The Ed Roberts Campus

Technical Report 3

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Mechanical Option

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Contents

Executive Summary

This technical report examines the specific equipment and operation of the mechanical system of the Ed Roberts Campus. Included in the report is a summary of design ventilation and conditioning loads, a detailed description of mechanical equipment, schematic operation diagrams and descriptions, and an evaluation of LEED points for the building mechanical system.

As investigated fully in Technical Report 2, the results from the energy model proved to be inflated when compared to the actualy design loads and capacities of the building. However, these design loads represent a building that works efficiently for the moderate climate zone of Berkeley, CA.

The Ed Roberts Campus uses 100% Outdoor Air to ventilate and condition the spaces within, and the five Air Handling Units provide a total of 278,000 cfm of airflow to the building. 59 Water Source Heat Pumps meet the majority of the cooling load with zone level control for each space. A total of nine exhaust fans remove all air from the building and basement parking garage. Chilled water for the HVAC system is supplied by two rooftop cooling towers. Hot water for the HVAC system is supplied by two gas-fired boilers in the rooftop mechanical room. In addition to the airside cooling and heating capabilities, a radiant floor system meets some of the load in the large open lobby and courtyard spaces and is supplied by the same hot and chilled water as the airside equipment.

The building owners believe that if LEED certification was applied for, a rating of LEED Gold could be acheived. While a complete evaluation is out of the scope of this report, an evaluation of small sections of LEED 2009 For New Buildings and Major Renovations shows that a total of 6 points could be gained from the Energy and Atmosphere section, as well as 7 points from the Indoor Environmental Quality section. These points were based on information readiliy available, and it is possible that more points could be awarded.

Building Overview

The Ed Roberts Campus is a 2-story, 80,000 sq. ft., transit-oriented community center located in downtown Berkeley, California. The campus is connected to a BART Station (Bay Area Rapid Transit) and is designed with a focus on accessibility for people with disabilities. Completed in 2011, the ERC is home to exhibition spaces, meeting spaces, a child development center, a fitness center, vocational training facilities, and offices.

Every square foot of the building is designed far and above the requirements of the Americans with Disabilities Act through a design concept called "Universal Design". Universal Design aims to create environments that are useful for people of all ages and abilities without additional cost. Extra-wide corridors, automatic doors, two-sided elevators are examples of this design ideal. In addition, the ERC's fully accessible connection to the BART station works to connect people directly to airports and bus stations around the city.

Leddy Maytum Stacy Architects

Design Overview

The Ed Roberts Campus is a community center with a focus on people with disabilities through a design concept called "Universal Design". This concept, which is to design the building to be accessible to as many people as possible, also carries over into the mechanical system design through very high indoor air quality standards. First, outdoor air entering the AHUs is treated by a two-stage filtration system. Second, the 100% Outdoor Air system allows for no contaminants to be recirculated in the building by exhausting all conditioned air back outside.

Climate Conditions

The Ed Roberts Campus is located in Berkeley, CA near the San Francisco Bay area. The climate conditions in the table below, taken from ASHRAE 2009 Handbook of Fundamentals, represent the design conditions at San Jose International Airport. This airport is also in Climate Zone 3C and, unlike the closer Oakland or San Francisco International Airports, is a similar distance away from the ocean as the ERC. Therefore it should be a reasonable representation of the conditions at the site. The indoor temperature conditions are determined by zone thermostats throughout the building and controlled by the occupants.

Table 1 - Outdoor Design Conditions

	Heating, 99.6%	Cooling , 0.4%		Dehumidification, 0.4%		
	DB [°F]	DB [°F]	MCWB [°F]	DP [°F]	HR [°F]	MCDB [°F]
San Jose Intl. Arpt.	35.7	92.3	66.9	63.1	86.5	76.6

Ventilation Requiremnts

With an emphasis on superior air quality proper ventilation air is necessary for the Ed Roberts Campus, and the mechanical system does provide adequate ventilation. The table below, from Technical Report 1, shows the ventilation rates as calculated using ASHRAE 62.1 procedures for Dedicated Outdoor Air Systems. As all five of the Air Handling Units in the building supply 100% Outdoor Air, the minimum ventilation outdoor air flows were easily met by the total airflow provided by the AHUs for conditioning.

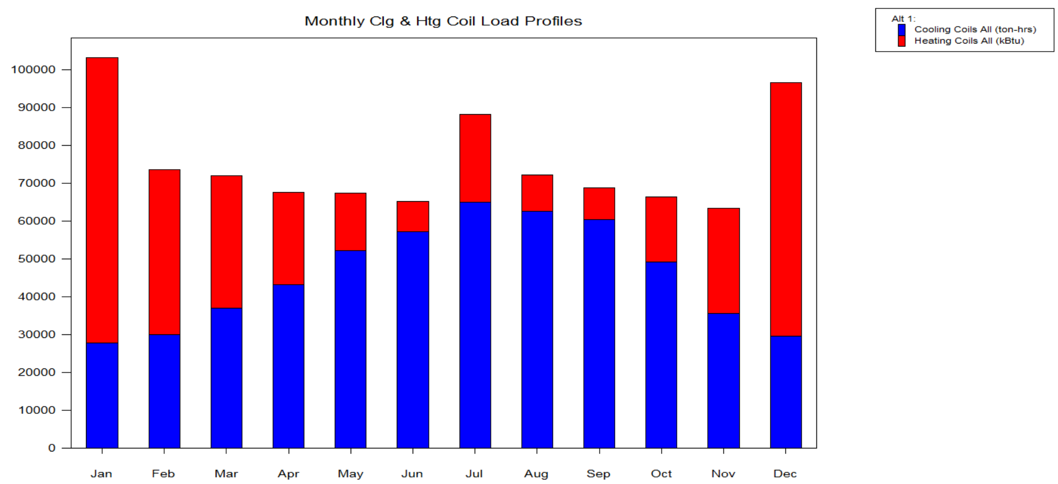
Table 2 - Ventilation Rates

	Design CFM	Outside Air %	Total Outside Air	62.1 Required Outdoor Air	Compliance
AHU-1	7,800	100	7,800	3388.94	Yes
AHU-2	5,500	100	5,500	513.18	Yes
AHU-3	3,500	100	3,500	999.67	Yes
AHU-4	6,000	100	6,000	1780.92	Yes
AHU-5	5,000	100	5,000	1178	Yes

Heating and Cooling Loads

The following chart graphs the monthly load profile for equipment in the building, shown in units of Ton-Hrs for cooling and kBTU for heating. The first chart shows that, for the most part, the total building load is somewhat constant throughtout the year. There are jumps in load in the coldest winter months, where heating loads are increased, and in the warmest summer month where cooling load is highest. However, this seems to represent a reasonable profile for a building in a temperate climate such as Berkeley, CA.

Figure 1- Monthly Load Profiles



The following table compares the designer loads for each AHU to the total cooling loads from a Trane Trace 700 model performed for Technical Report 2. It was reported that the model vastly over estimated the loads of the space due to difficulties modeling the specific configuration of the ERC's mechanical system. Upon further evaluation, however, it was determined that the listed design capacities for AHUs did not take into account the capacities of Water Source Heat Pumps assigned to the AHU zon es. The table below shows the design capacities of each AHU, as well as the design cooling and heating capacities for all 59 WSHPs. The results still show that the model loads do not exactly reflect the designed capacities for the equipment, but this is a much better representation.

Table 3 – Comparison of Design and Model Loads

	Design Capacity		Model Loads	
Equipment	**Cooling [MBH]**	**Heating [MBH]**	**Cooling [MBH]**	**Heating [MBH]**
AHU-1	84	295	1,185.10	871.9
AHU-2	59	208	172.4	120.2
AHU-3	38	132	580.1	327.2
AHU-4	65	227	787.1	427.6
AHU-5	135	189	52.6	67.6
WSHP	1478	1789		
Total	1859	2840	2777.3	1814.5

Energy Rates, Usage, and Costs

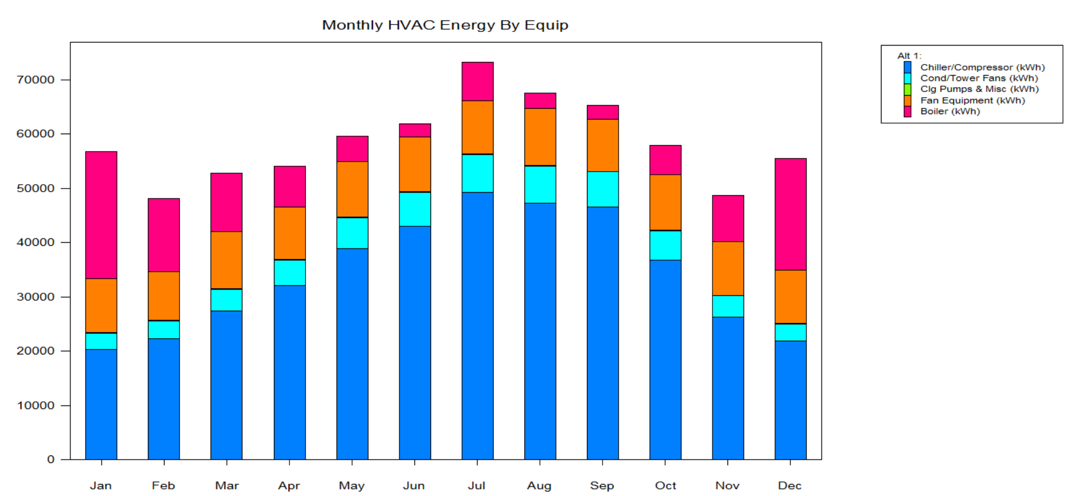
This table is referenced from the Pacific Gas & Electric Company website and shows the Demand and Total Energy charge rates for buildings zoned like the Ed Roberts Campus. This information was used in the Trane Trace 700 model from Technical Report 2, and the resulting energy costs for the building can be found below.

Table 4 - PG&E Electric Rates

Rate Schedule	Customer Charge	Season	Demand Charge [per kW]			Time of Use Period	Total Energy Charge [per kWh]		
			Secondary	Primary	Transmission		Secondary	Primary	Transmission
A-10 TOU	$4.59959 [per meter/per day]	Summer	$13.87	$13.10	$9.36	Peak	$0.17479	$0.16169	$0.13592
						Part-Peak	$0.16711	$0.15621	$0.13092
						Off-Peak	$0.14377	$0.13526	$0.11196
		Winter	$6.46	$6.67	$5.00	Part-Peak	$0.12798	$0.12044	$0.10640
						Off-Peak	$0.10796	$0.10405	$0.09135

This graph displays the energy use of specific equipment types throughout the building in kWh. The energy use of the equipment matches with the load profiles, with boiler energy spiking in December and January and cooling equipment energy peaking in July. The maximum energy use of the system is just above 70,000 KWh during the month of July.

Figure 2- Monthly Energy Use by Equipment Type [kWh]



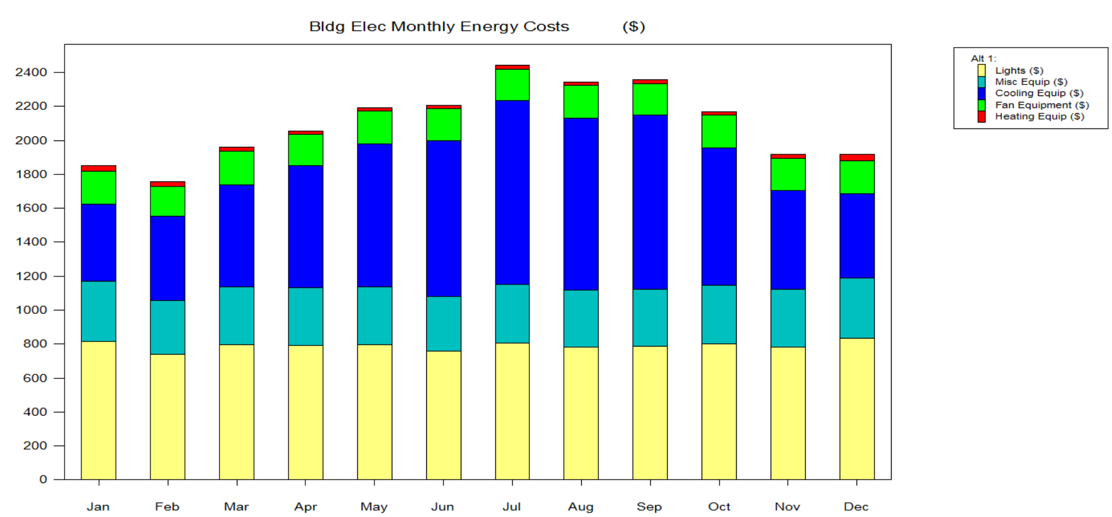
The table below lists the monthly utility cost of the Ed Roberts Campus, according the the Trace 700 model analysis. Utility cost information was gathered from the Pacific Gas and Electric Company website. Information is not available on the designed or actual operational costs of the building but, based on the results shown in the load section, it can be assumed that these values are somewhat inflated.

Table 5 - Monthly Utility Costs

Month	Utility Cost ($)
January	4,409
February	4,815
March	4,477
April	5,057
May	5,443
June	5,673
July	5,955
August	5,905
September	5,991
October	5,335
November	4,661
December	4,447
Total	62,168

The total cost of utilities per year is equal to 0.94 $\$/ft^2$ based on a building area of 66,166 ft^2, which is the area of conditioned space within the building (not including mechanical and parking garage spaces). The figure below, displaying monthly electricity costs per equipment type in kWh, shows that lighting is a constant high demand for electricity use and costs. The Trane Trace 700 model used standard fluorescent lighting to model the building, but the designer did specify some more efficient lighting fixtures that may reduce energy use.

Figure 3 - Monthly Electricity Costs by Equipment Type



Mechanical System

Equipment

Cooling

Cold water is supplied by two rooftop cooling towers. Return cold water enters at approximately 82 F and leaves at 70 F with a design flowrate of 200 gpm. This cold water is used to supply the water coils in AHUs 1-4, all 59 of the zone level water sourced heat pumps, and the three zones of radiant flooring.

Table 6 - Cooling Tower Schedule

Cooling Tower	Flow	Design Wetbulb	Water Temp F	
	GPM	F	Entering	Leaving
CT-1/2	200	63	82	70

Heating

Hot water is supplied by two gas-fired boilers located in the mechanical room in the basement (garage). Each boiler has an output capacity of 882 MBH, and minimum operating efficiency of 95%. Water enters the boiler at 80 F and is heated to 120 F for supply to water coils in all five AHUs, zone level water sourced heat pumps, and radiant flooring.

Table 7- Boiler Schedule

Boiler	Output MBH	Fuel Type	Water Flow GPM	Water Temp F	
				Entering	Leaving
B-1/2	882	Natural Gas	40	80	120

Airside Equipment

The airside equipment for the building includes five Air Handling Units, 57 zone-level water source heat pumps, and nine exhaust fans. AHU-1, AHU-3, and AHU-4 are constant volume units. AHU-1 serves the south end of the east wing and supplies 7,800 cfm. AHU-3 and AHU-4 serve the South and North, respectively, ends of the western wing, and supply 3,500 and 6,000 cfm of airflow. The final two air handling units utilize fans with Variable Frequency Drives, and thus supply varying volumes of air to the space. AHU-2 supplies the BORP office area with 5,500 cfm of air, and AHU-5 serves the courtyard area with 5,000 cfm.

Table 8 - Air Handling Unit Schedule

AHU	Area Served	% Outside Air	CFM	Fan RPM	Cooling Min Cap. MBH	Heating Min Cap. MBH
AHU-1	East Wing - South	100	7,800	1,089	84	295
AHU-2	BORP	100	5,500	1,734	59	208
AHU-3	West Wing - South	100	3,500	2,485	38	132
AHU-4	West Wing - North	100	6,000	1,169	65	227
AHU-5	Covered Court	100	5,000	1,993	135	189

These Water Source Heat Pump units manufactured by McQuay meet most of the cooling and heating loads of the zones they serve in the building. The zones of the building are served by one of the following types of heat pump, based on the load requirements of the space, and there were a total of 59 units at design. Each unit contains one water coil for both heating and cooling needs. Each unit also contains one supply fan specified as a double inlet, forward curved centrifugal fan. More design data is available in the table below.

Table 9 - Water Source Heat Pump Schedule

WSHP	Fan CFM	Cooling Capacity BTU/Hr	Heating Capacity BTU/Hr
HP-1	230	7,398	9,052
HP-2	300	9,084	11,509
HP-3	400	12,766	15,397
HP-4	500	17,869	20,427
HP-5	630	20,972	25,250
HP-6	800	27,648	31,733
HP-7	1,000	34,586	39,067
HP-8	1,200	39,071	45,707

Since the ERC utilizes a 100% Outdoor Air system, all air is exhausted by nine fans that serve different areas of the building. Exhaust Fans 1, 3,4,5, and 7 serve the BORP Office and other general office spaces. EF-2 serves restroom exhaust requirements. The largest fan, EF-6, serves the entire basement level parking garage with 72,000 cfm of airflow. The remaining fans serve smaller electrical, elevator and garbage rooms.

Table 10 - Exhaust Fan Schedule

Exhaust Fans	Type	Area Served	CFM	Motor RPM
EF-1	Centrifugal	BORP	5,500	1,725
EF-2	Centrifugal	Restroom	2,600	1,725
EF-3	Centrifugal	General	1,200	1,725
EF-4	Centrifugal	General	1,000	1,725
EF-5	Centrifugal	General	800	1,725
EF-6	Centrifugal Double Inlet	Garage	72,000	1,725
EF-7	Centrifugal	General	1,600	1,725
EF-8	Wall Propeller	Garbage Room	350	1,650
EF-9	Centrifugal	BART Elev. Room	1,200	1,725

Pumps

There are a total of seven dedicated pumps that are used in the HVAC system. Pump 7 is the only pump that does not run in parallel with another and served the radiant floor system. Pumps 1/2, 3/4, and 5/6 are pairs of parallel pumps that work on the water side of the system to move water from the cooling towers and boilers to the water coils in the AHUs and WSHPs. Pump arrangements P-1/2 and P-5/6 are both end suction type and provide the most flow. P-1/2 is located in the basement and boosts cold water from the cooling towers to the radiant floor system and on to P-5/6 which boosts water through to the water coils for primary cooling. P-3/4 is located in the mechanical room on the roof and pumps hot water from the boilers to the radiant floor system and water coils.

Table 11 - HVAC Pump Schedule

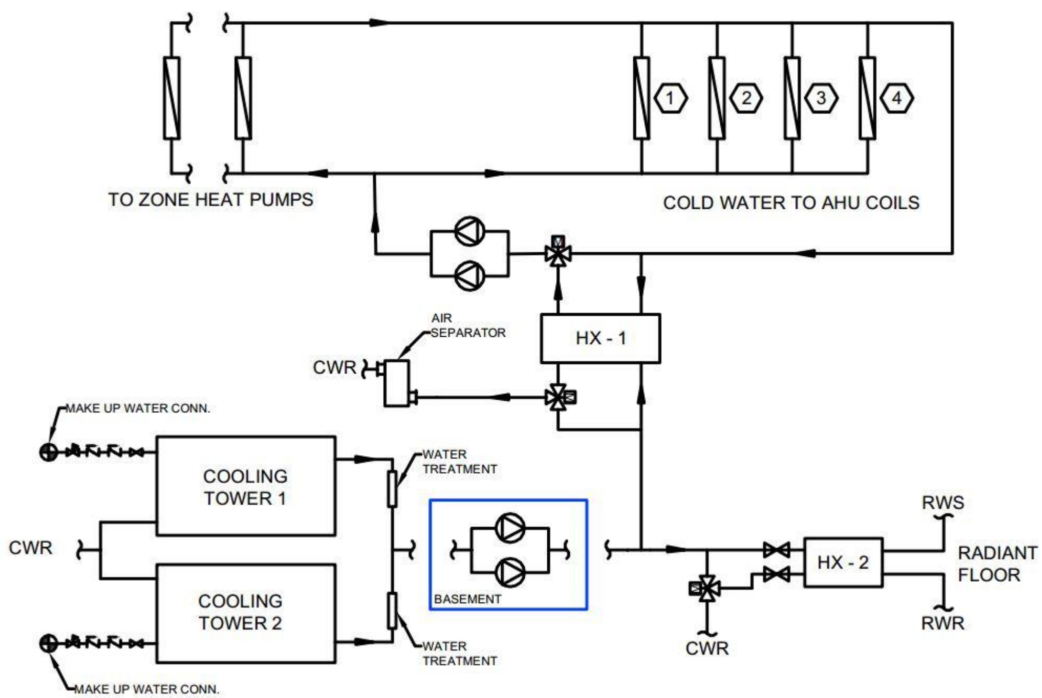
Pumps	Service	Type	GPM	Total Head [FT W.G.]
P-1/2	Cooling Towers	End Suction	200	40
P-3/4	Boilers	Inline	45	51
P-5/6	Condenser Water	End Suction	220	67
P-7	Radiant Floor	Inline	60	53

System Schematics and Operation

Chilled Water System

The chilled water return enters the each cooling tower at 82 F. Each tower also has a domestic water connection for any make-up water that is required in the system loop, and the connection is fitted with check valves to prevent backflow contamination into the domestic water system. Once this water has been cooled to the supply temperature of 70 F, it is treated by two purification filters before being immediately routed to the basement mechanical room where pumps P-1 and P-2, running in parallel, send water into the system. A portion of the chilled water supply is routed through heat exchanger HX-2 and to the radiant floor system. The radiant floor return water is run through an air separator, AS-2, and then pumped back to the cooling towers by pump P-7. The other portion of chilled water supply is routed through HX-1 and then pumped to cooling coils by pumps P-5 and P-6, which also run in parallel. Note that chilled water is not supplied to the water coil in AHU-5 because this packaged AHU contains a Direct Expansion refrigerant coil for its cooling purposes. The returning chilled water is then run through an air separator, AS-1, and back to the cooling towers for recirculation.

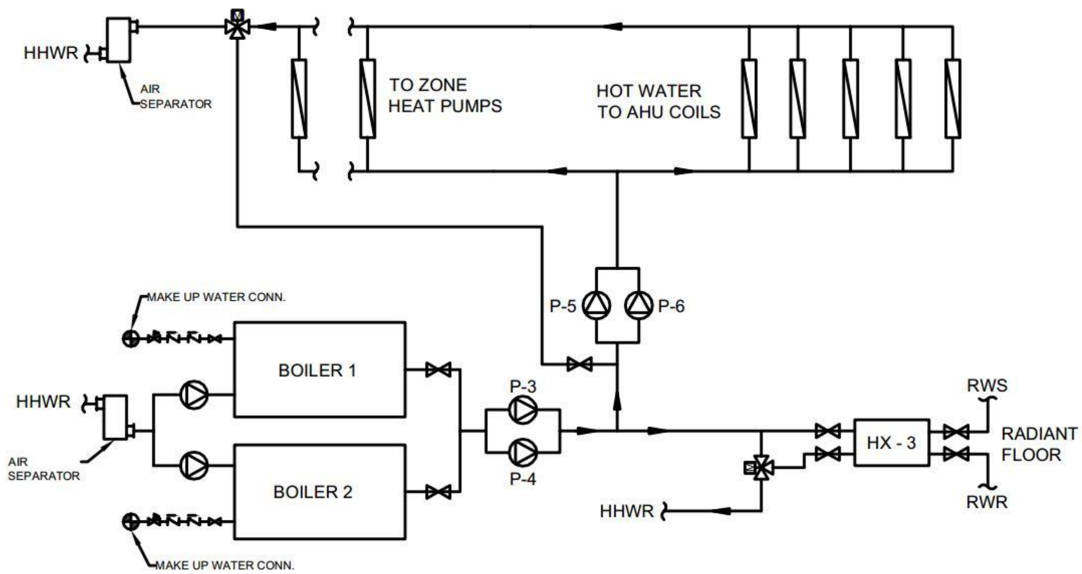
Figure 4 - Chilled Water Schematic



Heating Hot Water System

Returning hot water enters the two boilers by primary pump specified by the boiler manufacturer. The water is heated to a supply temperature of 120 F and run through two pumps, P-3 and P-4, running in parallel to be supplied to the system. Part of the hot water supply is run through a heat exchanger, HX-3, before entering the radiant floor system. Radiant return water is run back through HX-3 before returning back to the boilers. The other portion of heating hot water supply is sent through an additional two pumps, P-5 and P-6, and then distributed to the AHU water coils and the water sourced heat pumps. The return water from these coils is run through air separator AS-1 and combined with the radiant return water to run through AS-3 before recirculating through the boilers. Any required make up water can be supplied through domestic water connections on both boilers. These connection, like the cooling tower connections, are fitted with check valves to prevent contaminating backflow to the domestic water system.

Figure 5 - Heating Water Schematic



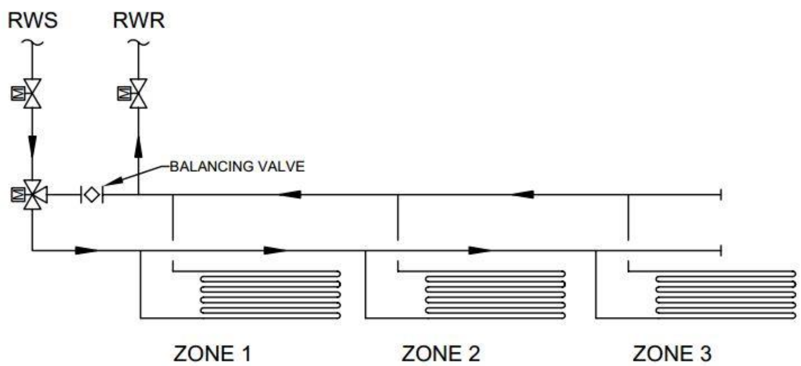
Radiant Floor

The building utilizes a radiant floor heating and cooling system for the open lobby and courtyard spaces. The three zones of the system receive supply water from the cooling towers and boilers that is mixed to the appropriate temperature with a zone controlled mixing valve. In addition, a small portion of return water can also be mixed for greater control. Cooling and heating capacities can be found in the table below.

Table 12 - Radiant Floor Schedule

	Area Served	Cooling Capacity [MBH]	Heating Capacity [MBH]
RF Zone 1	Courtyard North	27	18
RF Zone 2	Courtyard South	30	20
RF Zone 3	Lobby	58	30

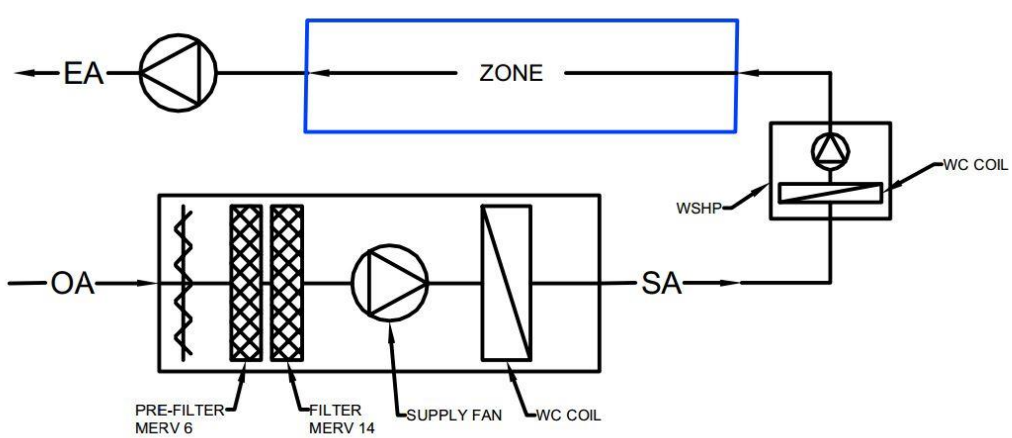
Figure 6 - Radiant Floor Schematic



Airside System

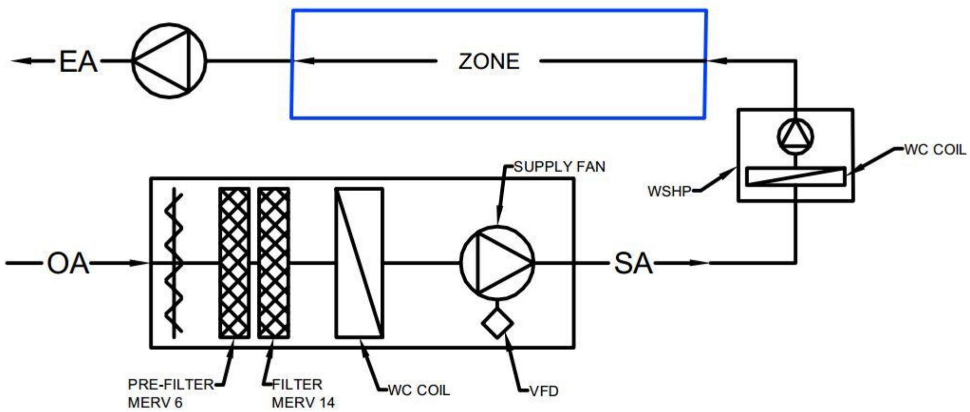
The airside system has several different configurations for the five different Air Handling Units. AHUs 1,3, and 4 have identical schematic operation, as illustrated in the first diagram. These three constant-volume units draw 100% outside air which is immediately passed through metal dampers and two filtering stages, which consist of a 2" MERV 6 pre-filtering stage followed by a final filtering stage with a 12" MERV 14 cartrige filter. This setup is typical for all air handling units in the building. The next section of the AHU setup is the fan, which is specified as a single inlet, belt-driven plenum fan. Operating information for these fans can be found in the previous equipment section. Next, the air passes over the main heating/cooling water coil. AHUs 1,3, and 4 only contain one coil, which receives water from the cooling towers and boilers as required. Once the air has left the AHU, it passes through zone level water source heat pumps. These units contain single water coils for the heating and cooling needs of each zone and are controlled by temperature inputs from thermostats in the space. Finally, all air from the zone is exhausted through fans which are specified in the previous equipment section.

Figure 7 - AHU-1, AHU-3, AHU-4 Airflow Schematic



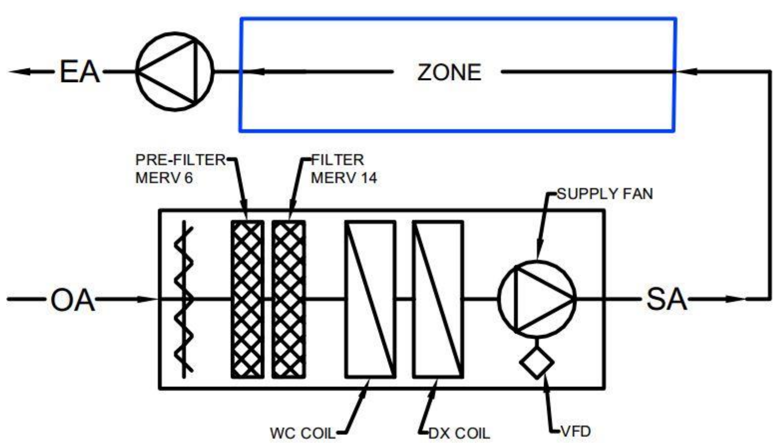
The schematic for AHU-2 is very similar to AHUs 1,3, and 4, with one notable exception. This unit is not constant volume, but instead is equipped with variable frequency drive control for the supply fan and operates as a variable air volume unit. The HVAC system is controlled by a 16-bit, Direct Digital Control (DDC) System that manages all equipment and temperature information, including the VFD fan controls. Note that the order of the water coil and supply fan have also been switched.

Figure 8 - AHU-2 Airflow Schematic



The schematic for AHU-5, which supplies air to the courtyard area, is also slightly different from the other units. In this unit air passes over the coils before the supply fan section. The first coil is a water coil used exclusively for heating. Cooling is done by a separate direct-expansion (DX) coil with R-22 refrigerant running through a separate refrigeration loop. Finally, the air passes through the fan section which is specified as a single inlet, single airfoil, plug type fan which is also controlled by a variable frequency drive for variable air volume operation. In this case, air going to the courtyard does not pass through any heat pumps at the zone level. The air meets the ventilation and conditioning requirements of the space and is exhausted to the outside.

Figure 9 - AHU-5 Airflow Schematic



Lost Space

The useful floor space lost because of the mechanicaly system in the Ed Roberts Campus is relatively small and has minimal effect on the architecture of the building. With the exception of one pump room, all mechanical equipment is located on the roof where there are no other occupiable spaces. The following table breaks down the space requiremtns of the entire system.

Table 13 - Mechanical Space Requirements

Space	Area [sq. ft.]
Mechanical Room	815
Rooftop Equipment	7,700
Pump Room	200
Shafts	270

LEED Evaluation

The Ed Roberts Campus building did not apply for LEED status. However, if status was applied for, building owners believe that LEED Gold could be achieved. Not enough information is available to evaluate the building against all criteria to determine if this claim is possible, but the sections of LEED 2009 New Construction that pertain to the mechanical system and its operation will be evaluated.

Energy and Atmosphere

EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems - YES

This prerequisite is aimed at verifying that the mechanical system has been appropriately tested for energy use using basic commissioning procedures. While information is not available about specific commissioning tests performed, it is a safe assumption to make that these minimum energy tests would have been performed.

EA Prerequisite 2: Minimum Energy Performance - YES

The purpose of this requirement is to ensure that certain minimum performance guidelines were used in the process of designing the mechanical system. Option 1 of this section specifies a 10% improvement on baseline performance for new construction. The building is equipped with energy efficient systems and designed with each space digitally monitored and controlled by occupants. It is a safe assumption that a 10% improvement on baseline performance would have been achieved, even though specific metrics are unavailable.

EA Prerequisite 3: Fundamental Refreigerant Management - YES

This prerequisite ensures that the building does not use chlorofluorocarbon (CFC) based refrigerant in the HVAC system per environmental guidelines. This requirement is met since the building used only R-22 refrigerant, which is not a CFC-based refrigerant, but is a HCFC-based refrigerant being phased out by the EPA.

Table 14 - LEED Energy and Atmosphere Credit Evaluation

Energy and Atmosphere	Possibe Points	Points Achieved	Comments
EA Credit 1: Optimize Energy Performance	1-19	1-4	*See Note 1*
EA Credit 2: On-Site Renewable Energy	1-7	0	*Building is not equipped with on-site renewable energy*
EA Credit 3: Enhanced Commissioning	2	0	*Information on independent commisioning is not available, points cannot be awarded*
EA Credit 4: Enhanced Refrigerant Management	2	2	*Small amount of refrigerant is compliant with Option 2 of this credit*
EA Credit 5: Measurement and Verification	3	0	*Measurement plan is in place but not enough information is available to determine compliance*
EA Credit 6: Green Power	2	0	*Green power is available, but not enough information is available to award points*

Note 1: While specific information on building performance vs. baseline performance is not available, a safe assumption can be made about EA Credit 1 given the stringent California Title 24 energy guidelines. The 1-4 credits afforded indicate that the building has achieved between 12% and 18% improvement over baseline.

Indoor Environmental Quality

IEQ Prerequisite 1: Minimum Indoor Air Quality Performance – YES

As found in Technical Report 1, the ERC meets the minimum ventilation requiremetns of ASHRAE 62.1. The ERC also meets the more strict California Title 24 codes for ventilation for all mechanically ventilated spaces. Therefore, this prerequisite is achieved.

IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control – YES

The Ed Roberts Campus is a 100% smoke-free environment, and thus meets the Option 1 requirement for ETS Control.

Table 15 - LEED Indoor Environmental Quality Credit Evaluation

Indoor Environmental Quality	Possible Points	Points Acheived	Comments
IEQ Credit 1: Outdoor Air Delivery Monitoring	1	1	*The building meets CO_2 monitoring requirements in all mechanically ventilated spaces*
IEQ Credit 2: Increased Ventilation	1	1	*100% outdoor air ventilation is provided*
IEQ Credit 3.1-3.2: Const. Indoor Air Quality Management Plan	1	0	*Information on construction IAQ plan is not available, no points can be awarded*
IEQ Credit 4.1-4.4: Low-Emitting Materials	4	4	*See Note 2*
IEQ Credit 5: Indoor Chemical and Pollutant Source Control	1	1	*All space air is exhausted and all outdoor is filtered with MERV 14 filters, requirements met*

IEQ Credit 6.1: Controllability of Systems – Lighting	1	1	*Occupant controlled lighting systems are specified throughout*
IEQ Credit 6.2: Controllability of Systems – Thermal Comfort	1	1	*Thermal comfort controls meet requirements*
IEQ Credit 7.1: Thermal Comfort – Design	1	0	*Compliance with ASHRAE Std. 55 is unknown, no points awarded*
IEQ Credit 7.2: Thermal Comfort – Verification	1	0	*Credit 7.1 not met, no points awarded*
IEQ Credit 8.1: Daylight and Views – Daylight	1	0	*Not enough of building spaces meet daylight requirement, no points*
IEQ Credit 8.2: Daylight and Views – Views	1	0	*Not enough spaces have direct sightline to daylight, no points*

Note 2: Exact information on Low-Emitting Materials is not available. However, emphasis on superior air quality and a neutral environment is evident throughout all aspects of design. It is a relatively safe assumption to make that these materials were used in construction.

References

The Ed Roberts Campus

Leddy Maytum Stacy Architects

Arup San Francisco

Pacific Gas & Electric Company

Utility Rates and Emissions Data

LEED 2009 For New Buildings and Major Renovation, *USGBC*