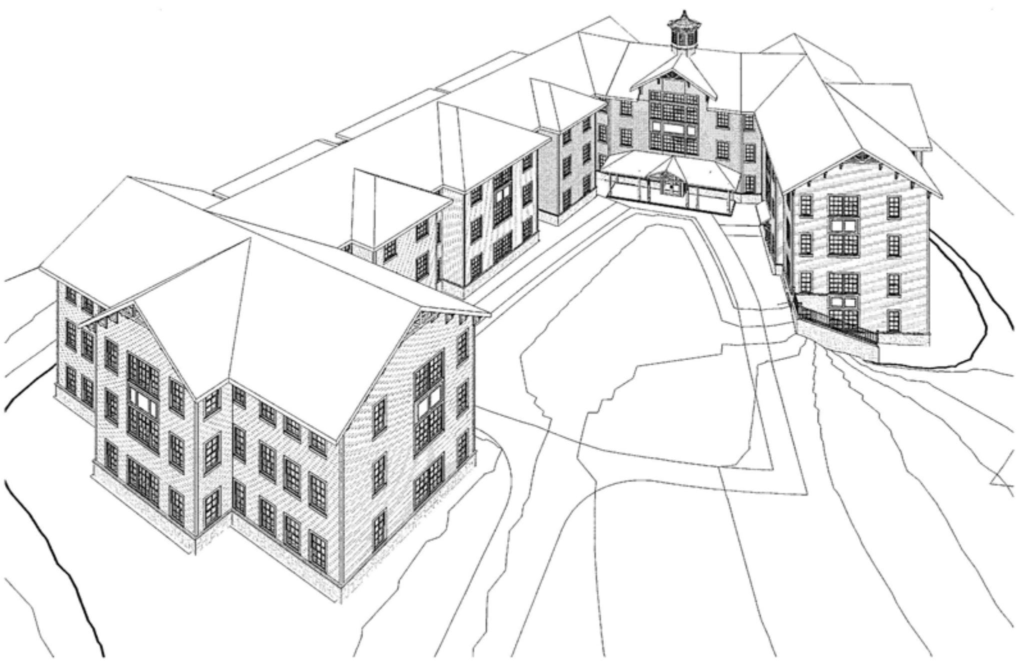
MECHANICAL SYSTEMS EXISTING CONDITIONS EVALUATION

MECHANICAL TECHNICAL REPORT #3



NEW STUDENT HOUSING BUILDING

AT

THE MOUNT ST. MARY'S UNIVERSITY

EMMITSBURG, MD

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2. EXECUTIVE SUMMARY

The purpose of this report is to perform a detailed analysis of the existing mechanical systems in the new student housing project at the Mount St. Mary's University. In order to accomplish this examination of the building's mechanical equipment selection and design, the objectives and requirements of the design are first described and evaluated.

To gain a better understanding of how the building actually functions, ventilation requirements, heating and cooling load estimates, and energy and cost analyses preformed in the previous two technical reports have been reexamined and resubmitted. In this way, one may be better capable of grasping the way that all of the building's systems work together and affect one another.

The building's actual mechanical systems are then evaluated and explained in depth, using schematic drawings to better illustrate the way the systems work. The geothermal heat pump system, the ventilation system utilizing energy recovery, and the domestic service water system are all broken down here in an attempt to better understand the building's systems as a whole.

Finally, the building is critiqued and found to be very well designed for a university as conscious about sustainable design as the Mount St. Mary's has proven to be. It is suggested here that while the chosen system may well be the best choice for a dormitory with an environmental conscience, it may not have been the most cost effective solution, and several alternatives are put forth for potential evaluation.

3. PRELIMINARY DESIGN

3.1. Design Objectives and Requirements

The Mount St. Mary's University began this new student housing project with a budget of approximately $10 Million, and their goal was to create a sustainable, environmentally friendly dormitory to house their growing population of students.

The vision for the project was to create an inviting dormitory consisting of 3- and 4-bedroom suites, each with its own living area and bathroom, as well as ample lounge space in which students could congregate and study. Each of these living units would have complete control over thermal comfort and lighting, and mechanical equipment would be as inconspicuous as possible. The building itself was to resemble a rural village, complementing the rest of the campus without being overly obtrusive, and at the same time, it had to be large enough to house approximately 200 students comfortably.

The university was also very interested in sustainable or "green" technologies. They wanted to project an image of environmental consciousness without taxing their budget too sorely or compromising the function of the building. A large number of windows were desired to take advantage of natural ventilation, and the university wanted to look into different options of sustainable design, such as energy recovery and geothermal heating and cooling, both of which were eventually adopted.

3.2. Indoor and Outdoor Design Conditions

The indoor design conditions on this project were based on standard summer and winter comfort levels for residential buildings. While each suite will have its own thermostat, allowing students to regulate the temperature to their own levels of comfort, the building was designed to maintain the setpoints that are listed in Table 3.2.1 below:

Table 3.2.1: Indoor Design Conditions

DESIGN CONDITIONS SCHEDULE										
Room Description	Occupied Hours						Unoccupied Hours			
	Summer		Winter		Ventilation		Summer		Winter	
	DB (°F)	% RH	DB (°F)	% RH	OA CFM	AC/hr	DB (°F)	% RH	DB (°F)	% RH
Residential Suite	75	50	70	30	50	1.0	85	50	65	30
Lobby	75	50	70	30	50	0.8	85	50	65	30
Lounge	75	50	70	30	50	0.8	85	50	65	30
Small Lounge	75	50	70	30	50	1.0	85	50	65	30
Electrical Room / Hallway	75	50	70	30	50	1.8	85	50	65	30

Outdoor design conditions were taken from Carrier's HAP for the city of Hagerstown, Maryland. They are shown in Table 3.2.2 below:

Table 3.2.2: Outdoor Design Conditions

OUTDOOR DESIGN CONDITIONS				
Design:				
	Dry Bulb Temp (°F)		Wet Bulb Temp (°F)	
Summer	94.0		75.0	
Winter	8.0		5.8	
Monthly:				
	Max. DBT	Min. DBT	Max. WBT	Min. WBT
January	50.8	28.8	47.0	28.3
February	54.0	32.0	52.0	31.5
March	65.0	43.0	61.0	42.5
April	75.0	53.0	65.0	52.5
May	84.8	62.8	70.0	62.3
June	91.0	69.0	73.0	66.5
July	94.0	72.0	75.0	68.8
August	94.0	72.0	75.0	68.8
September	88.8	66.8	72.0	65.4
October	78.0	56.0	67.0	55.5
November	68.8	46.8	61.0	46.3
December	56.0	34.0	52.0	33.5

3.3. Site Factors Influencing Design

One of the objectives of the new student housing project was for the final design of the building to fit in with the style of the campus, that is, to project the image of a rural village. The desired gabled roof allowed little space for a cooling tower or the condensing units that are required in air source applications. The university also disliked the idea of a "farm" of condensing units clustered directly behind the building. The rural atmosphere of the campus forced the university to look into other, less obvious approaches, and when the geothermal system was suggested, they happily accepted this alternative. Geothermal wells are invisible to the general public, and the system's efficient ability to save on energy usage made it even more attractive.

Also, the extremes of the temperature ranges in the summer and winter months allowed energy recovery to be adopted by the university for the project. Prior to the addition of the energy recovery units, the building design had been relying entirely on natural ventilation to meet the building's outdoor air requirements. As another form of sustainable design, these units could replace the exhaust fans with only a short period of payback while allowing a more generous amount of ventilation air to be introduced into the building.

3.4. Energy Sources and Rates

The new student housing project at the Mount St. Mary's University uses electricity for most of its systems, making use of natural gas only for the domestic hot water heater. Because the new student housing project is not yet built, electric and natural gas rates were assumed comparable to those provided by Baltimore Gas and Electric.

Electric rates were taken from the Large General Service schedule for Type II-A Market priced service. The electric service rates were separated into delivery service customer charge, demand charges, energy charges, and a delivery service charge. The energy charges were divided into peak, intermediate, and off-peak periods. Information pertaining to rating periods and electrical utility rates may be found in respective Tables A.1 and A.2 of Appendix A of this report.

Natural gas rates were taken from the General Service-C schedule, and rates were separated into customer and delivery charges. The distribution charge was broken down based on the amount of gas (therms) used in one month. Information pertaining to natural gas rates may be found in Table A.3 of Appendix A of this report.

There are no known incentives being offered that would influence energy consumption or operational costs.

3.5. Design Ventilation Requirements

The new student housing project at the Mount St. Mary's University utilizes a dedicated outdoor air system with energy recovery coupled with natural ventilation. Three energy recovery units provide a constant flow of 50 CFM of outdoor air to each of the building's heat pumps. It was determined by previous analysis in Technical Report #1 that natural ventilation from the windows alone would have been sufficient to adequately ventilate the building to the approval of ASHRAE Standard 62.1-2004.

It was determined by the mechanical consultant on the project that should natural ventilation alone be used, the building would be very negatively pressurized as well as possibly being underventilated in the winter months when windows would most often be closed. The energy recovery units were, therefore, proposed as an alternative to simple exhaust fans. Due to the University's dedication to environmentally friendly design, they adopted the plan, which would have initially supplied 100 CFM of ventilation air to each of the heat pumps. The flow was cut back to 50 CFM due to cost restraints.

The building ventilation analysis compiled in Technical Report #1 looked at the building's mechanical ventilation systems based on ASHRAE Standard 62.1-2004. The results of that study may be seen in Table 3.5.1 below:

Table 3.5.1: Calculated vs. Design Ventilation Flow Rates

	Max Z_p	System Ventilation Efficiency (E_v)	Population Density (P_s)	Occupant Diversity (D)	Uncorrected Outdoor Intake (V_{ou}) [CFM]	Nominal Outside Air (ΣV_{oz}) [CFM]	Required Outside Air (V_{ot}) [CFM]	Actual Supplied Ventilation Air [CFM]
ERU-1	0.11	1	60	0.87	1102	1161	1102	1050
ERU-2	0.10	1	66	0.79	1325	1431	1325	1050
ERU-3	0.09	1	57	1.00	990	1001	990	750
Total Building						**3593**	**3417**	**2850**

At first glance, it would appear that all three energy recovery units are undersized and do not meet the building's ventilation requirements. However, one must keep in mind the fact that natural ventilation alone would have been sufficient under the circumstances; the mechanical ventilation is only for supplemental and pressurization purposes. Had cost not constrained the units from delivering 100 CFM to each of the pumps, the mechanical system alone would have far exceeded the requirements listed in the Standard.

3.6. Design Heating and Cooling Loads

In order to create a comparison of estimated heating and cooling loads to those scheduled by the mechanical engineer, Carrier HAP was utilized in Technical Report #2 to simulate the new student housing project at the Mount St. Mary's University. A brief summary of calculated results as compared to actual design data is provided in Table 3.6.1 below. Some inconsistencies between the numbers can be contributed to incorrect estimates of schedules, lighting and electrical equipment power densities, and other general conditions. The large difference in the cooling and heating loads may also be contributed to the fact that the design data is based on the total rated capacity of the building's various geothermal heat pumps; the actual loads being seen by these units are not described on the design documents and are probably less than their rated capacities.

Table 3.6.1: Calculated vs. Design Cooling and Heating Loads

Energy Usage Comparisons						
System	Output	Cooling Total (Tons)	Cooling Sensible (Tons)	Heating (Tons)	Cooling (ft^2/Ton)	Heating (ft^2/Ton)
ERU-1	HAP	23.0	20.2	22.0	634	664
	Design	36.9	30.8	33.9	395	430
ERU-2	HAP	28.5	24.5	27.1	619	649
	Design	41.4	33.1	36.3	426	484
ERU-3	HAP	19.6	17.0	19.8	662	655
	Design	31.3	23.6	25.6	414	505

3.7. Annual Energy Usage

Carrier HAP was also used in Technical Report #2 to conduct electrical consumption and operating cost simulations. Using the same HAP file used for the design load estimation, the electric and natural gas rates from Baltimore Gas and Electric in Appendix A were incorporated into the program for correct rating periods and times of year. After running the simulation it was determined that the building's mechanical systems will account for roughly 57% of the building's annual energy consumption and 55% of the annual operating costs. Figure 3.7.1 below describes the annual building cost breakdown, and Figure 3.7.2 shows monthly operating costs.

Figure 3.7.1: Percentages of Total Annual Costs

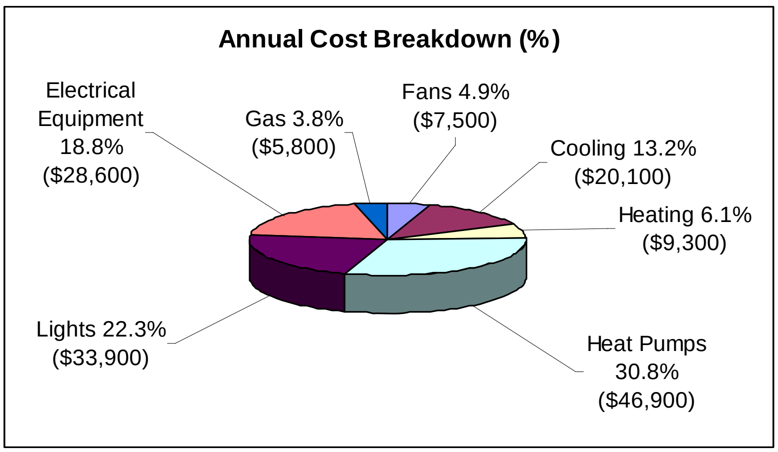
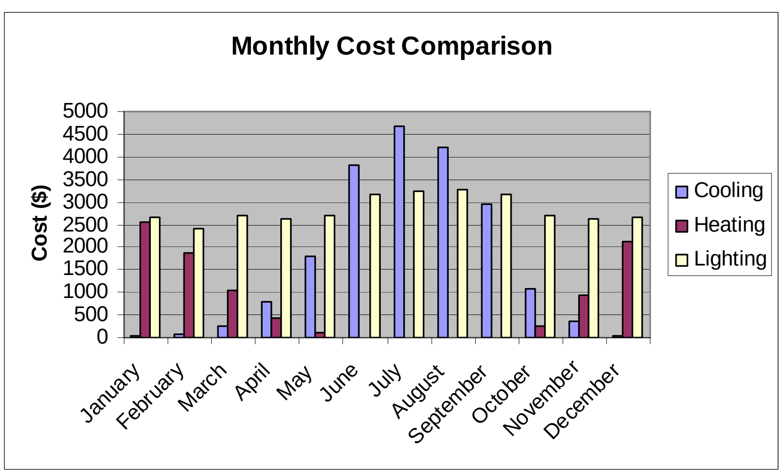


Figure 3.7.2: Monthly Cost Comparison of Major Energy Loads



4. SYSTEMS DESCRIPTION

The following are descriptions of the three main mechanical systems at the new student housing project, as well as their respective components. The three major systems analyzed are the geothermal heat pump system, the ventilation system with energy recovery, and the domestic service water system. A brief listing of abbreviations and symbols referenced in the following schematics is provided in Figure 4.1 below:

Figure 4.1: Abbreviations and Symbols Used in Following Schematics

ABBREVIATIONS AND SYMBOLS

CS	CONDENSER WATER SUPPLY
CR	CONDENSER WATER RETURN
OA	OUTDOOR AIR
EA	EXHAUST AIR
FD	FIRE DAMPER
CW	DOMESTIC COLD WATER
HW	DOMESTIC HOT WATER
HWR	DOMESTIC RECIRCULATED HOT WATER
RPBFP	REDUCED PRESSURE BACK FLOW PREVENTER
	BALL VALVE
	BUTTERFLY VALVE

4.1. Geothermal Heat Pump System

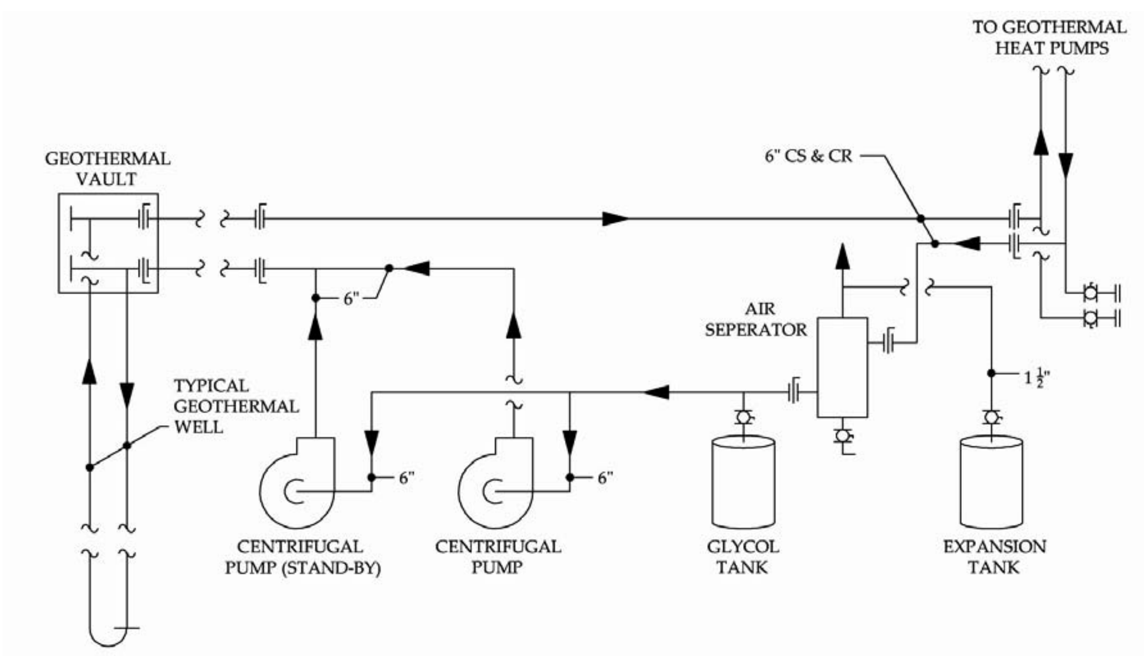
The new student housing project at the Mount St. Mary's University utilizes a geothermal heat pump system to both heat and cool the building. 125 vertical wells, each 4 inches in diameter and 200 feet deep, are located around the site and stem from a geothermal pipe distribution vault located beneath the main courtyard of the building. From this vault, the condenser water is distributed directly to the heat pumps located throughout the building for either heating or cooling.

The condenser water then returns to the building's mechanical room, where it is sent through an air separator, and it is approximately here that both the 160 gallon expansion tank and the glycol tank are linked to the system. The water is then run through one of two centrifugal pumps capable of moving 375 GPM and back out to the geothermal vault for redistribution to the vertical wells, as is shown in Figure 4.1.1 below.

Some of the benefits of this geothermal system, impacting first cost, maintenance costs, and energy costs, are that it eliminates the need for chillers, boilers, and cooling towers. Because of this, the heat pumps themselves are capable of achieving higher coefficients of performance and energy efficiency ratings than conventional heat pumps.

Technical information pertaining to the geothermal heat pumps, the centrifugal pumps, and the expansion tank can be found in the schedules in Appendix B of this report.

Figure 4.1.1: Geothermal Heat Pump System Schematic



4.2. Ventilation System

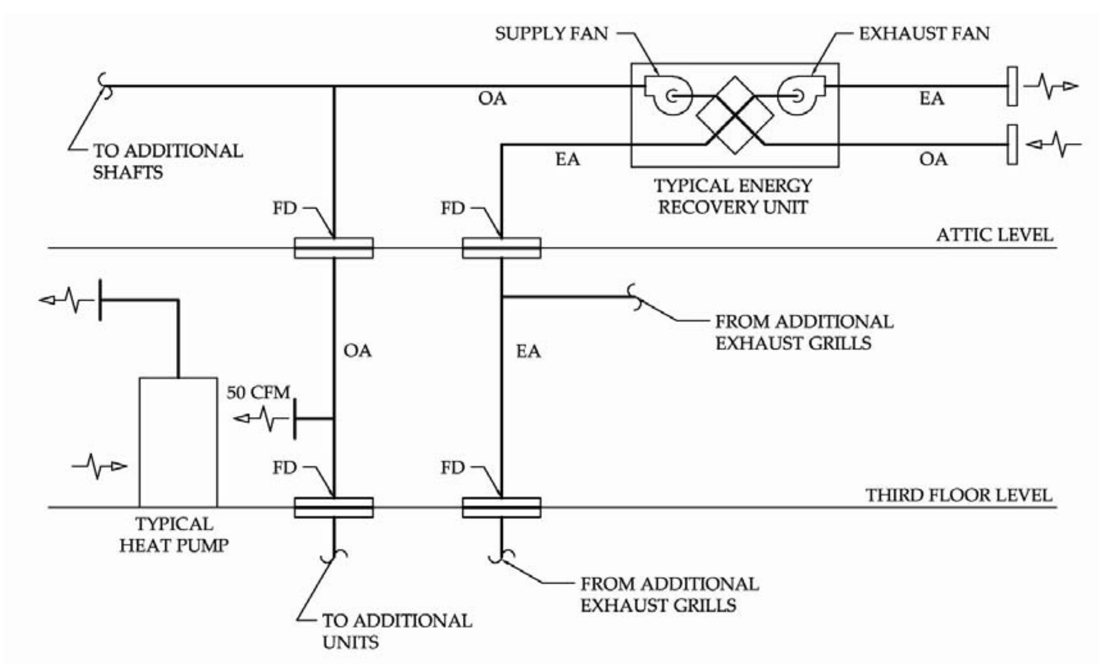
The building's ventilation system serves a supplemental function and is coupled with natural ventilation. It consists of three energy recovery units located in the attic of the building, which were incorporated into the system in place of exhaust fans in an attempt to keep the building pressurized and to increase the amount of outdoor air reaching the occupied spaces.

Fifure 4.2.1 below describes ventilation/exhaust air cycle typical of all three of the building's energy recovery units. Exhaust air is pulled from bathrooms and mechanical rooms throughout the building at a rate comparable to that of the ventilation air being brought in. These energy recovery units utilize the wasted energy in the exhaust streams to pretreat the ventilation air being brought into the building. Electric duct heaters may then be utilized during winter months to raise the temperature of the air further. This air is then supplied directly to the closets housing the individual heat pumps at a constant rate of 50 CFM, where it is mixed with recirculated air and conditioned further before being supplied to the space.

Using energy recovery to pretreat the ventilation air saves a great deal of energy later in the process of heating and cooling. During the extremes of the summer and winter, pretreating the ventilation air can reduce the overall outdoor air load to as low as 20% of what it would be without energy recovery.

Technical information pertaining to the energy recovery units and electric duct heaters can be found in the schedules in Appendix B of this report.

Figure 4.2.1: Ventilation System with Energy Recovery Schematic

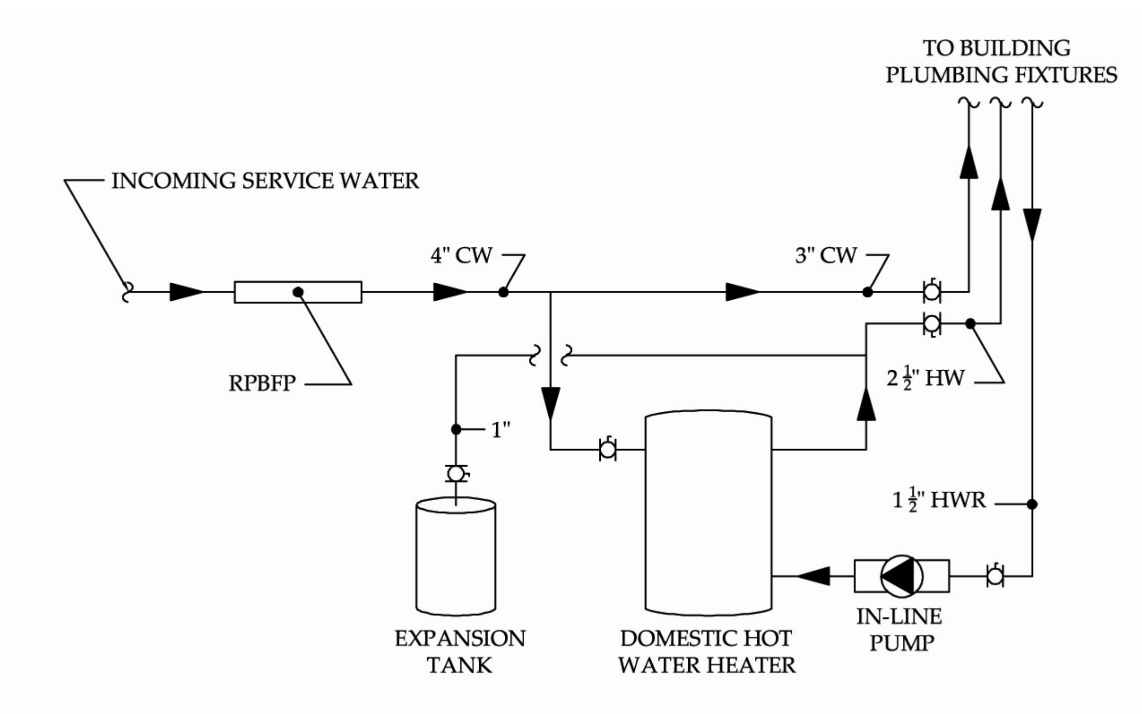


4.3. Domestic Service Water System

The building's incoming domestic service water is brought in through a reduced pressure back flow preventer into the mechanical room in the basement. From there, the water is split from a 4 inch pipe into 3 and 2 ½ inch pipes, the latter of which then feeds into a 750 GPH domestic hot water heater connected to a 35 gallon expansion tank, as is shown in Figure 4.3.1. Bother the cold and hot water are then fed to all the various bathrooms, janitor's closets, and water fountains located throughout the building. The hot water is continuously recirculated through a 15 GPM in-line pump located in the mechanical room. The recirculation loop is shown returning to the domestic hot water heat through the in-line pump in Figure 4.3.1 below.

Technical information pertaining to the domestic hot water heater, the in-line pump, and the expansion tank can be found in the schedules in Appendix B of this report.

Figure 4.3.1: Domestic Water Service System Schematic



4.4. Operating History

The new student housing project at the Mount St. Mary's University is not yet built, and, therefore, it has no operating history.

5. SYSTEM CRITIQUE

After the completion of this analysis of the mechanical systems at the new student housing project at the Mount St. Mary's University, it is apparent to the author that the mechanical systems chosen for the project fit the building's requirements and objectives very nicely. The university set out to create an energy efficient and sustainable building to house its students, and for a dormitory the size of this one, geothermal heating and cooling coupled with energy recovery is probably as close to an optimum system as possible.

The only real disadvantage of these systems seems to be in consideration of first costs and maintenance costs. The geothermal system is very expensive to install, and the site work and placement of the vertical wells quickly comes to take up a large portion of the budget on any project in which geothermal heating and cooling is utilized. On this project, the cost of installing the geothermal system became prohibitive to the point where many value engineering decisions had to be made that had not initially been accounted for. One example of this is the fact that the three energy recovery units were initially supposed to supply 100 CFM of ventilation air to each of the spaces served; however, the units had to be sized down to half this capacity to even justify their additional cost to the project.

Maintenance on the geothermal system could also be a greater factor in the future in the event that there should be a problem with the wells or the geothermal vault. The additional site work necessary under such circumstances could prove far more costly than service work on a typical cooling tower.

It could prove beneficial, therefore, to compare the life cycle cost of the present geothermal system to that of more conventional water-source systems or even to newer technology such as variable refrigerant volume. In either case, it is the opinion of the author that to satisfy the scope for this particular project, the designed system is most likely the best choice regardless of cost.

APPENDIX A - UTILITY INFORMATION

Table A.1: BG&E Rating Periods

Rating Periods	
Summer:	
Peak	10 AM to 8 PM on Weekdays
Intermediate	7 AM to 10 AM and 8 PM to 11 PM on Weekdays
Off-Peak	All Weekends and Holidays
Non-Summer:	
Peak	7 AM to 11 AM and 5PM to 9 PM on Weekdays
Intermediate	11 AM to 5 PM on Weekdays
Off-Peak	All Weekends and Holidays

Table A.2: BG&E Electrical Utility Rates

Delivery Service Customer Charge:	$100.00/Month	
Delivery Charges	Summer ($/kW)	Non-Summer
Transmition Charge for Market-Priced Service:	0.98	0.98
Delivery Service:	2.67	2.67
Energy Charges	Summer (¢/kWh)	Non-Summer
Generation Charge for Market-Priced Service:		
Peak	15.138	12.236
Intermediate	11.835	10.662
Off-Peak	10.340	8.646
Delivery Service Charge:	1.239 ¢/kWh	

Table A.3: BG&E Natural Gas Utility Rates

Natural Gas Utility Rates	
Customer Charge	
	$100.00/Month
Delivery Price	
First 10,000 Therms:	19.75 ¢/Therm
All Over:	9.48 ¢/Therm

APPENDIX B - SCHEDULES

Table B.1: Energy Recovery Unit Schedule

ENERGY RECOVERY UNIT SCHEDULE

Desig.	Airflow Conditions					Supply Fan					Exhaust Fan				
	SA (CFM)	OA (%)	EA (CFM)	EA ESP (IN. WC)	SA ESP (IN. WC)	Type	CFM	TSP (IN. WC)	HP	BHP	Type	CFM	TSP (IN. WC)	HP	BHP
ERU-1	1050	100	1050	0.75	0.75	Belt	1050	0.86	3/4	0.5	Belt	1050	0.86	3/4	0.5
ERU-2	1050	100	1050	0.75	0.75	Belt	1050	0.86	3/4	0.5	Belt	1050	0.86	3/4	0.5
ERU-3	750	100	1100	0.75	0.75	Belt	1050	0.86	3/4	0.5	Belt	1050	0.86	3/4	0.5

ENERGY RECOVERY UNIT SCHEDULE (CONTINUED)

Desig.	Design Conditions				Outdoor Air Loads with Energy Recovery			
	EAT (Summer) DB / WB	EAT (Winter) DB / WB	LAT (Summer) DB / WB	LAT (Winter) DB / WB	Cooling Total (MBH)	Cooling Reduction (MBH)	Heating Total (MBH)	Heating Reduction (MBH)
ERU-1	95.0 / 78.0	0.0 / 0.0	78.6 / 66.1	59.7 / 48.8	12.5	49.9	14.0	55.7
ERU-2	95.0 / 78.0	0.0 / 0.0	78.6 / 66.1	59.7 / 48.8	12.5	49.9	14.0	55.7
ERU-3	95.0 / 78.0	0.0 / 0.0	78.6 / 66.1	59.7 / 48.8	12.5	49.9	14.0	55.7

Table B.2: Geothermal Heat Pump Schedule

GEOTHERMAL HEAT PUMP SCHEDULE

Desig.	Nominal MBH	Nominal CFM	OA CFM	ESP (IN.)	Cooling Capacity @ 77°F EWT (BTU/hr)		Cooling		Condenser Water		Heating Capacity @ 35°F EWT (BTU/hr)	Heating	
					Total	Sensible	EAT DB / WB	LAT DB / WB	GPM	Max WPD (FT.)		EAT DB / WB	LAT DB / WB
HP-1	24	630	50	0.74	21,360	16,200	76.2 / 64.8	53.5 / 53.5	4.9	10.25	18,148	67.6 / 32.0	94.3 / 32.0
HP-2	24	900	50	0.55	22,540	19,300	76.0 / 64.3	56.1 / 56.1	6.5	18.00	19,440	68.1 / 32.0	88.1 / 32.0
HP-3	30	1000	50	0.67	28,900	22,400	75.8 / 64.0	55.0 / 54.3	8.1	10.25	28,900	60.0 / 32.0	84.0 / 32.0
HP-4	12	400	50	0.37	11,100	10,200	77.0 / 66.0	57.2 / 57.2	2.4	13.40	9,780	66.2 / 32.0	88.7 / 32.0
HP-5	24	630	0	0.74	21,360	16,210	75.0 / 63.0	53.7 / 53.7	4.9	10.25	18,150	70.0 / 32.0	93.5 / 32.0
HP-6	9	300	0	0.67	8,180	7,600	76.2 / 64.8	53.5 / 53.5	1.8	6.13	7,625	67.6 / 32.0	94.3 / 32.0

Table B.3: Fan Schedule

FAN SCHEDULE

Desig.	Area Served	CFM	ESP (IN.)	Motor			RPM	Min. Fan Diameter	Drive Type	Control
				HP	Max. BHP	Volts / Phase				
EF-1	Mechanical Room Exhaust	375	0.8	1/10	-	120 / 1	1600	7"	Direct Drive	ATC
EF-2	Laundry Exhaust	1320	1.5	1/2	0.3	120 / 1	1600	25"	Direct Drive	ATC

Table B.4: Pump Schedule

PUMP SCHEDULE								
Desig.	Service	GPM	Head (FT.)	Motor			RPM	Control
				HP	Max. BHP	Volts / Phase		
P-1	Condenser Water Pump	375	150	25	22.4	208 / 3	3500	ATC
P-2	Condenser Water Stand-By	375	150	25	22.4	208 / 3	3500	ATC
P-3	Domestic HW Recirculation	15	18	1/3	-	120 / 1	3500	ATC
P-4	Elevator Sump Pump	45	20	1/2	0.3	120 / 1	3600	Float

Table B.5: Expansion Tank Schedule

EXPANSION TANK SCHEDULE								
Desig.	System	Type	Tank Volume (GAL.)	Min. Accep. Volume (GAL.)	Air Charge		Dimensions (IN.)	
					Precharge PSIG	Oper. PSIG	Diameter	Height
EXP-1	Geothermal	Vertical Bladder	160	100	12	180	30	68
EXP-2	Domestic Water	Vertical Bladder	35	15.5	40	150	16	45

Table B.6: Mechanical Equipment Schedule

MECHANICAL EQUIPMENT SCHEDULE					
Desig.	Service	Capacity	Gas Input MBH	HP / kW	Volts / Phase
DHWH-1	Domestic Hot Water Heater	750 GPH @ (40° - 120°F)	600	1/3 HP	115 / 1
UH-1	Unit Heater	10,200 BTU/hr	-	3 kW	208 / 1

Table B.7: Electric Duct Heater Schedule

ELECTRIC DUCT HEATER SCHEDULE				
Desig.	kW	Volts / Phase	Stages	Dimensions (IN.)
EDH-1	14	208 / 3	3	14 x 14
EDH-2	14	208 / 3	3	14 x 14
EDH-3	14	208 / 3	3	14 x 14

REFERENCES

- "ANSI/ASHRAE Standard 62.1-2004 - Ventilation for Acceptable Indoor Air Quality." ASHRAE, Inc. Atlanta, GA. 2004.
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