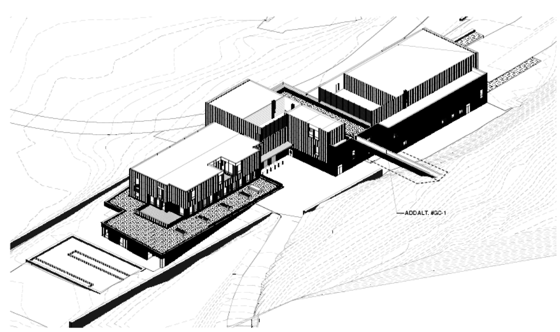
Technical Assignment 3

Mechanical Systems Existing Conditions Evaluation

Slippery Rock University Student Union

Slippery Rock, PA



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Executive Summary

This technical report is to provide an in depth summary and show a fundamental understanding of how the mechanical system functions in the Slippery Rock University Student Union. The report begins with a description of the mechanical system. It shows the intent and objectives that the design is hoping to achieve along with the different systems used and a list of the schedules.

The section following continues to describe the system in greater detail. Schematics showing the process of heat transfer throughout the system were created to show how heat moves from system to system from start to finish. These schematics also provide an easy and concise description of exactly what is occurring in each system.

The next section describes the credits that relate to the Slipper Rock University Student Union's mechanical system. It provides the intent of each credit that hope to be attained and what the engineers have done in order to be awarded each point. The building is currently designed to achieve LEED Silver with the potential to be LEED Gold if they to choose to pursue several more points.

Overall, this technical report will provide a detailed mechanical system analysis of the Slippery Rock University Student Union. Each system is described in detailed and can be easily understood after reviewing the report.

Mechanical System Description

Mechanical Design Objectives

The Slippery Rock University Student Union construction is currently underway with building completion estimated to be in late November of 2011. The building will serve many different types of activities and will house spaces such as a bookstore, kitchen, cafeteria, ballroom, theater, student lounges, and will also have various offices and conference rooms. With such a diverse environment, it is important to ensure comfort and wellbeing for the occupants throughout the long operation hours during all months of the year. In order to achieve this, careful planning was incorporated into the design to allow the occupants to have control of each space as much as possible.

In most cases, the building exceeds minimum ventilation requirements set forth by ASHRAE Standard 62.1 and the minimum system efficiencies stated in ASHRAE Standard 90.1. The SRU Student Union is designed in order to obtain a LEED Silver Rating. To able to accomplish this achievement, efficient energy recovery units with a hot water heat transfer system are used with auxiliary back up. Due to the different types of spaces in the building, simultaneous heating and cooling will be occurring, which allows for these units to run effectively.

Comfort is another major priority within the SRU Student Union. Each office, conference room, and lounge area in the building is equipped with a VAV box along with a thermostat so the individuals can have the space at their own comfort level. The nature of the building requires the larger spaces to be monitored by automatic controls to keep each space at a satisfactory temperature and humidity throughout the operational hours. When outdoor conditions are suitable, natural ventilation can be utilized by operable windows where applicable. With careful consideration, the SRU Student Union will be a safe and comfortable environment for the occupants.

Energy Sources

The Slippery Rock Student Union will use various means of energy. The majority of the energy consumption will be in the form of electricity. The building will also use natural gas, and steam from the nearby campus steam plant. The following chart shows the energy costs per type.

Table 1 – Electricity Demand and Consumption Rates

Electricity Rates		
	0-100 kW	>100 kW
Electric Demand ($/kW)	7.04	6.05
	0-40,000 kWh	>40,000 kWh
Electric Consumption ($/kWh)	0.05113	0.04615

Table 2 – Natural Gas Rates

Natural Gas Consumption Rates	
Natural Gas ($/therm)	1.16

Table 3 – Steam Rates

Steam Consumption Rates	
Steam ($/therm)	1.057

Design Conditions

The following design conditions were used based on the weather data for the location of the building provided by the ASHRAE Handbook of Fundamentals which is the same as the TRACE 700 load calculation program.

Table 4 – Summer and Winter Design Conditions

Summer Conditions	
Indoor (°F)	74
Outdoor(°F)	86

Winter Conditions	
Indoor (°F)	70
Outdoor(°F)	5

Calculated and Designed Ventilation Requirements

A detailed ventilation requirement analysis was conducted to ensure compliance with the minimum ventilation rates stated in ASHRAE Standard 62.1. Based on the outdoor conditions, up to 32 percent outdoor air is designed to be used in the buildings air handling units. The building is also able to incorporate natural ventilation through exterior rooms. The atrium also has operable doors and windows along with an oversized exhaust fan located at the roof of the atrium that doubles to allow for natural ventilation and acts as a safely mechanism to remove smoke in case of a fire. The exhaust fan is equipped with a VFD to be used during hours of natural ventilation. The following table shows the designed ventilation requirements based from the drawings versus the estimated ventilation rates calculated from the TRACE 700 model. The model from the previous report uses the minimum ventilation rates stated in ASHRAE Standard 62.1.

Table 5 – Calculated vs. Designed Ventilation Rates

Ventilation Rates	
Calculated (CFM)	32010
Designed (CFM)	38215

Design Load Estimates

In the previous technical report, a TRACE model was created by separating the building into different zones based on the location and which air handler served each zone. The model provided estimated loads for the building throughout the year. These estimated loads were then compared to the design loads determined by the engineers found and calculated in the design documents. It appears that the estimated loads from the TRACE model were higher than the designed load conditions found from performing calculations based on the schedules from the design documents. Whereas, the designed ventilation rates exceed the ventilation rates estimated in the model. These differences could be due to several estimations made during the creation of the model. The estimated values do however appear to be within reasonable accuracy. The following table shows the estimated vs. designed loads.

Table 6 – Calculated vs. Designed Loads

Estimated vs. Designed Loads			
	Cooling (ft^2/ton)	Heating (Btuh/ft^2)	Ventilation Air (cfm/ft^2)
Estimated	375.9	30.3	0.245
Designed	299.4	28.2	0.322

Estimated Annual Energy Use

An energy analysis was conducted to determine the average distribution of each energy type throughout the building over an entire year.

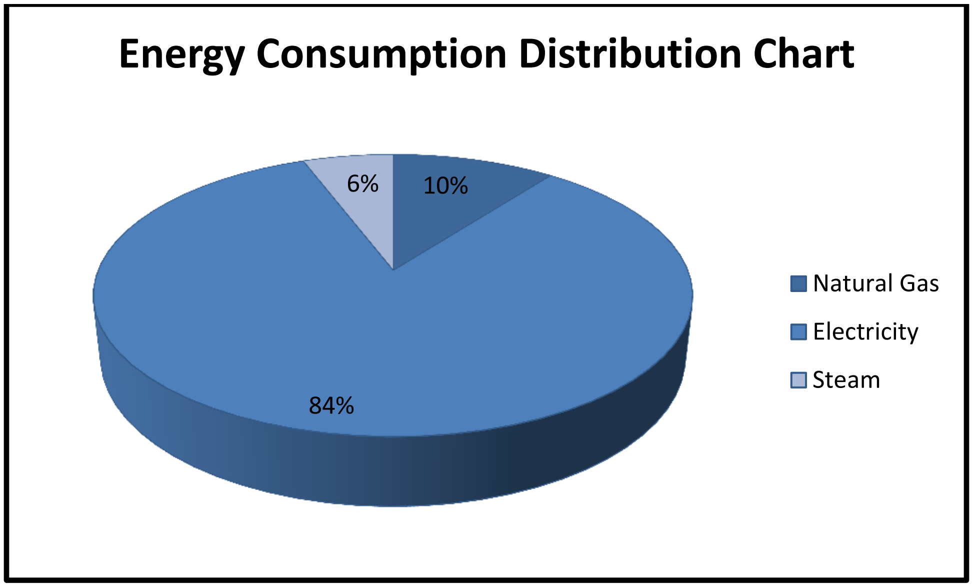

Figure 1 – Energy Distribution Chart

As shown above, the majority of the energy cost is due to the high electrcity usage throughout the entire building. Low, Medium and high pressure steam from the campus steam plant is taken to the heat exchangers and then used for domestic hot water and the hot water heating system. The make-up air handlers are gas fired and use a large portion of the natural gas in the building. Domestic hot water is also heated by hot water tanks using natural gas and steam.

The following pie chart shows the energy distribution throughout the different pieces of mechanical equipment in the building. As shown in the chart, over one-third of the energy used is in the supply fans. This could be due to overcoming the static pressure caused by the energy recovery wheels in the energy recovery units. They are also high power output fans, up to 50 hp and blowing a maximum of 26,000 cfm.

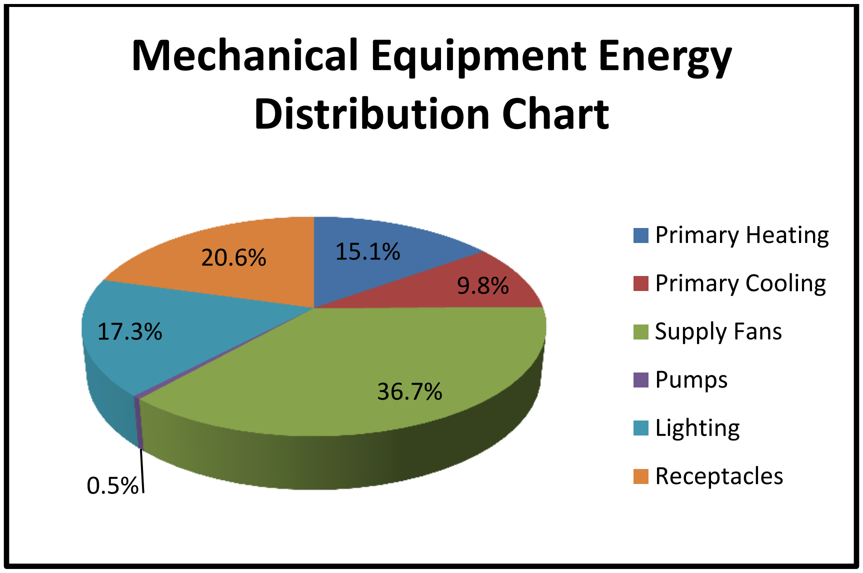

Figure 2 – Mechanical Equipment Energy Distribution Chart

Mechanical Equipment Schedules

Most spaces in the building are heated, ventilated, and cooled by five separate energy recovery units with a hot water heat transfer loop between the units in the system. Each energy recovery unit serves a different zone located in the building. The zone each unit serves is located on the schedule. Three make-up air handlers are used to provide 100 percent outdoor ventilation air to the kitchen area due to the mass amount of exhaust air from the kitchen hoods. The ductless split system is used to keep the IT rooms from overheating throughout the building. These rooms contain building servers and electrical equipment that put off large amounts of heat.

Table 7 – Make-Up Air Unit Schedule

Gas Fired Make-Up Air Unit Schedule					
	Air Flow (CFM)	EAT (°F)	LAT (°F)	Motor Size (hp)	Gas Input (btu/hr)
MUA - 1	2500	-5	55	3	400000
MUA - 2	6075	-5	55	5	750000
MUA - 3	3660	-5	55	3	400000

Table 8 – Energy Recovery Unit Schedule (Winter Conditions)

Energy Recovery Unit Schedule (Winter Conditions)										
	Heat Transfer Section					Heat Recovery Section				
	Air Flow (CFM)	Water Flow (GPM)	EAT (°F)	LAT (°F)	Water (EWT/LWT) (°F)	Air Flow (CFM)	Outdoor Air Temp (°F)	Supply Air Temp (°F)	Effectiveness (%)	Location
ERU - 1	24000	205	64	98	50/42	6500	0	47	67	Commons
ERU - 2	16000	136	65	99	50/42	3800	0	49	69	Café/Kitchen
ERU - 3	24000	205	65	99	50/42	4700	0	47	66	Office/Meeting
ERU - 4	26000	210	64.5	95	50/42	6500	0	47	67	Ballroom
ERU - 5	16000	135	64.5	98	50/42	4000	0	48.5	68	Bookstore

Table 9 – Energy Recovery Unit Schedule (Summer Conditions)

Energy Recovery Unit Schedule (Summer Conditions)										
	Heat Transfer Section					Heat Recovery Section				
	Air Flow (CFM)	Water Flow (GPM)	EAT (°F)	LAT (°F)	Water (EWT/LWT) (°F)	Air Flow (CFM)	Outdoor Air Temp (°F)	Supply Air Temp (°F)	Effectiveness (%)	Location
ERU - 1	24000	205	77/64	52.5	95/107	6500	92	82	61	Commons
ERU - 2	16000	136	76.5/63.5	52	95/107	3800	92	81	64	Café/Kitchen
ERU - 3	24000	205	76.5/63.5	52	95/107	4700	92	82	60	Office/Meeting
ERU - 4	26000	210	76.5/64	53.5	95/107	6500	92	82	61	Ballroom
ERU - 5	16000	135	76.5/64	52.5	95/107	4000	92	81	63	Bookstore

Table 10 – Ductless Split System Schedule

Ductless Split System		
Indoor Evaporator Units		
	Cooling Capacity (btu/hr)	CFM
S - A	12000000	390
S - B	12000000	390
S - C	18000	480
Outdoor Condensing Units		
	Cooling Capacity (btu/hr)	CFM (fan)
ACCU - A	36000000	3530
ACCU - B	36000000	3530
ACCU - C	18000	480

Table 11 – Cooling Tower Schedule

Cooling Tower Schedule						
	Flow (GPM)	Air Flow (CFM)	EWT	LWT	Blower Motor (hp)	Spray Motor (hp)
CC - 1	415	56000	105	95	15	2
CC - 2	415	56000	105	95	15	2

Table 12 –Unit Heater Schedule

Unit Heater Schedule						
	Min capacity (btu/hr)	EWT	LWT	Flow (GPM)	LAT	Min CFM
Unit - A	40000	190	163	3	120	620
Unit - B	40000	190	163	3	95	1120
Unit - C	20000	190	163	1.5	121	300

Table 13 – Pump Schedule

Pump Schedule			
	Flow (GPM)	Head (ft H2O)	Motor hp
HW - 1	310	70	10
HW - 2	310	70	10
HT - 1	830	70	30
HT - 2	830	70	30
HT - 3	120	30	2
HT - 4	120	30	2

Table 14 – VAV Schedule

Variable Volume Air Valve With Hot Water Reheat				
Mark	Nominal Air Flow (CFM)	Air Flow Range (CFM)	Capacity (BTUH)	Flow (GPM)
A	200	0 - 200	5200	1
B	300	210 - 350	7500	1
C	600	360 - 750	18000	1.5
D	800	760 - 900	20000	1.5
E	1200	910 - 1300	26000	1.8
F	1600	1310 - 1800	39000	2.6
G	2000	1810 - 2400	49000	3.3
H	3000	2500 - 3500	70000	4.7

Mechanical System Space Requirements

The building was designed to isolate the areas containing mechanical equipment. A large mechanical room is located on the northwest end on the first floor of the building. It houses heat exchangers, domestic hot water tanks, pumps, expansion tanks, various types of vavles, and piping. Another mechical room is located on the first floor located on the northern side of the building that contains an energy recovery unit that services the bookstore and surrounding support areas. The ductless split system evaporators are located in the IT rooms throughout the building. Each condesndsor serves three indoor evaporators. The remaining four energy recovery units, two cooling towers, three ductless split system condensors, three make-up air units, and exhaust fans are located on the rooftop.

Table 15 – Mechanical System Space Requirements

Mechanical System Space Requirements	
	Area (ft^2)
First Floor	2970
Roof	8610
Total	11580

Schematic Diagrams

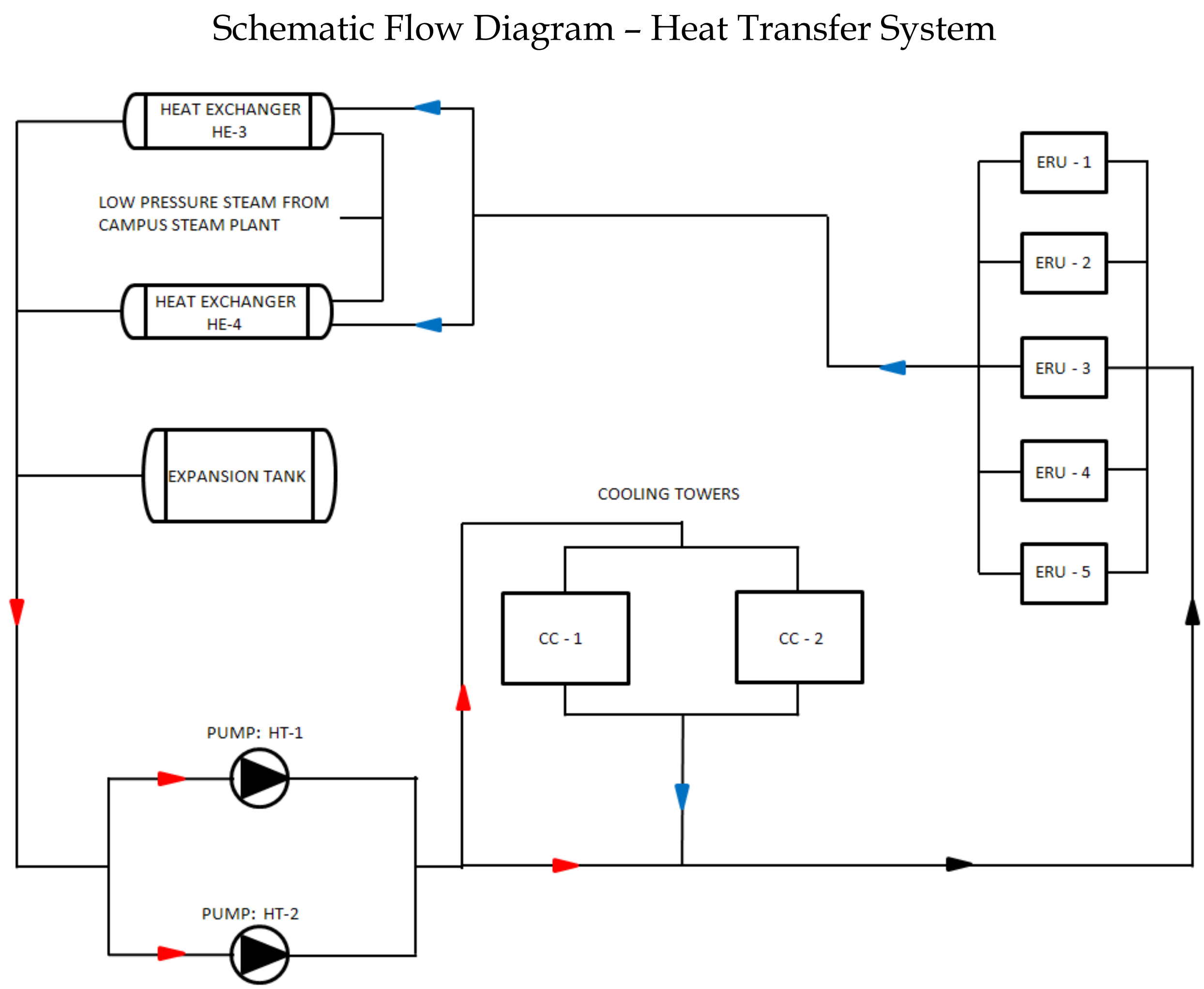

Figure 3 – Heat Transfer System

The heat transfer system is the primary means of heating, cooling, and ventilating the building. The water circulates between the five energy recovery units, and then each unit delivers air to its respective zone. This allows for simultaneous heating and cooling throughout the building with energy being transferred between spaces in order to conserve energy. When the cooling demands are high enough, the heat transfer water loop will pass through the cooling towers to provide sufficient cooling for the building.

Schematic Flow Diagram – Hot Water Heating System

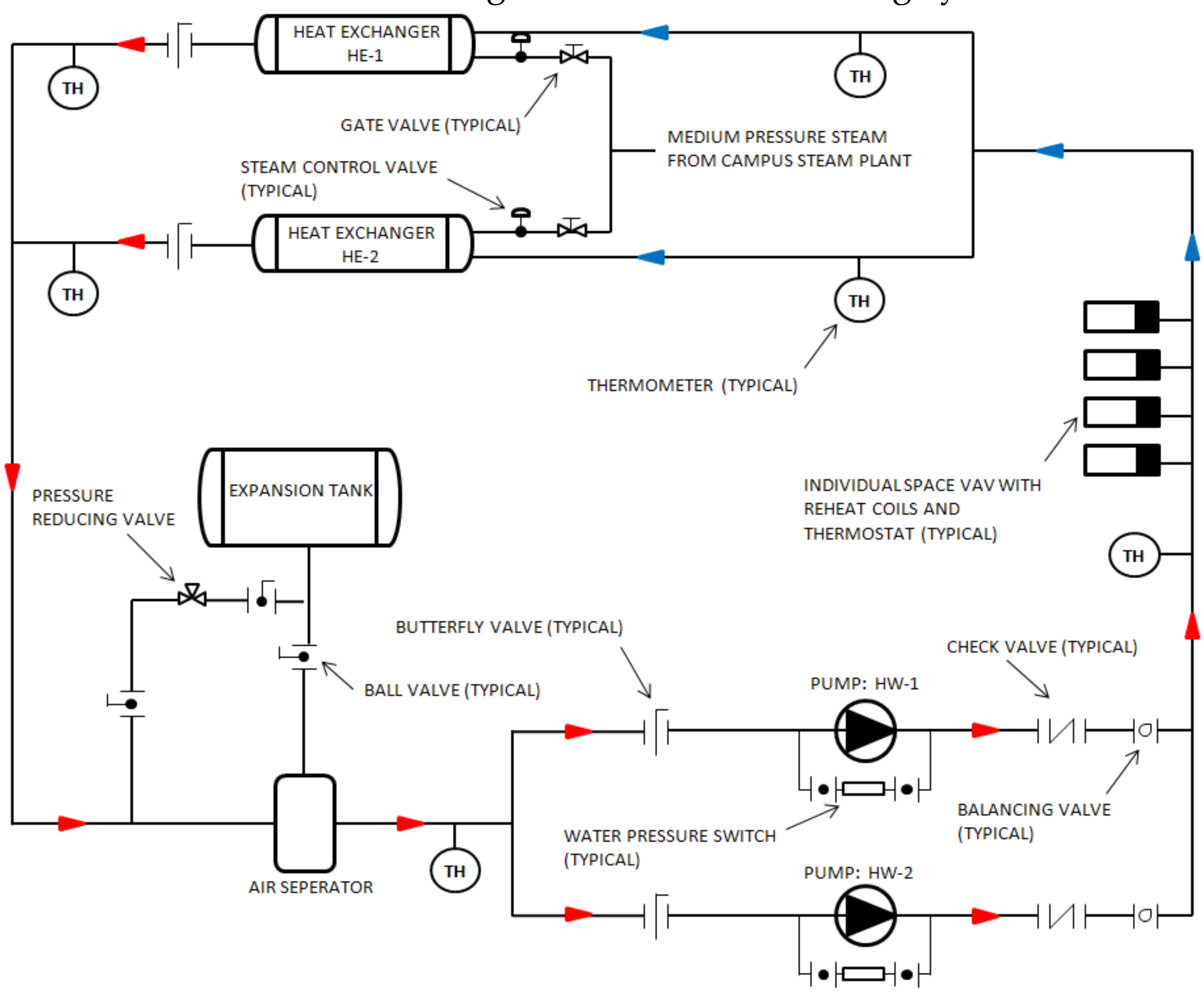

Figure 4 – Hot Water Heating System

When heating, the campus steam plant provides the building with steam, which is taken to the heat exchangers then used to heat the building via the energy recovery units. When the heating demand is high, an auxiliary hot water heating system is used to provide sufficient heat to the spaces. Again, heat exchangers use steam from the campus steam plant then use hot water pumps with variable frequency drives to pump the water throughout the building based on the load. The water reaches the heating coils located in various spaces. Then, using variable air volume with hot water reheat coils and thermostats, the occupants have individual climate control.

Air Flow Schematic Diagram – System ERU-1 thru ERU-5

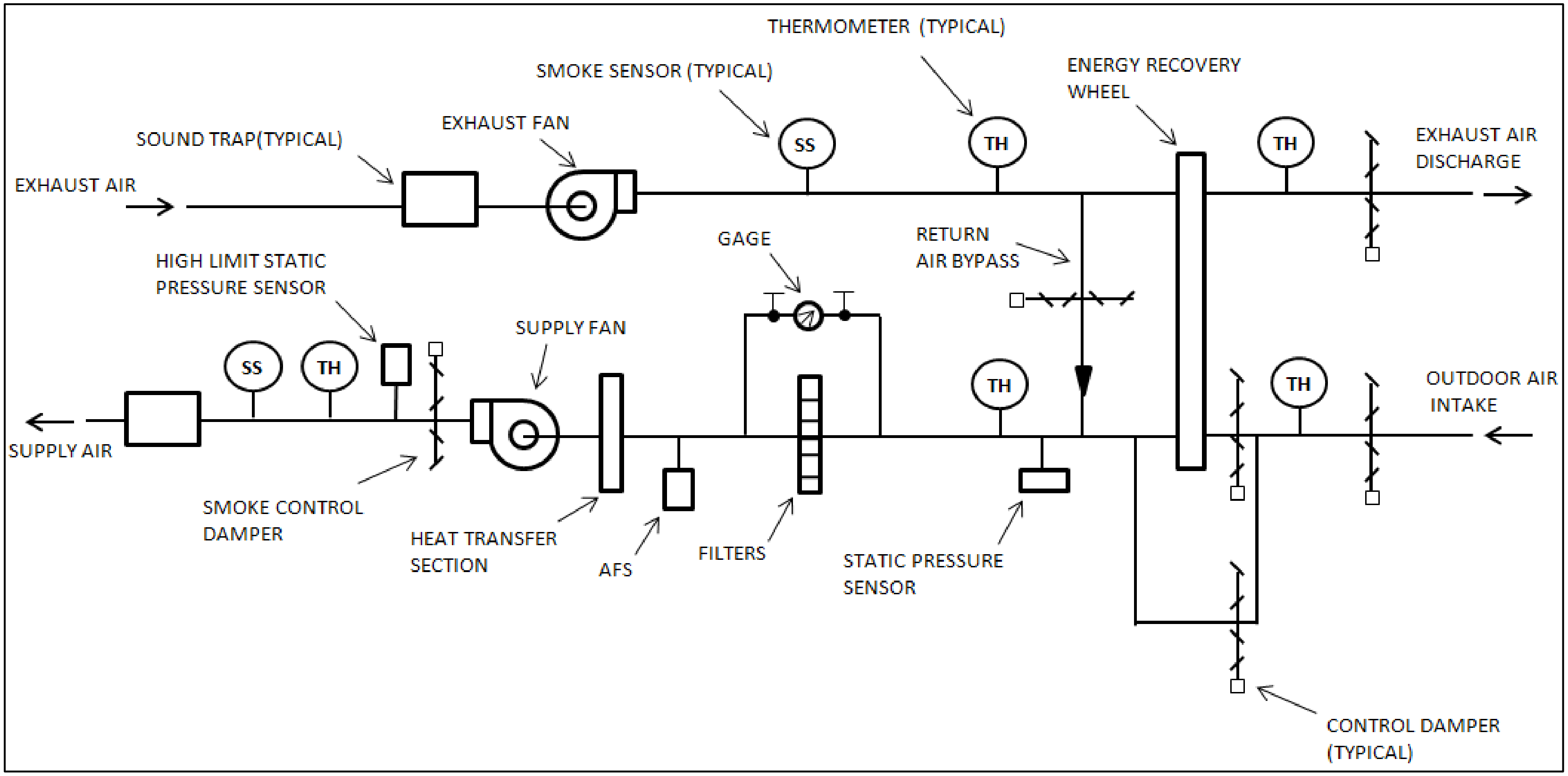

Figure 5 – Air Side System for ERU 1 – ERU 5

LEED for New Construction Version 3

Background

The Slippery Rock University Student Union will be attempting to achieve a LEED Rating. The building will hope to score 54 points, which puts it between 50 to 59 points achieving LEED Silver with an opportunity to achieve LEED Gold. The summary below will describe the points in Energy and Atmosphere along with Indoor Environmental Quality that the building will be anticipating to be awarded pertaining to the buildings mechanical system. The prerequisites for each section are assumed to be compliant.

Energy and Atmosphere

EA-P1: Fundamental Commissioning of Building Energy Systems

Intent: To verify that the project's energy-related systems are installed, and calibrated to perform according to the owner's project requirements, basis of design and construction documents.

EA-P2: Minimum Energy Performance

Intent: To establish the minimum level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use.

EA-P3: Fundamental Refrigerant Management

Intent: To reduce stratospheric ozone depletion.

EA-C1: Optimize Energy Performance

Intent: OPTION 1: Whole Building Energy Simulation - Demonstrate a percentage improvement in the proposed building performance rating compared with the baseline building performance rating. Calculate the baseline building performance according to Appendix G of ANSI/ASHRAE/IESNA Standard 90.1-2007 (with errata but without addenda1) using a computer simulation model for the whole building project. The minimum energy cost savings percentage for each point threshold is as follows.

The Slippery Rock University Student Union will conserve energy by at least 28 percent when compared to the base case in ASHRAE Standard 90.1 through a detailed energy model comparison.

EA-C3: Enhanced Commissioning

Intent: To begin the commissioning process early in the design process and execute additional activities after systems performance verification is completed.

A third-party commissioning agency, Iams Consulting, has been brought in to perform the enhanced commissioning process throughout and post construction.

EA-C4: Enhanced Refrigerant Management

Intent: Select refrigerants and heating, ventilation, air conditioning and refrigeration (HVAC&R) equipment that minimize or eliminate the emission of compounds that contribute to ozone depletion and climate change. The base building HVAC&R equipment must comply with the following formula, which sets a maximum threshold for the combined contributions to ozone depletion and global warming potential.

CJL Engineering have documented that the refrigerants used comply with the new formula for enhanced refrigerant management.

Indoor Environmental Quality

EQ-P1: Minimum Indoor Air Quality Performance

Intent: To establish minimum indoor air quality (IAQ) performance to enhance indoor air quality in buildings, thus contributing to the comfort and well-being of the occupants.

EQ-P2: Environmental Tobacco Smoke (ETS) Control

Intent: To prevent or minimize exposure of building occupants, indoor surfaces and ventilation air distribution systems to environmental tobacco smoke (ETS).

EQ-C1: Outdoor Air Delivery Monitoring

Intent: To provide capacity for ventilation system monitoring to help promote occupant comfort and well-being.

CJL Engineering has designed the SRU Student Union with CO_2 sensors meet the LEED criteria. All densely occupied spaces are equipped with CO_2 sensors with alarms when CO_2 levels exceed the maximum safe levels. Compliance is found in the design documents.

EQ-C2: Increased Ventilation

Intent: To provide additional outdoor air ventilation to improve indoor air quality (IAQ) and promote occupant comfort, well-being and productivity.

CJL Engineering has documented that the minimum requirements from ASHRAE Standard 62.1 are exceeded by a minimum of 30 percent.

EQ-C3.1: Construction Indoor Air Quality Management Plan – During Construction

Intent: To reduce indoor air quality (IAQ) problems resulting from construction or renovation and promote the comfort and well-being of construction workers and building occupants.

The mechanical contractor, Renick Brothers Inc., is to work with CJL Engineering to ensure that proper measures are taken to protect any onsite absorptive materials.

EQ-C3.2: Construction Indoor Air Quality Management Plan – Before Operation

Intent: To reduce indoor air quality (IAQ) problems resulting from construction or renovation to promote the comfort and well-being of construction workers and building occupants.

Option 1, Flush out, will be conducted prior to the buildings occupancy.

EQ-C5: Indoor Chemical and Pollutant Source Control

Intent: To minimize building occupant exposure to potentially hazardous particulates and chemical pollutants.

DRS Architects and CJL Engineering have teamed up and reviewed any plans for potential hazardous gases or chemicals to ensure clean and safe environment.

EQ-C6.2: Controllability of Systems – Thermal Comfort

Intent: To provide a high level of thermal comfort system control by individual occupants or groups in multi-occupant spaces (e.g., classrooms or conference areas) and promote their productivity, comfort and well-being.

CJL Engineering has documented that a minimum of 50 percent of the building occupants have individual comfort controls. This was confirmed from the design documents.

EQ-C7.1: Thermal Comfort – Design

Intent: To provide a comfortable thermal environment that promotes occupant productivity and well-being.

CJL has documented that the HVAC system conforms to the requirements set in ASHRAE Standard 55.

Overall System Evaluation

Due to the nature of the building, the energy recovery unit system seems to be a system that can provide thermal comfort and wellbeing to its occupants efficiently. With an auxiliary heating and cooling system, the building is capable of using minimal energy while being able to satisfy comfort needs during peak load conditions throughout the entire year. Most spaces are equipped with thermostats that allow for the occupants to control the climate by the VAV with reheat coils.

The designed building has been compared to a baseline model and reports that it will save an estimated 28 percent of total energy on an annual basis. This lower energy consumption allows the SRU Student Union to have the potential to reach LEED Silver rating. At this time, LEED score sheets report more credits are being examined, allowing for the possibility of achieving LEED Gold rating.

The designers did well with isolating the mechanical systems. Only two spaces contain inside the building contain mechanical equipment with the exception of the IT rooms that have evaporators. The remaining equipment is located on the roof. This allows for the building to use space more efficiently and effectively. It also makes it easier to identify a problem if one were to occur. With only three different locations, while knowing what space each piece of equipment servers, it should allow for simpler problem solving when maintenance is needed.

Overall, the SRU Student Union has made occupant environmental control and thermal comfort one of the highest priorities. Along with using efficient heating and cooling techniques, the building will allow an efficient system to run at a reduced energy consumption cost.

References

CJL Engineering Mechanical Drawings and documents

DRS Architects Architectural Drawings and documents

ASHRAE Handbook of Fundamentals 2009

Previous Senior Thesis Reports 2009 – 2010

LEED 2009 for New Construction and Major Renovations

Appendix A: List of Tables and Figures