Rami Moussa
Mechanical Option
Advisor: Professor Treado
11/29/10

Peirce Hall, Kenyon College

Technical Report 3:

Mechanical Systems Existing Conditions Evaluation

Table of Contents

Executive Summary

Technical Report Three is intended to describe features of the mechanical systems installed in Peirce Hall. A breakdown of design requirements, external influences on the design, major hardware components, system configuration, control logic, operation characteristics, and environmental effects are provided in the following pages.

As a part of Kenyon College, the mechanical systems of Peirce Hall did not have very large restrictions other than local and international codes. Incentives and rebates were not considered leading most of the design decisions to be based on local yearly weather conditions, existing conditions, and the desires of the owner.

Major systems in the building include the variable primary flow chilled water system, steam system and hot water systems driven by a steam to hot water converter, and the seven air handling unit and multi fan coil unit ventilation system. Systems are controlled by a Building Automation System (BAS) and Direct Digital Control (DDC) System.

Environmental effects were measured with a comparison to the LEED 2009 for New Construction and Major Renovations certification checklist. The current systems in Peirce Hall satisfy 27 of the 80 points available in the checklist, not enough to be considered LEED certified. This could however be remedied with making the facility comply with ASHRAE Standards 62.1 and 90.1.

Background

In 2005 Pierce Hall at Kenyon College in rural Gambier, Ohio was a similar multifunctional facility as it is today. Students mainly made use of the dining hall and recreation space and faculty had offices located on the upper floors. Heating was provided by the campus steam system in place to heat water for baseboard and convector units. Means for cooling however were hardly in place. Primary cooling was provided by four air handlers coupled with air cooled condensing units located away from the building. Three air handlers were located in ceiling plenums and one in a mechanical closet serving the music room. This layout would not provide adequate heating, ventilating, and air conditioning for an expanded building.

In 2006 the original HVAC system was completely gutted, with the exception of the very little duct work left in the music room, and new systems were designed to be put in place. The new HVAC system had to serve the 33,000 SF addition along with the 33,000 SF of renovated space. The design for the new systems, by Syska Hennessy Group, Inc. and led by Pat Halm (who is no longer with the company), were driven by the intentions of creating an efficient, economical, reliable, flexible, and maintainable system. A number of codes and guidelines were followed and considered in the design process. Some highly influential codes included the Ohio Administrative Code, International Building Code 2000 Edition, International Mechanical Code 2000 Edition, ASHRAE Standard 90.1, 2001, and International Fire Code 2000 Edition. Due to the flexible nature of the large open site, the majority of the design decisions were based on these goals and building codes rather than spatial limitations.

Gambier, Ohio is a small town in central Ohio, 55 miles Northeast of Columbus. As a part of the Kenyon College campus, Peirce Hall had very few obstructions in the near vicinity which created few restrictions to the design and construction of the new addition and renovation. Rebates such as those provided by energy providers and tax reliefs were not driving factors in decisions made regarding the mechanical system design for the facility.

System Description

Chilled Water System

In the prior Peirce Hall HVAC design as described, there was no chiller plant. Therefore, in order to fit a chiller into the designated mechanical room, a chiller with separate modules that could be brought through a 3' wide door was necessary. Chilled water is produced by one five section, 241 ton capacity, modular chiller located in a mechanical room on the lower level (level half underground, between the basement and first floor). Each module contains two scroll type compressors. Chilled water is supplied via a variable primary pump arrangement with one primary pump and an equally sized back-up pump to the 4 air handlers with cooling coils. Chiller design conditions are as follows:

Chiller	Total Capacity [tons]	Primary kW/Ton	EER	Evaporator		
				GPM	EWT [F]	LWT [F]
CH-1	241	0.69	17.39	340	60	43

Table 1. Chiller Design Conditions

The condenser water system uses a 720 GPM, cross flow type cooling tower located on the South roof of the second floor. Due to the desire of operating the cooling tower in the winter and the very cold winters in Gambier, Ohio, electric pan heaters were designed for the sump basin of the tower and electric trace was designed for the condenser water pipe that ran outside the building. The fan of the tower is equipped with a variable frequency drive. Cooling tower design conditions are as follows (additional system information can be found in Appendix A.1):

Cooling Tower	Motor BHP	GPM	EWT [F]	LWT [F]
CT-1	20	720	85	95

Table 2. Cooling Tower Design Conditions

Fan coil units are used for many small applications such as cooling elevator and data rooms. However, there is one significant use of a fan coil unit (FCU) to supply air to the music room. This is where a FCU was used in the previous design and rightfully so, as this room could easily have less consistent use and produce a significant load when in use. Design conditions for the air cooled condensing unit and air conditioning unit used in the music room are as follows:

Air Cooled Condensing Unit	CMF	Fan Speed [RPM]
ACCU-6	2,500	1,100

Table 3. Air Cooled Condensing Unit Design Conditions

Air Conditioning Unit	CMF	Total BTU/HR	MHP
ACU-6	1,620	48,000	3/4

Table 4. Air Conditioning Unit Design Conditions

Heating System

Kenyon College uses centralized steam production and distributes it through the campus. The previous Peirce Hall mechanical system tapped into this steam distribution and currently supplies medium pressure (26 PSI) steam. Steam is directly used to supply coils in air handlers, some unit heaters, and dishwashers in kitchens. Other components of the heating system are supplied with hot water.

The steam to hot water converters that were previously installed in Peirce Hall were consolidated and upgraded in the renovation process. Hot water is supplied at 190°F to scattered unit and cabinet unit heaters, convectors, and a radiant floor system. The radiant floor system covers the portion of the lower level floor that overlaps the basement. Converter design conditions are as follows:

Steam-to-Hot Water Converter	Shell Side		Tube Side		
	Pressure [PSI]	Min. Cap. [LBS/HR]	GPM [F]	EWT [F]	LWT [F]
HX-1	15	1,071	68.3	160	190

Table 5. Steam to Hot Water Converter Design Conditions

Air-Side Heating and Cooling

All air handling units but one are located in three primary mechanical rooms, two rooms on the lower level and one in a second floor attic. The single separate air handler, AHU-7, is a component of the basement heating and ventilation system and as such is located in the basement. Two air handlers on the lower level (which uses a slab-on-grade floor) and the air handler in the basement are supplied air through an under-slab intake shaft. Other air handlers use intake louvers in the building facade for air supply.

Air handling unit layouts are rather standard. Units are arranged to provide a variable temperature supply. Two sets of filters are present in units, one 35% pre-filter and a 65% cartridge filter. Supply fans are centrifugal fans, some coupled with variable frequency drives, and have vibration control devices. Exhaust fans are axial or inline centrifugal types, located on roofs or in mechanical rooms. Sound attenuators are connected to the air discharge and air intake of units. All air handling units with cooling capabilities are capable of using economizer cycles. A summary of air handling unit characteristics are shown in Table 6.

AHU	System	Location	CFM	Starter	Flow Control	Economizer
1	Kitchen/Servery	New Attic 214	8000	Yes	Volume Dampers	Yes
2	Pub/Peirce Hall	Mech L29	11300	Yes	VAV Terminal Units	Yes
3	Tower	Mech L14	6800	VFD	VAV Terminal Units	Yes
4	Dining Hall	Mech L29	30000	VFD	VAV Terminal Units	Yes
5	Catering Make-Up	New Attic 214	6850	VFD	Constant	No

6	Servery Make-Up	New Attic 214	10500	VFD	Volume Dampers	No
7	Loading Dock B04	Loading Dock B04	3680	Yes	Volume Dampers	No

Table 6. Air Handling Units

Accountable Space

Due to the components involved in any mechanical system type whether it be air or liquid, a significant amount of floor space must be sacrificed. The amount of floor and shaft area used by each system was determined by summing the area occupied by each floor mounted piece of equipment and rising duct. Air side systems clearly used more space than hydronic systems. This was primarily due to the large equipment such as air handlers and ducts as opposed to pumps and piping. Space occupied by equipment located on the roof such as exhaust fans and the cooling tower were not included in what was considered lost space. The radiant floor heating system also was not included in this study since they are located inside of a slab-on-grade. A summary of usable floor space lost is shown in Table 7 and a more detailed breakdown is shown in Table A.2.

System	Total Area (ft^2)
Air	1020
Hydronic Heating	342
Hydronic Cooling	114

Table 7. Total Usable Floor Space Lost with Mechanical Systems

Performance

Design Conditions

Since Gambier, Ohio is only 55 miles Northeast of Columbus, Ohio, yearly weather data from Columbus was used to approximate the exterior environmental conditions of Peirce Hall. As such, the conditions used for analysis were the 0.4% and 99.6% cooling and heating conditions shown in I-P units in Table 8.

Heating DB	Cooling DB/MCWB		Evaporation WB/MCDB		Dehumidification DP/HR/MCDB		
99.6%	0.4%		0.4%		0.4%		
3.2	91.1	73.8	76.7	86.8	73.6	129.0	81.2

Table 8. Yearly Weather Data for Columbus, Ohio[1]

Interior design conditions of Peirce Hall, despite the highly varying use of space, is quite consistent. Design temperature can be found in Table 9. Dining rooms, the music room, and the computer room have identical set points allowing for slightly cooler interior temperatures in the winter to conserve energy. The offices stay at a constant temperature of 75°F year round due to the consistent and more prolonged use of the spaces. Kitchens have a higher cooling temperature and a lower heating temperature than the common space conditions as recommended by 2009 ASHRAE Handbook of Fundamentals. Mechanical spaces such as mechanical rooms, elevator rooms, and electrical rooms are allowed to reach a maximum temperature of 85°F in the summer. Although a precise design temperature for the winter has not been specified, some of these facility rooms have been equipped with unit heaters in preparation for an event where heating is necessary.

Space Type	Design Temperature [F]	
	Summer	Winter
Dining Rooms	75°F	72°F
Kitchen	78°F	70°F
Offices	75°F	75°F
Music Room	75°F	72°F
Computer Rooms	75°F	72°F
Mechanical Rooms	85°F	
Elevator Equipment Rooms	85°F	
Electrical Rooms	85°F	

Table 9. Interior Design Conditions

Design Ventilation Requirements

The ventilation system designed for the new Peirce Hall uses seven air handlers, supplying a total of 77,100 CFM to spaces. The first four units are used for primary ventilation air flow and three additional units are used for make-up air to kitchens, the main servery area, and the loading dock. Ventilation rates determined by ASHRAE Standard 62.1 have been satisfied in almost all areas and in some places greatly over supplied by up to 1146.6%. One air handler has been found to be 14.3% under the required ventilation rate as a result of mainly storage spaces not being ventilated. A comparison of required ventilation and minimum supplied ventilation is shown in Table A.3.

In areas where exhaust is required such as kitchens, make-up ventilation rates and occupant densities are not specified by ASHRAE Standard 62.1. As a result of this ventilation rates for kitchens and areas following similar circumstances are assumed to be the same as the area based exhaust rate of 0.7 CFM per square foot, regardless of the need to negatively pressurize the zone. Since the primary function of Peirce Hall is as a dining hall, a large kitchen staff should be anticipated. In the design of the hall's ventilation system, an occupant density of 20 people per 1,000 square feet and ventilation requirement of 20 CFM per person was used. This difference between ASHRAE Standard 62.1 requirement and design intent was the main factor in calculating differing ventilation rates of up to 1146.6% in areas like the kitchen.

Design Heating and Cooling Loads

The variety of mechanical design strategies used in the Peirce Hall mechanical systems are the result of attempts to manage the different heating and cooling loads present in the different spaces of the multi-use facility. Load sources range from standard contributors such as occupants and kitchen equipment to the large glass roof over a lounge/circulation space that accounts for 11% of Peirce Hall's roof area. The values used to approximate occupant loads in spaces in the designed system can be found in Table 10 and values used in the system analysis performed in Technical Report Two can be found in Table 11 which were more exclusive values recommended by ASHRAE.

Space Type	Sensible [Btu/h]	Latent [Btu/h]
Dining Rooms	275	275
All other areas	250	250

Table 10. Design Occupant Load Contribution

Space Type	Sensible [Btu/h]	Latent [Btu/h]
Cafeteria	275	275
Kitchen	275	275
Mechanical Room	250	200
Class Room	250	200
Office Space	250	200
Rest Room	245	155
Storage	245	155

Table 11. Analysis Occupant Load Contribution

In the design of the mechanical system currently used in Peirce Hall, lighting power densities used were those suggested by ASHRAE productions such as Standard 90.1 and the

2009 ASHRAE Handbook of Fundamentals unless otherwise specified. The densities used for the systems analysis used the summed input wattage of lamps divided by the area of the space. Values used in the design can be found in Table 12, where values used in the analysis can be found in Technical Report Two.

Space	Power Density	
	Lighting	Equipment
Public Area Lobby	1.5	1
Offices	2	3.5
MEP Rooms	1.5	*
Dining Rooms	2	4.5
Kitchen	2	4.5

*As per manufacturer data

Table 12. Designed Lighting Power Densities

A design load calculation was previously prepared by Syska Hennessy Group, Inc. One discrepancy that distinguishes the analysis model from the design model is the population values used in select spaces. Rather than using occupancy statistics from the design model, most were taken from the architectural design drawings. The difference in total population between models is 123 occupants where the analysis model is designed for the larger occupancy. Major occupancy differences can be found in Table 13. The greatest differences in space occupancy occur in the spaces designed for the largest occupancy. The provided model was most likely designed to anticipate that the space would never be fully occupied. In the case of the main dining hall, the Great Hall, the design model greatly over compensates for the architectural design occupancy. This could also be an attempt to estimate the most realistic occupancy possible. Table 14 shows the comparison of block and peak cooling and heating loads required from the heating and cooling plant between design and analysis model.

Room Name	Area [ft^2]	Design Population	
		Analysis	Design
Pub	4001	265	110
Servery	5002	193	104
Student Org. Lounge	359	24	8
Great Hall	4148	277	350

Table 33. Major Area Population Differences

Load Type	Cooling [ft^2/ton]		Difference	Heating [MBH]		Difference
	Analysis	Design		Analysis	Design	
Block	265.7	242.5	9.57%			
Peak	278.7	252	10.60%	4.483	4.329	3.56%

Table 44. Overall Plant Requirements

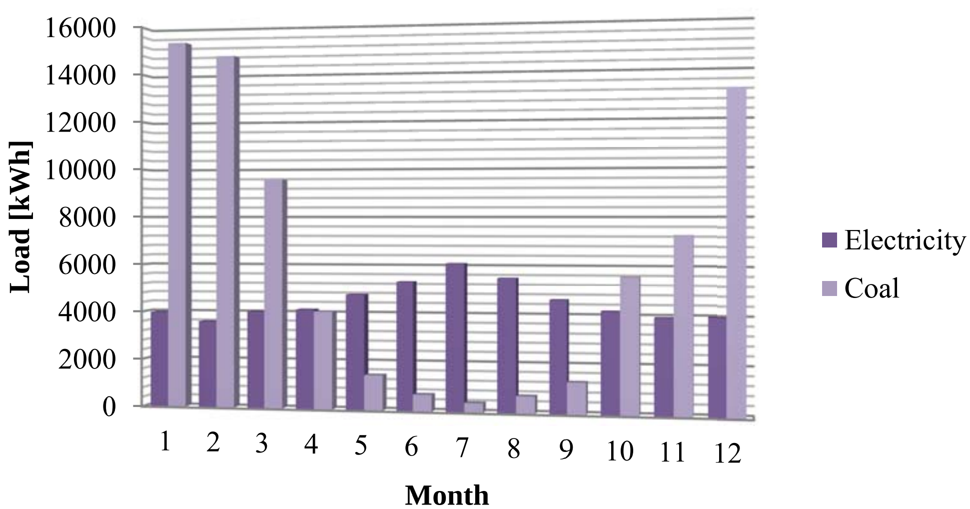
Annual Energy Use

The load model created by Syska Hennessy Group, Inc. for Peirce Hall did not include an energy model and no other energy or energy cost analysis was done. The model was used to size cooling and heating mechanical equipment. However, from the systems created in Trane Trace 700 an energy analysis was conducted in hope of finding areas of high energy consumption. With the results gathered from the energy analysis described and performed in Technical Report Two, the following data sets in Table 15 and Graph 1 were prepared.

From the analysis, it is clear that Ohio's cold climate created a need for a large amount of heating. Of the electrical systems, lighting systems drew more power than the next leading load, supply fan power, by a factor of three. High lighting loads can be attributed largely to the 1500 and 1200W dining space luminaires. The load from pumps seems very low since the cooling tower is in operation all year. However since heating relies more heavily on medium pressure steam, pumping loads for condensate are minimal.

Load	Energy [Btu x 10^6/yr]	Load Base Percentage
Primary Heating	7,587.90	59.10%
Primary Cooling	438.05	3.41%
Cooling Tower	121.01	0.94%
Supply Fans	1,051.92	8.19%
Pumps	9.78	0.08%
Lighting	3,492.55	27.20%
Receptacle	137.65	1.07%
Total	12,838.86	

Table 15. Annual Load Breakdown by System



Graph 1. Monthly Utility Usage

System Operation

The new Peirce Hall mechanical system was designed with intentions of making the most efficient, economical, reliable, flexible, and maintainable system as possible. This could only be attained with an effective control system to run the new equipment. All components of the installed HVAC systems are controlled by a building automation system (BAS) that incorporates a direct digital control (DDC) system. This BAS allows facility managers to monitor space conditions and the corresponding equipment to be controlled from an authorized computer in any location with access to the internet. This allows for much more safe and smooth operation of the new systems. Operation of cooling and heating systems in Peirce Hall will be describe in the following.

Chilled Water - Condenser Water Systems

Chilled water is cooled by a single five section modular chiller and circulated by one chilled water pump with one equal sized back-up pump. Condenser water pumping is similarly circulated with one supply pump and an equal sized back-up. Pumps are operated and alternated on a predetermined schedule to optimize performance and prevent excessive wear to one pump over the other. The BAS is used to continuously monitor water temperature and reset temperature schedules to determine and activate the number of compressors required to produce the desired chilled water temperature.

The cooling tower and condenser water pumps are enabled by the DDC System programmed schedule or the operator can manually activate the system. The condenser water system will run whenever cooling is required and will initiate cooling before the CH-1 turns on. Condenser water pump motor operation and condenser water flow and temperature are all monitored by the BAS. The cooling plant control system will optimize the condenser water temperature to the chillers to minimize energy consumption of the combination chiller-tower.

The cooling tower is equipped with a variable speed drive and sensors to control condenser water temperature. Between the condenser water supply and return is a bypass with a modulating valve. This valve will remain open until a temperature sensor in the condenser water return rises past the set point. At this time the modulating valve will slowly close and condenser water will begin to flow through the cooling until the desired return temperature is reached. If the bypass is completely closed and return condenser water is above the set point, the cooling tower fan speed will increase. If condenser water cools below the set point, the reverse will occur. The BAS monitors the fan motor operation, basin water level, and fan speed. When monitoring fan motor operation, a time delay will be applied between bypass valve closing and increase of fan speed. This is done to prevent short cycling of the tower fan. Condenser water heating methods such as basin water heaters and heat trace are activated when outdoor air temperature fall to 35°F.

Steam - Hot Water Systems

Much of the heating in Peirce Hall is provided by radiant heating, using either steam or water. Water is heated in a steam to hot water heat exchanger. Hot water is circulated by one of two equally sized pumps, activated by a manual command or by the DDC System programmed schedule only when the chilled water system is disabled and the outdoor temperature has fallen below 60°F. Steam to the heat exchanger is controlled by the BAS with two modulating valves, a 1/3rd and 2/3rd valve. A temperature sensor in the hot water supply will detect a decrease in supply temperature, open the 1/3rd valve and if the temperature continues to drop past a second set point the 2/3rd valve will open. The reverse will occur with a raise in supply temperature. If the valves fail, they fail in the wide open position. Hot water supply temperature is reset according to differing outdoor air temperatures. When the outdoor air temperature drops to -6°F or below the hot water supply temperature is 190°F. And when outdoor temperature is 60°F the hot water supply temperature is 140°F.

A secondary hot water loop supplies hot water to the radiant floor system with a three-way mixing valve and one of two equally sized circulating pumps. A temperature sensor in the supply loop allows the DDC System to determine when to open the mixing valve. This will introduce more hot water from the primary loop into the secondary loop in order to maintain a constant radiant floor system temperature. A two way valve in the system supply is regulated by a space air temperature sensor. The system hot water temperature resets maintain a 72°F or 60°F air temperature depending on an occupied or unoccupied space condition respectively.

Heating equipment such as unit heaters and cabinet unit heaters have space temperature sensors on the fan returns to determine the need for operation. These units use the same reset conditions as the radiant floor system.

Air Systems

A variety of air handling system types are used in Peirce Hall, however units have a few control features in common. Outdoor air dampers are a normally closed modulating type, return dampers are a normally open modulating type, and discharge dampers are a normally closed two position type. Chilled water coils are full faced with automatic controls and normally closed modulating control valve to maintain supply or space temperature set points. Pre-heating coils are internal face type with a bypass damper with normally open modulating control valves and automatic control logic for freeze protection. Low temperature switches or freeze-stats are installed downstream of the heating coils to stop fan operation when the entering air temperature to the coil falls below 32°F. All systems are started by a programmed schedule or a manual command. When an air handling system is started the first operation to occur is the opening of the outdoor air damper. Then pre-heat coils are activated allowing the supply and return/exhaust fan soft start. Finally air is mixed with bypass open until discharge set points are met and supply dampers are opened. When an air handling system is off, all control valves return to their normal position except for the pre-heat coil valve which remains under control to maintain a temperature of 75°F to 80°F monitored by its temperature sensor.

LEED Assessment

As stated by the United States Green Building Council, the developers of the LEED system, "LEED is an internationally recognized green building certification system." The LEED certification system is a method of rating the strategies and technologies used in buildings that affect energy savings, water efficiency, CO_2 emission reduction, and improving indoor environmental quality. Qualifications for LEED ratings vary between building and construction types like residential, commercial, and retail.

The LEED rating system used for Peirce Hall is the LEED 2009 for New Construction and Major Renovations. After demolishing a portion the original Peirce Hall, the gross square footage of the addition doubled the square footage of the facility. Since this LEED category focuses on new construction and projects that involve new equipment rather than maintenance of existing equipment and the Peirce Hall renovation, addition, and expansion project included almost complete replacement of the existing building systems, it was determined that this project fell under the "Major Renovation" category. However the LEED 2009 for New Construction and Major Renovations certification can be applied, per standard requirements the building must first successfully qualify the LEED 2009 Minimum Program Requirements. A review of these requirements is available in Table 16. A summary of the qualified points, by section of the LEED certification checklist are shown in Table 17.

Requirement	Status
Must comply with environmental laws.	☑
Must be a complete, permanent building or space.	☑
Must use a reasonable site boundary.	☑
Must comply with minimum floor area requirements.	☑
Must comply with occupancy rates.	☑
Must allow USGBC access to whole building energy and water usage data.	*
Must comply with a minimum building area to site ratio.	☑

* This will be assumed for this study since data could easily be assembled via the BAS monitoring system

Table 16. LEED 2009 Minimum Program Requirement Assessment[2]

Section	Points Acquired
Sustainable Sites	9/29
Water Efficiency	4/10
Energy and Atmosphere	5/35
Materials and Resources	2/14
Indoor Environmental Quality	6/15
Innovation Design	1/6
Regional Priority	0/4
Total	27/80

Table 17. LEED Qualification Checklist Summary[3]

Sustainable Sites

Since the Peirce Hall project was a renovation and addition the site was predetermined. However as a part of the Kenyon College campus, precautions were still taken to ensure proper treatment of the site. Erosion and drainage plans were developed to ensure proper function of the landscape until soil had settled to its more permanent state. These plans did not however reduce drainage or make use of rainwater in any way. As a part of a college campus, there were also available resources to qualify the development density and community connectivity credits. Public transportation is not available in the rural town of Gambier and not many efforts were put into encouraging efficient transportation, other than installing a few new bike racks. In the design of the hardscape and roofing materials, there was no consideration for the possible solar reflectance. Light pollution has been minimized by using very little exterior lighting, however maintains a safe and comfortable environment.

Water Efficiency

The plumbing system design has made efforts to use efficient fixtures such as low flow toilets and urinals. These meet the baseline requirement of LEED, however do not satisfy the use of 20% less than the baseline. This means that the prerequisite for water use is not satisfied, making Peirce Hall ineligible for LEED certification. Although there are no mechanical landscape irrigation systems, a significant use of domestic water in many facilities.

Energy and Atmosphere

After installation of the building energy systems test reports including instrument set points and normal operating valve performance were submitted. An energy model was not created to study whether building performance exceeded values provided by ASHRAE Standard 90.1. The study done in Technical Report 1 shows that the Peirce Hall mechanical system does not totally comply with each area of 90.1. This dissatisfies the minimum energy performance prerequisite making the optimization of energy performance credits irrelevant. In a worst case scenario the calculation done in Table 18 represents the environmental effect of refrigerant used in the only significant source, the condensing unit for the music room ACCU-6. Since the calculated ozone depletion and global warming potential is less than 100, this system satisfies LEED certification. Renewable energy is not used in this project, however energy used can be monitored by the BAS.

Refrigerant	ODP	GWP	Lr	Life (yrs)	Mr	Rc (lbm/ton)	LCGWP	LCODP	LCGWP + LCODP x 105
HCFC-22	0.055	1700	0.02	10	0.1	1.56	79.56	0.002574	79.83027

LCODP: Lifecycle Ozone Depletion Potential (lbCFC11/Ton-Year)
LCGWP: Lifecycle Direct Global Warming Potential (lbCO2/Ton-Year)
GWPr: Global Warming Potential of Refrigerant (0 to 12,000 lbCO2/lbr)
ODPr: Ozone Depletion Potential of Refrigerant (0 to 0.2 lbCFC11/lbr)
Lr: Refrigerant Leakage Rate (0.5% to 2.0%; default of 2% unless otherwise demonstrated)
Mr: End-of-life Refrigerant Loss (2% to 10%; default of 10% unless otherwise demonstrated)
Rc: Refrigerant Charge (0.5 to 5.0 lbs of refrigerant per ton of cooling capacity)
Life: Equipment Life (10 years; default based on equipment type, unless otherwise demonstrated)

Table 18. Refrigerant Ozone Depletion and Global Warming Potential[4]

Material and Resources

Since the Peirce Hall project included a renovation, much of the original facility is still intact. Approximately half of the materials from the original facility remain for use. There were no plans to reuse any of the demolished materials. Specific local vendors were not mentioned as a requirement.

Indoor Environmental Quality

The mechanical system of Peirce Hall is very close to satisfying ASHRAE Standard 62.1 Section 4 through 7 but does not quite comply, dissatisfying the minimum indoor air quality performance prerequisite. Not all spaces receive over 30% of the ventilation they require, however CO_2 sensors do assist in control of the ventilation system. Few low-emitting finish materials were used in the project. Lighting is controlled automatically by a system designed to activate systems only when needed and maximize energy savings. Thermal space control is controlled by the BAS in most spaces and only occupant controllable in spaces such as offices. Since the main use of the facility is a dining hall, the majority of occupants do not have control over their thermal environment. However, thermal environment being controlled by the BAS allows each space to be designed for maximum comfort and can be verified by temperature sensors in each space. A day lighting study has not been conducted to determine the amount of daylight in each space, however the majority of spaces have some sort of day lighting and allow views to the outdoors.

Innovative in Design and Regional Priority

Information on whether systems have been effective has not been made available, however one LEED AP was involved in the design of the Peirce Hall mechanical systems. No credits were gained due to the location of Kenyon College.

Overall System Evaluation

The Peirce Hall renovation, addition, and expansion project was one intended to make the facility a more useful, comfortable, and better performing building. This goal was attempted by the use of efficient equipment design and smart controls. These two areas have shown to be great strengths in this facilities mechanical system.

Mechanical rooms have been well placed in the facility allowing for the most practical distribution schemes. Space was used well such as the utilization of the attics for mechanical space and good plenum design. Even though the facility had no centralized chiller plant prior to the renovation, one was created with marginal success. The space used for the chiller plant is in a less desirable location which restricted the size of the chiller, but a working solution was found. Maintenance of the systems is reasonably simple, with all access doors required by ASHRAE Standard 62.1 satisfied and well designed mechanical room layouts.

The control system for the mechanical systems is the strongest part of the design. Facility managers have complete digital control over systems and can monitor every feature necessary such as differential pressures and control valve positions. These make way for extremely efficient scheduling and operation of the building systems.

The actual operating and construction cost of the systems have not been made available. However, by using general energy values from a study done in Technical Report 2 the yearly operation of the mechanical systems seem to be quite affordable at $1.378 per square foot.

The weaker areas of the Peirce Hall mechanical system design become more evident when studying the compliance of the design with ASHRAE Standards 62.1 and 90.1. Ventilation values are disputable in areas of highly fluctuating and great populations. One large issue of complying with 90.1 has nothing to do with the mechanical system, but the percent of glazing in the roof. This was compensated with high performing glass, but an appeal would most likely be necessary to achieve certification. Lighting power densities are higher than accepted by the standard in some areas, but again this does not have to do with the mechanical system.

Due to noncompliance with areas of 62.1 and 90.1, much of the LEED 2009 for New Construction and Major Renovations was not applicable. The new Peirce Hall was not eligible for LEED certification with 27 points, 13 short of certification. With compliance to ASHRAE standards, these points could be achieved.

References

1. *ASHRAE Handbook: HVAC Applicaions*; Owen, Mark S., Ed.; The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.: Atlanta, GA, 2007.
2. United Stated Green Building Council. LEED 2009 Minimum Program Requirements. 2009. 28 Nov. 2010 <www.usgbc.org>
3. United Stated Green Building Council. LEED 2009 for New Construction and Major Renovations. 2009. 28 Nov. 2010 <www.usgbc.org>
4. Environmental Protection Agency. "Class II Ozone-depleting Substances." 28 Nov. 2010 <www.epa.gov/Ozone/science/ods/classtwo.html>.

Appendix

A.1 Additional Major System Component Data

Pump	GPM	MHP
CWP-1	720	25
CWP-2	720	25
CHWP-1	340	10
CHWP-2	340	10
HWP-1	100	5
HWP-2	100	5
HWP-3	10	1/2
HWP-4	10	1/2

Table A.1.1. Pump Design Conditions

Fan	CFM	MHP	V/PH/HZ
EF-1	7,600	5	208/3/60
EF-2	10,800	5	208/3/60
EF-3	6,800	3	208/3/60
EF-4	30,000	15	208/3/60
EF-8	3,200	1-1/2	208/3/60
EF-15	3,445	1	208/3/60
EF-24	9,200	5	208/3/60
SF-1	220	1/2	115/1/60

Table A.1.2. Fan Design Conditions

A.2 Usable Floor Space Lost with Mechanical Systems

Level	System	Equipment	Area (ft^2)	Total Area Per Level per System (ft^2)
B	Air	AHU-7	18.50	18.50
	Hydronic Heating	HWH-1&2	22.00	27.50
		CP-3	5.50	
L	Air	AHU-2	130.00	557.00
		AHU-3	99.75	
		AHU-4	205.00	
		EF-19	3.00	
		Duct Risers	119.25	
	Hydronic Heating	HWP-1&2, HX-1, ET-1	36.00	157.33
		HWP-3&4	4.50	
		CP-1	9.00	
		CP-2	4.00	
		CP-4	5.83	
		FTR	98.00	
	Hydronic Cooling	CH-1	48.50	94.50
		Expansion Tanks	4.00	
		CHWP-1&2	20.00	
		CWP-1&2	22.00	
1	Air	Duct Risers	82.22	82.22
	Hydronic Heating	FTR	124.83	124.83
	Hydronic Cooling	ACCU-1,2,5	13.35	19.60
		ACCU-6	6.25	
2	Air	AHU-1	117.33	345.93
		AHU-5	91.83	
		AHU-6	109.80	
		ACU-6	3.50	
		EF-24	14.30	
		EF-25	2.70	
		Duct Risers	6.47	
3	Air	Duct Risers	9.97	9.97
	Hydronic Heating	FTR	18.67	18.67
4	Air	Duct Risers	6.36	6.36
	Hydronic Heating	FTR	13.33	13.33

A.3 Ventilation Requirement and Assessment

AHU	$Z_{p\ Max}$	E_v	D	$\Sigma(R_p x P_z)$ [cfm]	$\Sigma(R_a x A_z)$ [cfm]	V_{ou} [cfm]	V_{ot} [cfm]	ΣV_{oz} [cfm]	Design Vent. [cfm]	Percent Difference
1	0.06	1	0.010	149.15	578.15	579.63	579.63	845.90	2100	148.3%
2	1.03	0.638	0.379	6111.75	1466.82	3785.47	5933.35	7578.57	9200	21.4%
3	0.71	0.492	0.071	1058.79	476.82	551.86	1121.67	2101.41	1800	-14.3%
4	0.60	0.690	0.496	7755.83	1988.40	5835.93	8457.87	11530.63	15000	30.1%
5	0.28	0.8	0.000	0.00	653.90	653.90	817.37	817.37	6850	738.1%
6	0.08	1	0.015	247.50	594.54	598.34	598.34	842.32	10500	1146.6%
7	0.094	1	0.000	0.00	375.88	375.88	375.88	438.38	3680	739.5%

Z_p - Zone primary outdoor air praction

E_v - System ventilation efficiency

D - Occupancy diversity

R_p - Outdoor airflow rate required per person

P_z - Zone population

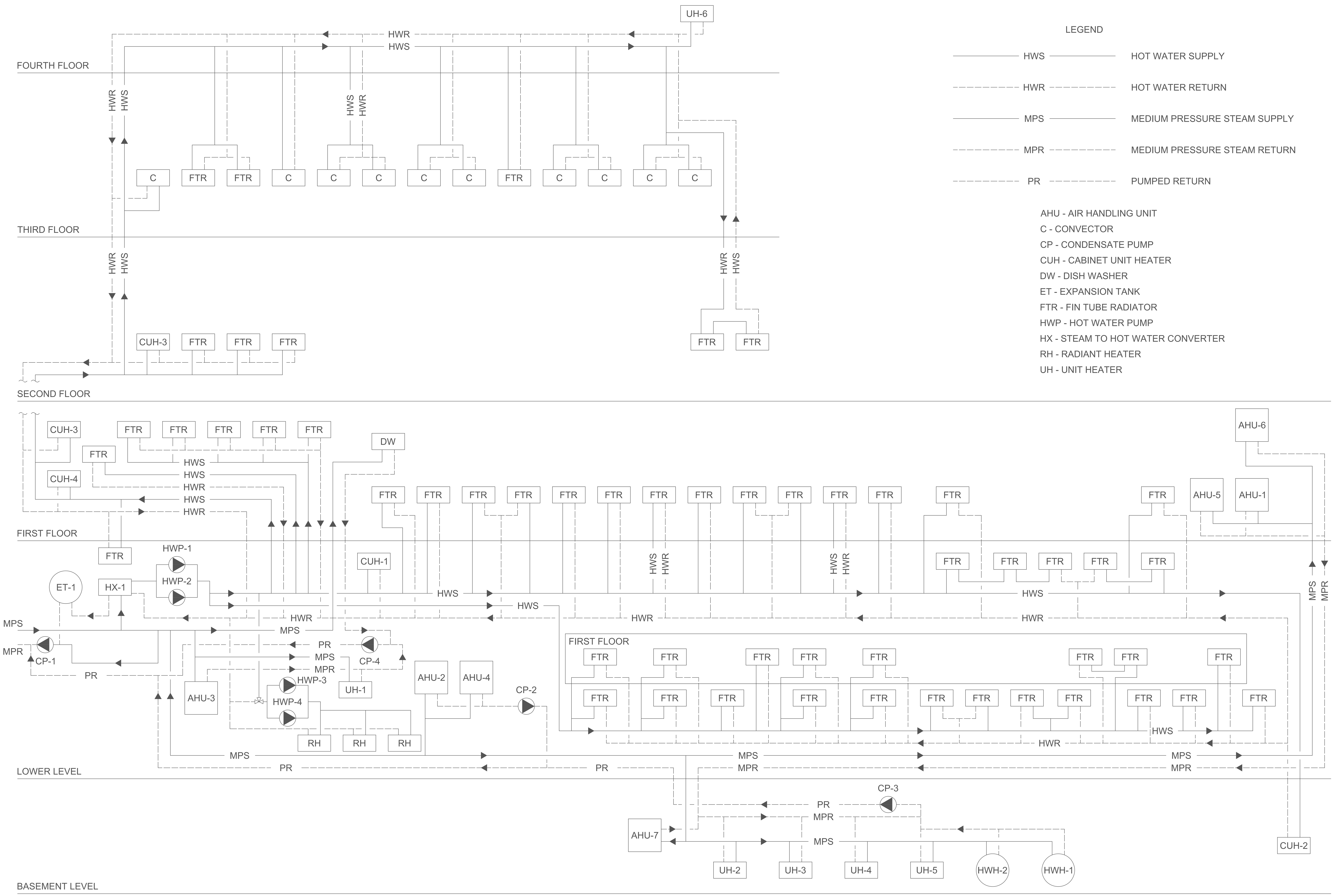
R_a - Outdoor airflow rate required per unit area

A_z - Zone floor area

V_{ou} - Uncorrected outdoor air intake

V_{ot} - Design outdoor air intake flow

HOT WATER AND STEAM FLOW DIAGRAM



CHILLED WATER AND CONDENSER WATER FLOW DIAGRAM

CHWS	CHILLED WATER SUPPLY
CHWR	CHILLED WATER RETURN
CWS	CONDENSER WATER SUPPLY
CWR	CONDENSER WATER RETURN