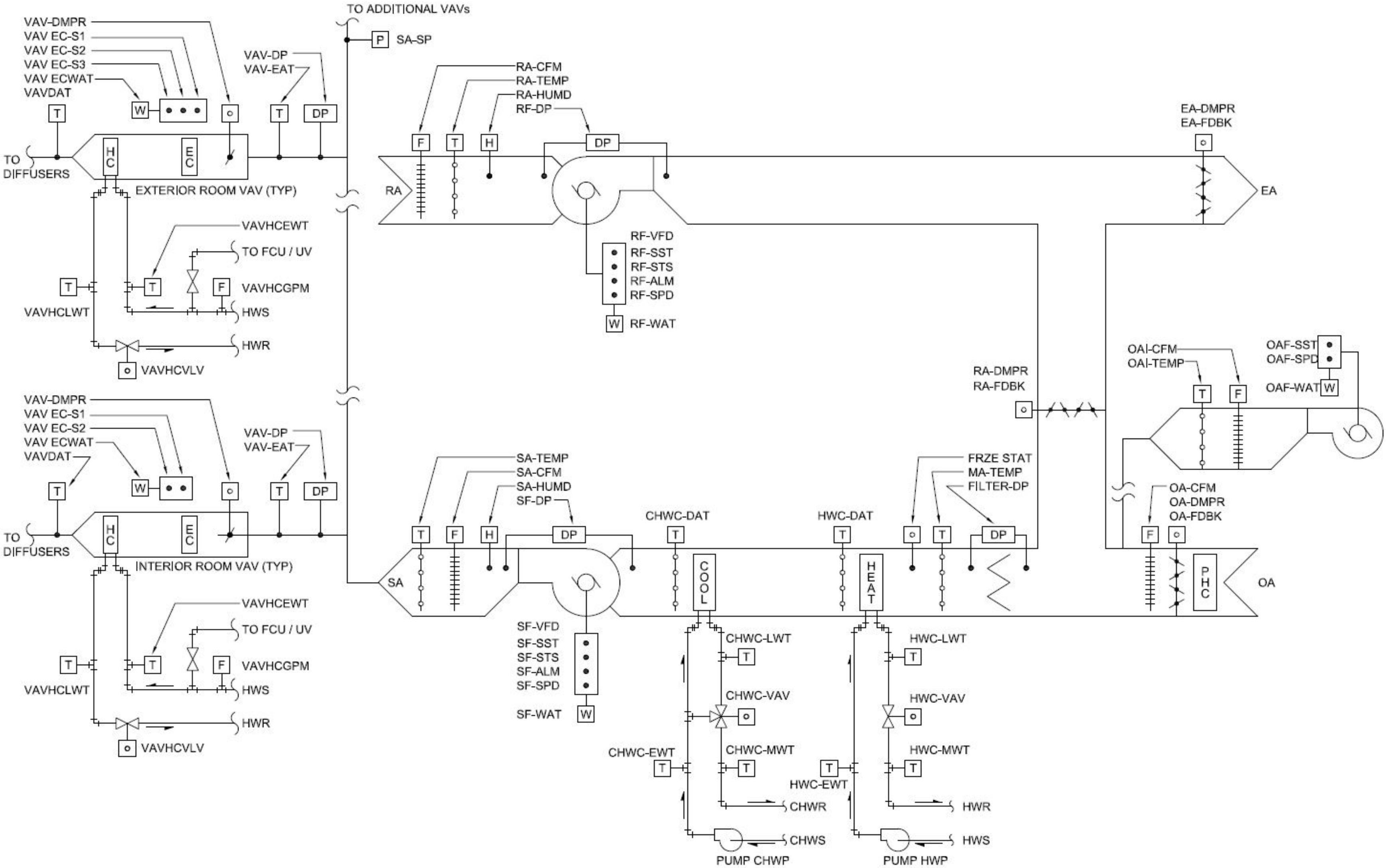
1. Setpoints, loops, control modes, alarms, etc.
2. Design airflow rates schedule
3. Zone minimum outdoor airflow
4. The occupied minimum airflow Vmin with CO_2 sensor
5. Active maximum and minimum setpoints
6. Control Logic
7. Alarms
8. Hierarchical alarm suppression
9. Testing/Commissioning Overrides
10. System Requests
    a. Cooling SAT Reset Requests
    b. Static Pressure Reset Requests
    c. Heating Water Setpoint Reset Requests
    d. Boiler Plant Requests

See Appendixes D & E for fan coil unit and unit ventilator control schematic. For additional information on ERS Test System control sequences contact the ERS.

5.3 ERS General Service DDC System

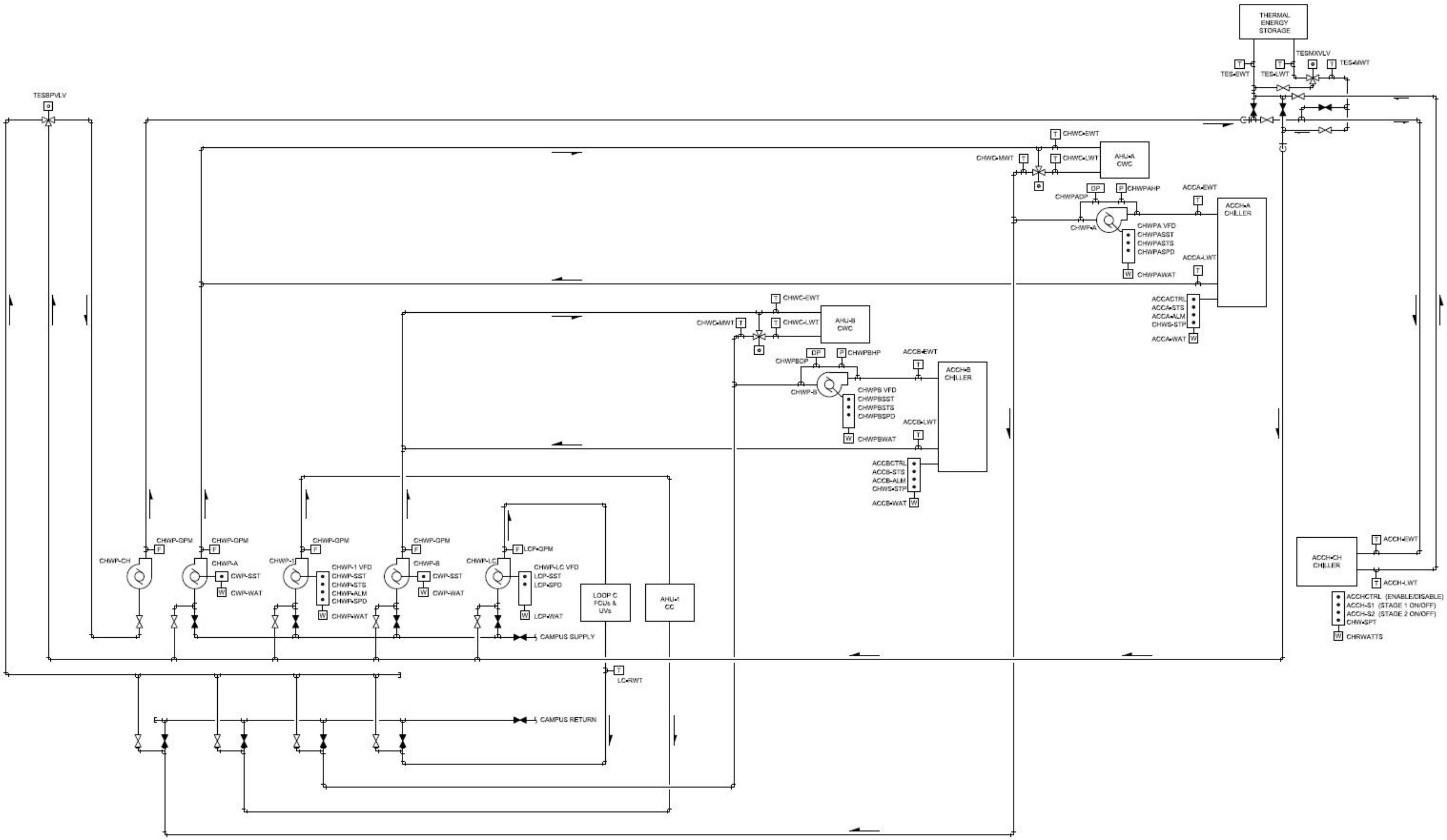
The DDC system for the ERS General Service System is a Schneider Electric/TAC/Invensys I/A Series BACnet compatible system based on Niagara AX framework. This system is associated with the general service air handling unit AHU-1, the fan powered VAV boxes and lighting for the general service areas of the facility, and is completely independent of the ERS Test System. The general service DDC system is for maintaining comfort and indoor air quality in the general service spaces used by ERS staff and occupants attending training and instruction.

Appendix A AHU & VAV Control Schematic



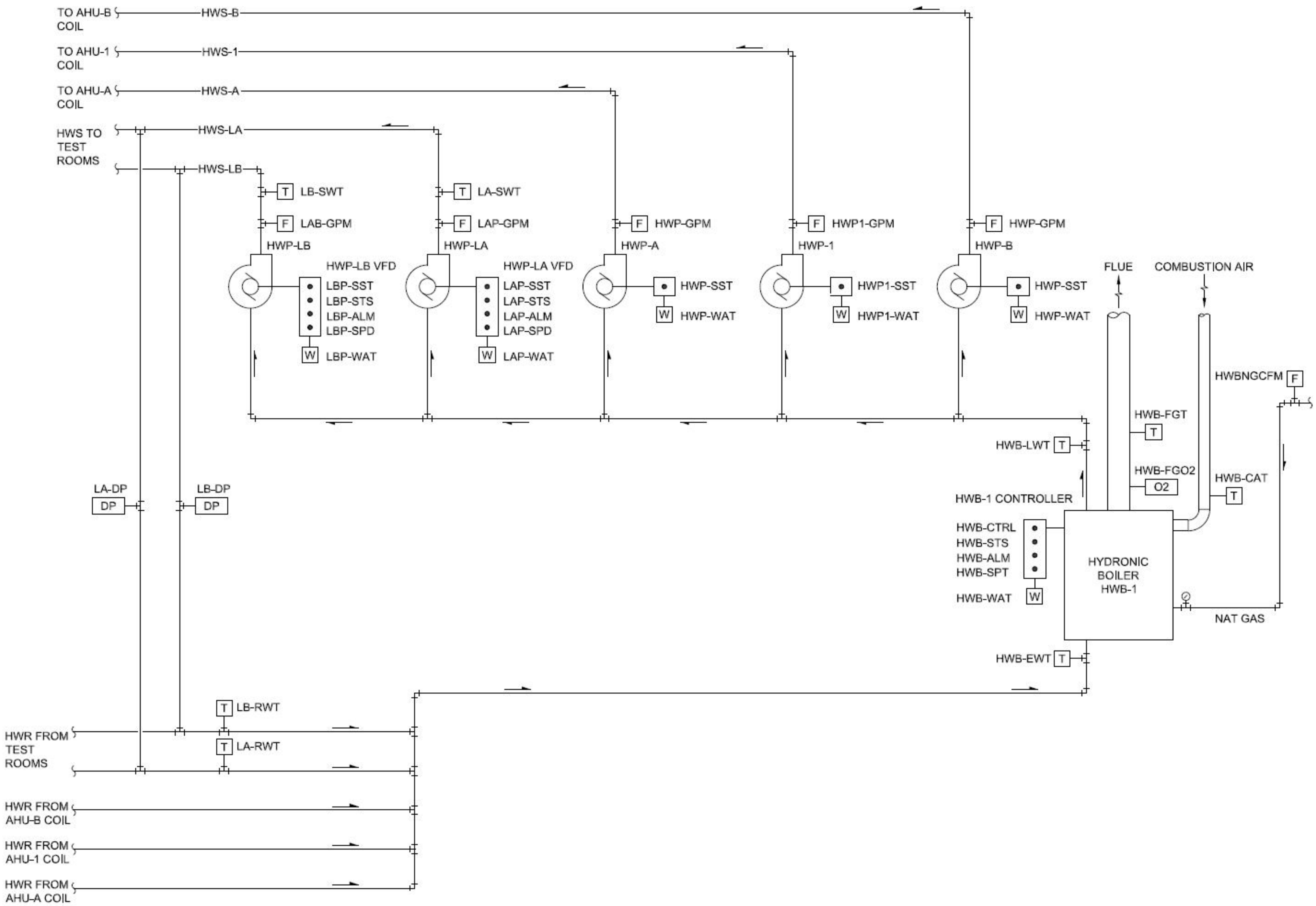
Appendix A. AHU & VAV Control Schematic

Appendix B Chilled Water System Control Schematic



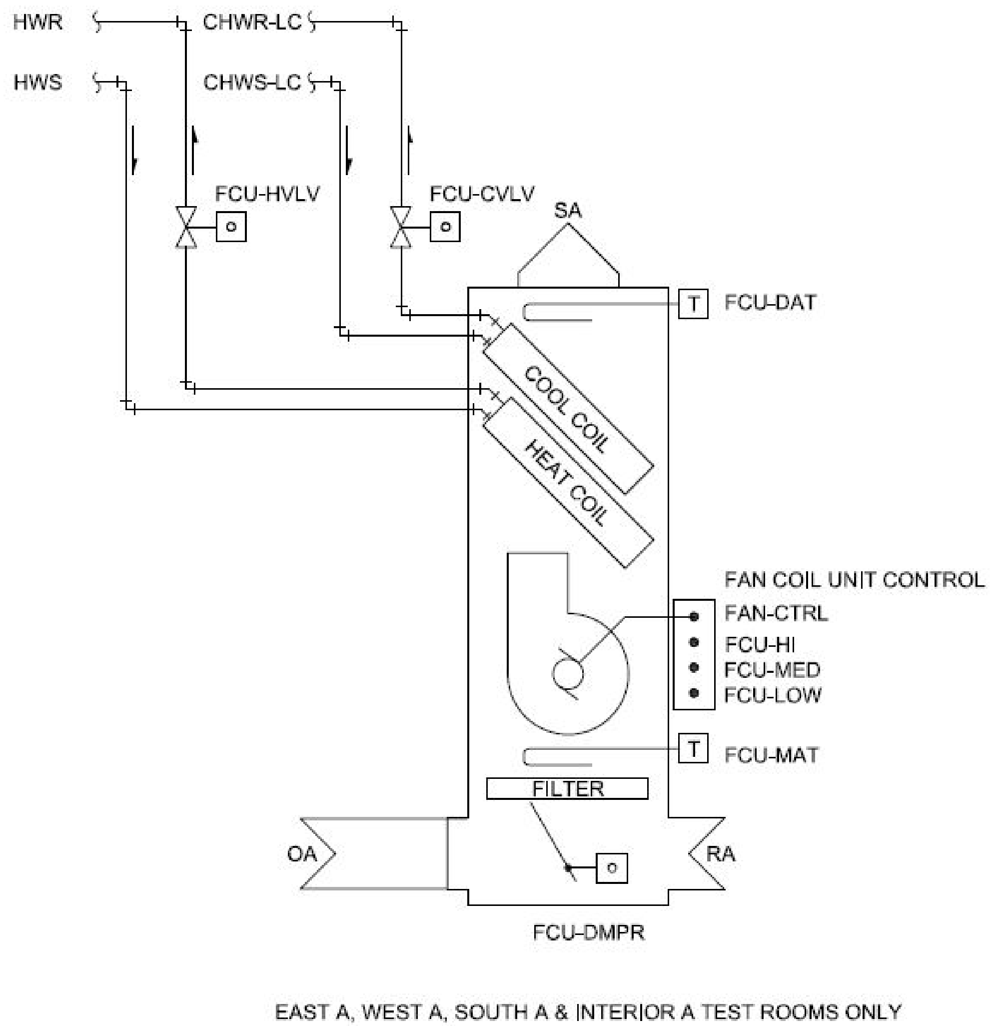
Appendix B. Chilled Water System Control Schematic

Appendix C Heating Water System Control Schematic



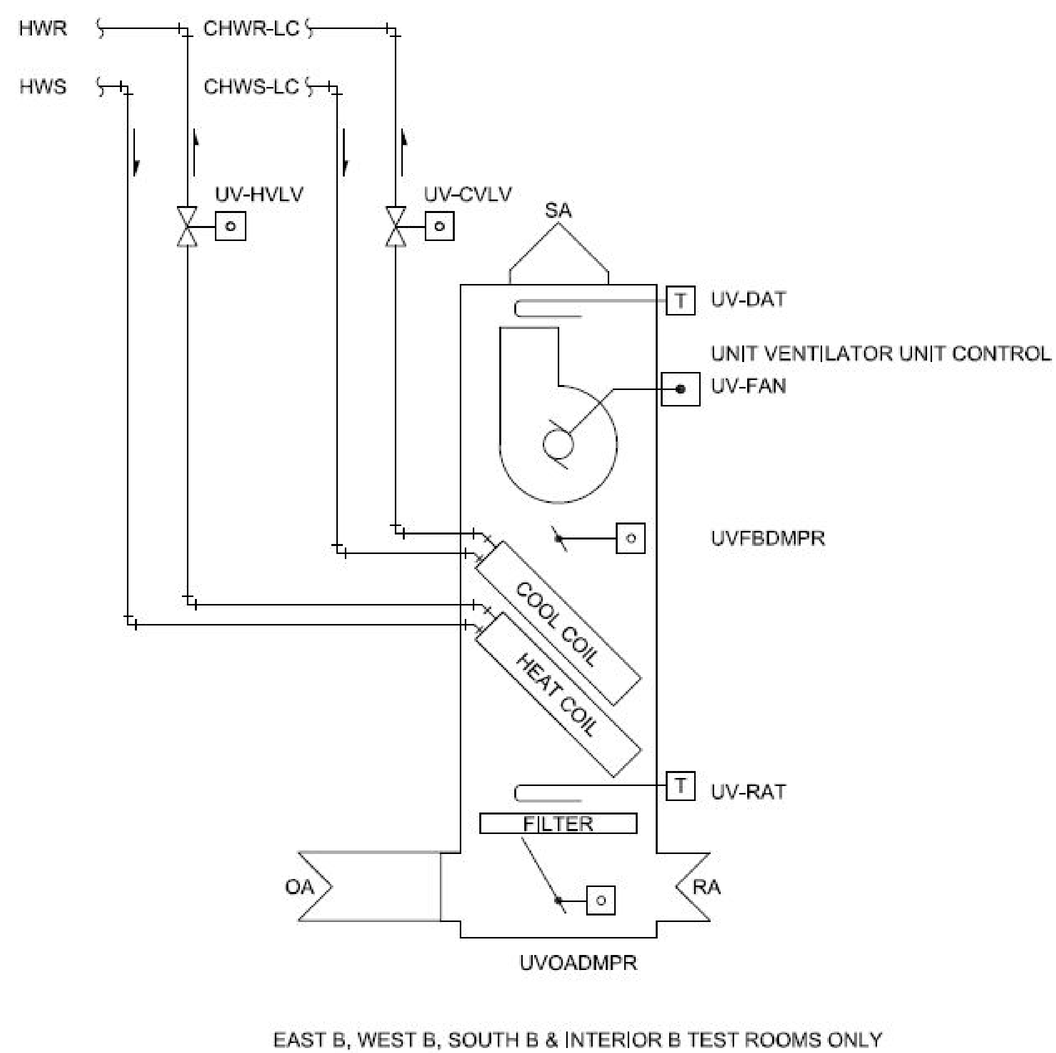
Appendix C. Heating Water System Control Schematic

Appendix D Fan Coil Unit Control Schematic



Appendix D. Fan Coil Unit Control Schematic

Appendix E Unit Ventilator Control Schematic



Appendix E. Unit Ventilator Control Schematic