Grunenwald Science and Technology Building

Clarion University- Clarion, PA

Technical Report Three:

Mechanical Systems Existing Conditions Evaluation

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Executive Summary

The content of this report includes a summary of the mechanical system, by the design requirements, external influences, and the various components used throughout the system. An overall evaluation of the system is provided along with the operation of the building.

The mechanical system does use sustainable ideas and energy consumption reduction as a basis for the initial design approach. The building does implement 5 VAV AHU's, 3 of which are 100 percent outdoor air, and the other 2 are standard VAV systems that use an economizer with CO2 measurement controlling the damper for outside air. The Grunenwald Science and Technology Building uses (2) 250 ton centrifugal chillers which are water cooled by 2 cooling towers. Hot water is produced by passing the campus generated steam through a plate and frame heat exchanger with water, and the water is used in the pre-heating and heating coils of the AHU's.

The sustainable design approach can be seen in the energy efficient equipment used for the building. The energy reduction was calculated to be 40 percent better than the baseline building when analyzed for the LEED credit. The designers were able to meet many of the LEED credits associated with the mechanical system in the following two sections; Energy and Atmosphere and Indoor Environmental Quality. A grant from the government allowed for the use of a micro turbine to produce on-site energy powered by natural gas. The micro turbine does not only produce electricity but the heat produced is used to precondition outdoor air. The designers did use rooftop photovoltaic panels that produce on-site electricity as well, but not enough to earn LEED points.

The overall cost of the mechanical system was \$6.25 million, while the total construction cost was \$34 million. The operational cost of the building was calculated to be \$1.43/sf, which is relatively low for this type of building. With the use to the VAV systems which have become standard in office buildings the maintenance costs should be low with building engineers knowing how to work with these systems.

Mechanical System Design

Introduction:

The Grunenwald Science and Technology Building is a 3-story, 108,560 square foot, university laboratory and classroom building on Clarion University's campus. The building is comprised of approximately 50 percent laboratories, 20 percent classroom, and 10 percent offices. The laboratories are served by a 100 percent outdoor air VAV system, while the other spaces are served by a conventional VAV system. It is designed to achieve a LEED Gold rating through the use of sustainable technologies and innovative design approaches.

Design Objectives and Requirements:

The main design objective for the Science and Technology Building was to focus on sustainability and a reduction in energy consumption while obtaining a LEED certification and meeting the ASHRAE Standards. In order to meet the standards, the building must meet specific energy, ventilation, equipment, and temperature requirements. With these both in mind the designers produced a VAV system using 100 percent outdoor air for the zones handling the laboratory spaces, and used a conventional VAV system for the classrooms and offices. The mechanical system consists of high efficiency chillers and cooling towers, while using the central campus plant steam to pass through a plate and heat exchanger to heat the water used in the heating coils in the systems. The 100 percent outdoor units utilize a glycol runaround coil to pre-treat air entering the AHU's, while the all the systems use energy recovery wheels to pre-treat the air using either the exhaust air or the heat produced by the on-site micro turbine.

Site and Budget:

The site for the Grunenwald Science and Technology Building is located on the campus of Clarion University in Clarion, PA. At Clarion University, the new building was built on the same site as the previous Pierce Science Building constructed in 1968. In the center of the building, the newly renovated planetarium was preserved from the previous Pierce Science Building along with a large lecture hall located on the first floor, directly below the planetarium. The building sits on the same footprint of the previous building and the location of a faculty parking lot as it did not add more impermeable surfaces than what was previously on the site. The building was awarded for $34 million, which was within the established budget for the university. One item that was nearly left out due to budget concerns was the micro turbine as the calculated payback period exceeded 30 years. The university was able to obtain a government grant for the micro turbine allowing the design team the ability to use this technology with no cost to the university who began seeing savings upon installation into the building.

Mechanical System Initial Cost:

The estimated final cost including change orders for the mechanical system for the Grunenwald Science and Technology Building was $6.25 million. This number includes the plumbing that is associated with the HVAC systems. The calculated cost per square foot of the building floor area is $57.57. The total cost of the mechanical system accounts for 18.4 percent of the total construction cost for the building.

Energy Sources:

The campus does utilize district steam which is produced at a central plant that is delivered to the building and is passed through a plate heat exchanger with water that then runs through the heating coils. The electricity for the campus is provided by Allegheny Power. The costs were 4.8 cents/kWh for electricity and 1.195 $/therm for the purchased steam from the central campus steam plant, as was used for the analysis for Technical Report Two.

Outdoor and Indoor Design Conditions:

This information was obtained from Technical Report Two as it was used in the analysis of the building in Trace 700. Grunenwald Science and Technology Building is located on the campus of Clarion University in Clarion, PA. The city that has similar weather conditions and location to the Science and Technology Building was Erie, PA. The design outdoor air conditions for Erie, Pa were obtained from the ASHRAE Handbook of Fundamentals 2009. The heating design month was July, while the cooling design month was January, and can be seen in the following table. The data was used for the 0.4 percent and 99.6 percent design conditions.

Table 1- Outdoor Air Design Conditions

Summer		Winter
DB (F)	MCWB (F)	DB (F)
85.8	72.7	2.9

The indoor design conditions were obtained from the design documents and can be seen in the following table.

Table 2- Indoor Air Design Conditions

Cooling Set Point	75 F
Heating Set Point	68 F
Relative Humidity	50%

Lost Space:

The mechanical room is located on the first floor, with each of the (5) air handling modular units located on the penthouse level. The mechanical shafts run to each of the floors from the respective modular unit located on the penthouse level. The total area lost due to mechanical space can be found in Table 3 broken down by floor. The average plenum height for each floor is 3 feet, and is used for the mechanical system along with the electrical, lighting, and telecommunication systems.

Table 3- Lost Floor Area

Floor	Lost Space (sf)
1st	2,097.25
2nd	217.5
3rd	217.5
Total	2,532.25

Equipment Summary:

The building is served by (5) VAV air handling units to provide the required ventilation to each of the spaces. The air handling units are modular units located on the penthouse level and the information on each can be seen in Table 4.

Table 4- Air Handling Units Design Information

Unit	Design Max CFM	Design Min OA	Humidifier Capacity(lbs/hr)	Glycol Run-around Coil (gpm)
AHU-1	40,890	100 percent	782.2	162
AHU-2	41,735	100 percent	782.2	165
AHU-3	27,500	13,000 CFM	Not Available	Not Available
AHU-4	24,000	4,553 CFM	Not Available	Not Available
AHU-5	22,450	100 percent	420.8	90

The air side includes multiple exhaust fans to serve the laboratory spaces that use fume hoods and flexible exhaust ducts. The data for the fans, exhaust, return, and supply, can be found in Table 5, while the data for the energy recovery units used by passing outdoor air with the exhaust air can be seen in Table 6.

Table 5- Mechanical System Fans

Fan Tag	Flow Rate (CFM)	Actual Hp
EF-1	38000	60
EF-2	38000	60
EF-3	38000	60
EF-4	38000	60
RAF-3	22000	25
RAF-4	19400	25
EF-5	4500	3
EF-6	2895	3/4
EF-7	1750	1/6
EF-8	1000	1/8
EF-9	1000	1/8
EF-10	2100	2
EF-11	750	1/4
AHU-1	40890	75
AHU-2	41735	75
AHU-3	27500	25
AHU-4	24000	25
AHU-5	22450	40
ERU-1 Supply	13000	10
ERU-1 Exhaust	14050	15
ERU-2 Supply	4553	3
ERU-2 Exhaust	4891	5

Table 6- Energy Recovery Wheels

Unit	Supply CFM	Exhaust CFM	Heat Exchanger Motor hp	Wheel Effectiveness
ERU-1	13,000	14,050	1/2	78.5%
ERU-2	4,553	4,891	1/4	69.7%

The Science and Technology Building uses (2) 250 ton centrifugal chillers, that pump the condenser water to the (2) cooling towers. One of the plate and frame heat exchangers is used with condensate water and chilled water, while the other two implemented in the design use the campus steam to heat the water used in the heating coils. The chiller information can be found in Table 7, and the cooling towers can be found in Table 8. The plate and frame heat exchangers were described in Table 9.

Table 7- Chillers

Label	Capacity (Tons)	Evaporator gpm	Condensor gpm	Evaporator EWT	Evaporator LWT	Condenser EWT	Condenser LWT	Full Load kW/Ton	50 % Load kW/Ton
CH-1	250	1000	750	56	48	85	94.4	0.615	0.363
CH-2	250	1000	750	50	44	85	94.4	0.615	0.363

Table 8- Cooling Towers

Label	Capacity tons	Condenser gpm	Fan hp	Fan CFM	EWT (F)	LWT (F)	Equipment gpm/hp
CT-1A and CT-1B	312	750	15	59,380	95	85	50

Table 9- Plate and Frame Heat Exchangers

Equipment Tag	Steam Side (Frame)			Water Side (Plate)		
	Max Steam Pressure	Steam Side Pressure	Capacity (lb/hr)	GPM	LWT (F)	EWT (F)
HX-1	150	15	8,650	435	180	140
HX-2	150	15	8,650	435	180	140
	Condensate Side (Frame)			Water Side (Plate)		
	GPM	LWT (F)	EWT (F)	GPM	LWT (F)	EWT (F)
HX-3	6	52	50	6	54	56

All the pumps used in the mechanical design use variable frequency drive motors and are used for the condenser water, primary chilled water, and secondary chilled water. With the use of a runaround coil a pump was needed for this along with the hot water and condenser recovery water used in the plate and frame heat exchanger. The building also uses (2) condensate pumps for the entire building and for the rooftop equipment. The pumps are described in Table 10 with the service type and the pump type.

Table 10- Pump Schedule

Pump Tag	Service	Type	GPM	Hp	Head (ft H2O)	RPM
P-1	Condenser water	End-suction	750	40	115	1800
P-2	Condenser water	End-suction	750	40	115	1800
P-3	Primary Chilled Water	End-suction	1050	20	50	1800
P-4	Primary Chilled Water	End-suction	1050	20	50	1800
P-5	Secondary Chilled Water	Vertical Split Case	1050	40	85	1800
P-6	Secondary Chilled Water	Vertical Split Case	1050	40	85	1800
P-7	Hot Water	End-suction	501	20	90	1800
P-8	Hot Water	End-suction	501	20	90	1800
P-9	Runaround Heat Recovery	End-suction	480	15	80	1800
P-10	Runaround Heat Recovery	End-suction	480	15	80	1800
P-11	Condensate Recovery	Inline	3	1/2	25	1800
P-12	Condensate Recovery	Inline	3	1/2	25	1800
P-13	Freeze Protection	Inline	35	1/3	15	1750
P-14	Freeze Protection	Inline	35	1/3	15	1750
P-15	Freeze Protection	Inline	20	1/4	15	1750
P-16	Recirculation	Inline	40	3/4	25	1750
CP-1	Entire Building	Duplex	60	1.5	25 psig	3500
CP-2	Rooftop Equipment	Simplex	12	1/3	15 psig	3500

System Operations

Schematics:

The water sided cooling is shown in Figure 1 through the use of 2 cooling towers, that feed in to the condensers of the centrifugal chillers shown in Figure 2. These two make up the water side cooling schematic while Figure 3 is the water side heating along with the campus steam loop used with the plate and frame heat exchanger.

Figure 1: Cooling Tower Schematic

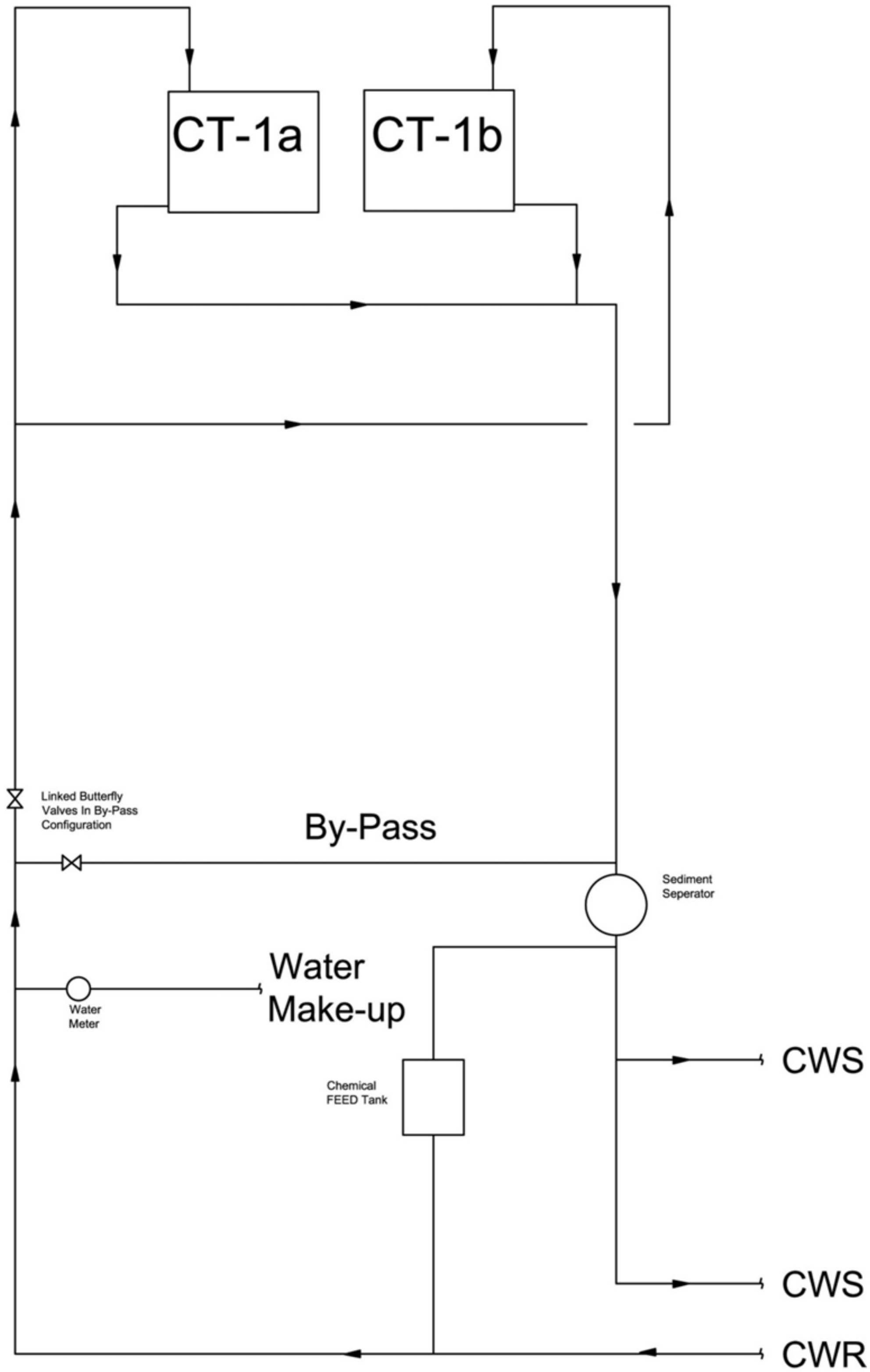


Figure 2- Chiller Schematic

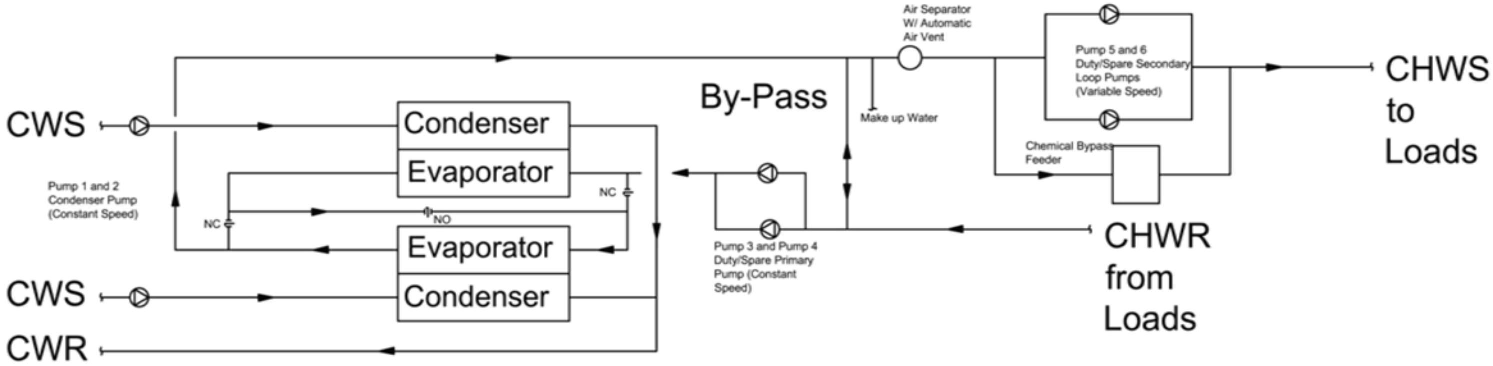
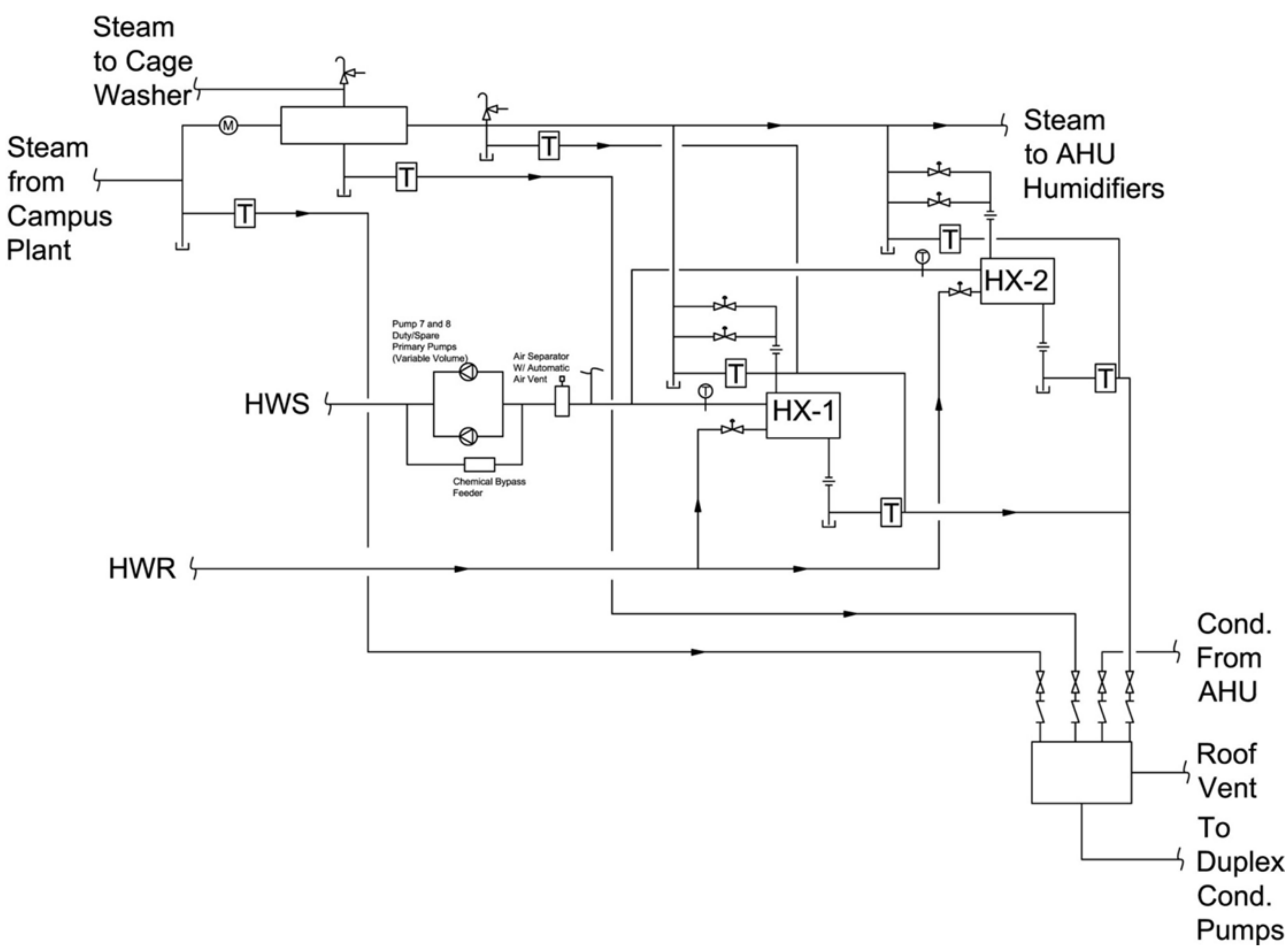


Figure 3- Hot Water & Steam Schematic



Air Side:

The Grunenwald Science and Technology Building utilizes VAV systems for air delivery to zones. All of the VAV terminal units are supplied with air from the modular AHU's that are located on the roof. The use of a BACnet control system allows for the system to start based on the optimum time for heating or cooling associated with the occupancy schedule for the building. The pressure for the building is important to not allow transfer of contaminants from the laboratory spaces, which is controlled by varying the supply and exhaust fans to obtain negative or positive pressure for the correct spaces. The zones use both humidity and temperature sensors that allow the BACnet system to modulate the supply air in either heating or cooling mode. The heating and cooling coils are fed by hot or chilled water which is produced by the processes shown in Figures 2 and 3. Through the use of CO2 meters and flow meters, economizer dampers vary to allow more outside air in as needed to meet the higher CO2 concentrations. This allows for the minimum outdoor air in the building to always be met with additional outdoor air being delivered as required.

The outdoor air for the VAV systems is pretreated by energy recovery wheels that use exhaust air from the two systems in a counter flow to the outdoor air. In the 100 percent outdoor air VAV systems the outdoor air is pretreated by a glycol runaround coil that exchanges heat with the exhaust plumes from the laboratory spaces. The exhaust air from the labs that could contain contaminants is thrown at high velocity so that neighboring buildings or the Science and Technology Building are not affected.

Water Side- Chilled:

The chilled water in the Grunenwald Science and Technology Building is obtained by the use of centrifugal chillers. The chilled water system utilizes a primary/secondary pump flow system, which is shown in Figure 2. The primary pumps on the chilled water system supply the evaporator, while the secondary pumps distribute the chilled water throughout the system to the loads. As can be seen in Figure 2, the chillers are set up to be in series to provide energy savings as each of the chillers will only need to lower the temperature of the water by 6 degrees Fahrenheit. The BACnet sequences and controls the final chilled water temperature out of the second chiller in series is 44 degrees Fahrenheit. When the load is quite small one chiller is shut down, since each chiller was sized to meet the full load and is not efficient when operating at part loads. This can be seen in the piping configuration in the schematics where the piping from the evaporators has valves that can be closed.

The system has redundancy built in with the use of duty and spare pumps. Upon failure of the duty pump the space pump is automatically turned on and is sized to meet the full load. This is done for the primary and secondary loop pumps. The condenser pumps do not have redundancy built.

The cooling towers seen in the schematic in Figure 1 cools the condensate water to 65 degrees Fahrenheit from the exit temperature of the Condenser of 95 degrees Fahrenheit. The chilled water is used in the cooling coils in each of the modular air handling units.

Water Side- Hot:

The hot water for the heating coils is produced by the campus supplied steam, which is produced by natural gas boilers. The steam from the campus supply is passed through a pressure reducing station that is shown on Figure 3. This steam is stepped down in pressure and then is used for either the humidification of air in AHU's 1, 2, and 5 or it is passed through the plate and frame heat exchanger. The water leaves the exchanger at a maximum temperature of 180 degrees Fahrenheit and a passes the temperature sensor in the hot water supply adjusts the total steam into the exchanger allowing for the lower hot water temperatures. The temperature sensor can be seen on the schematic after both of the exchangers in the supply water line. The pumps use redundancy with the duty and spare alignment discussed in the previous system.

Information and Data found in Previous Technical Reports

The information in the following section was covered in the two previous Technical Assignments. The material covered that does repeat pertains to ASHRAE Standard 62.1 and 90.1, and the Building Load analysis.

Ventilation Requirements:

All (5) systems were analyzed with the results for each of the systems contained within Appendix A and Appendix B. The calculations were completed using the ASHRAE Standard 62.1 User Manual, which includes a Microsoft Excel based spreadsheet. The spreadsheet has inputs such as; type of space, assumed population, and square footage of the room. For the purpose of this study all spaces were analyzed for the (3) 100 % outdoor air units. The ventilation rate was found to always meet the minimum requirement of outdoor air provided to each space except for two spaces which are labeled as the critical spaces for the analysis of AHU-1, 2, 5. The two spaces that do not comply with Section 6 are a Clean Room and Cold Room as they do not receive the minimum ventilation rate.

The VAV systems were analyzed using the same process as the 100 % outdoor air units, and all spaces in the VAV system comply with the minimum ventilation rates stated in Section 6 of

ASHRAE Standard 62.1- 2007. The ventilation system efficiency (E_v) can be found on in the spreadsheet highlighted in blue for the VAV system. The VAV systems as designed is greater than the CFM required of outdoor air when the calculation requires 11,500 CFM, therefore it complies with Section 6. This can be seen in the Table 11, that all of the air handling units do comply with the ventilation requirements.

Table 11- Ventilation Requirements

Unit	Design Max CFM	Design Min OA	ASHRAE 62.1 Min OA	Compliance
AHU-1	40,890	100 percent	100 percent	Achieved
AHU-2	41,735	100 percent	100 percent	Achieved
AHU-3	27,500	13,000 CFM	9,500 CFM	Achieved
AHU-4	24,000	4,553 CFM	2,000 CFM	Achieved
AHU-5	22,450	100 percent	100 percent	Achieved

Heating and Cooling Loads:

The modeled building load was calculated using Trane Trace 700 for the five air handling units serving the building spaces. These five units will be compared to the as-designed units listed in the design documents in the following areas; cooling ft^2/ton, heating Btuh/ft^2, total supply air cfm/ft^2, and ventilation supply cfm/ft^2. Table 12 summarizes the as-designed information with the data collected from the block load model run in Trace.

Table 12- Comparison Between As-designed vs. Modeled

Area (sf)	AHU	Cooling sf/ton		Heating Btuh/sf		Supply Air cfm/sf		Ventilation OA %	
		Designed	Modeled	Deigned	Modeled	Designed	Modeled	Designed	Modeled
19493	1	211.4	283.9	34.0	23.5	2.05	1.98	100	100
16653	2	177.3	202.6	40.6	31.8	2.51	2.11	100	100
32055	3	370.0	295.4	27.8	31.7	0.86	0.77	13.0	35.1
18163	4	240.3	230.8	42.9	31.7	1.51	1.68	4.56	21.9
15730	5	237.8	265.7	23.1	8.4	1.53	1.21	100	100

The modeled does vary from the designer's calculated loads, which could be due to a number of reasons. The first reason for a slight variation in loads is the modeling approach used a block load in order to get a reasonable estimate while the engineer used a room by room analysis that should be more accurate. The calculations used for determining wall and window areas is not as accurate as directly importing a 3D building model such as from Revit. Another reason for slightly different results is the use of different simulation programs to obtain the data.

The loads vary in both directions due to the inaccuracies of the block model that was utilized and the other reasons listed previously. The percent of error is in the range of 20 to 35 percent for both the cooling and heating loads, with a few loads having less than 10 percent error. The total cooling load for the Science and Technology Building was calculated to be different than the design calculated by 5 percent more, while the heating total was increased by 24 percent in the student model. The total CFM for the building was calculated to be less than that found in the design documents, which may explain the higher percentage of outdoor air for AHU-3 and AHU-4.

Annual Energy Use:

The following table shows the comparison in energy consumption between the design calculation and the block load model calculation. All the data in the table was obtained from the LEED submission for the design values and Trane Trace 700 for the modeled loads.

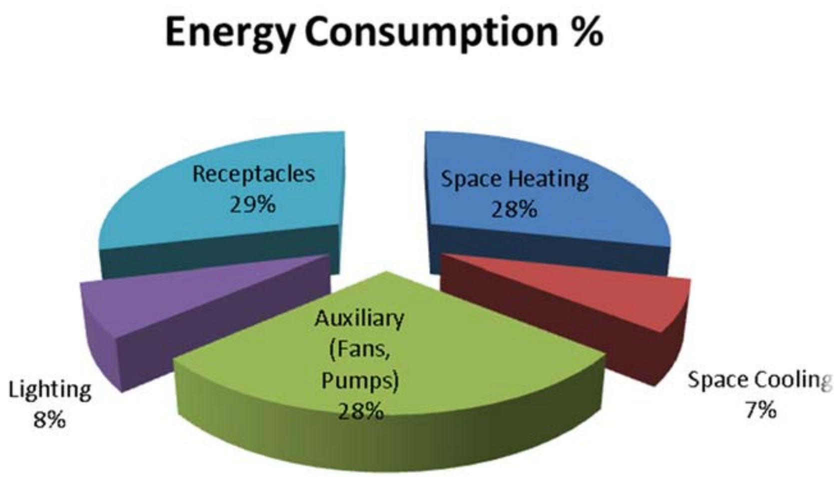
Table 13- Annual Energy Consumption Comparison

Energy Use	Modeled	Designed
Space Heating	334,000 (kBtu)	448,521 (kBtu)
Space Cooling	289,042 (kWh)	252,002 (kWh)
Auxiliary (Fans, Pumps)	1,132,269 (kWh)	1,188,325 (kWh)
Lighting	302,358 (kWh)	558,189 (kWh)
Receptacles	1,153,669 (kWh)	608,648 (kWh)
Cogeneration	Not Modeled	-1,515,247 (kBtu)

The differences seen in the receptacle consumption may be due to the assumptions made in the W/sf that were used while the designer had specific data on the equipment that was used in each space.

The cogeneration was not modeled in Trace due to user knowledge of modeling a micro turbine and photovoltaic solar panels in order to be able to calculate an energy savings from these energy producing products. The largest producer of electricity in the Science and Technology Building is the receptacles followed by the fans and pumps for the systems in the buildings. The space heating consumptions differ due to difficulty modeling the heating system with the use of a plate frame heat exchanger between steam and water for use in the heating coils. The cogeneration is on site produced energy that will be used for heating and electricity throughout the building. The figure below shows the energy consumption percentage for each use for the Science and Technology Building. The Receptacles use 29 percent, while the Auxiliary energy and space heating accounts for 28 percent of the energy consumption each.

Figure 4- Energy Consumption %

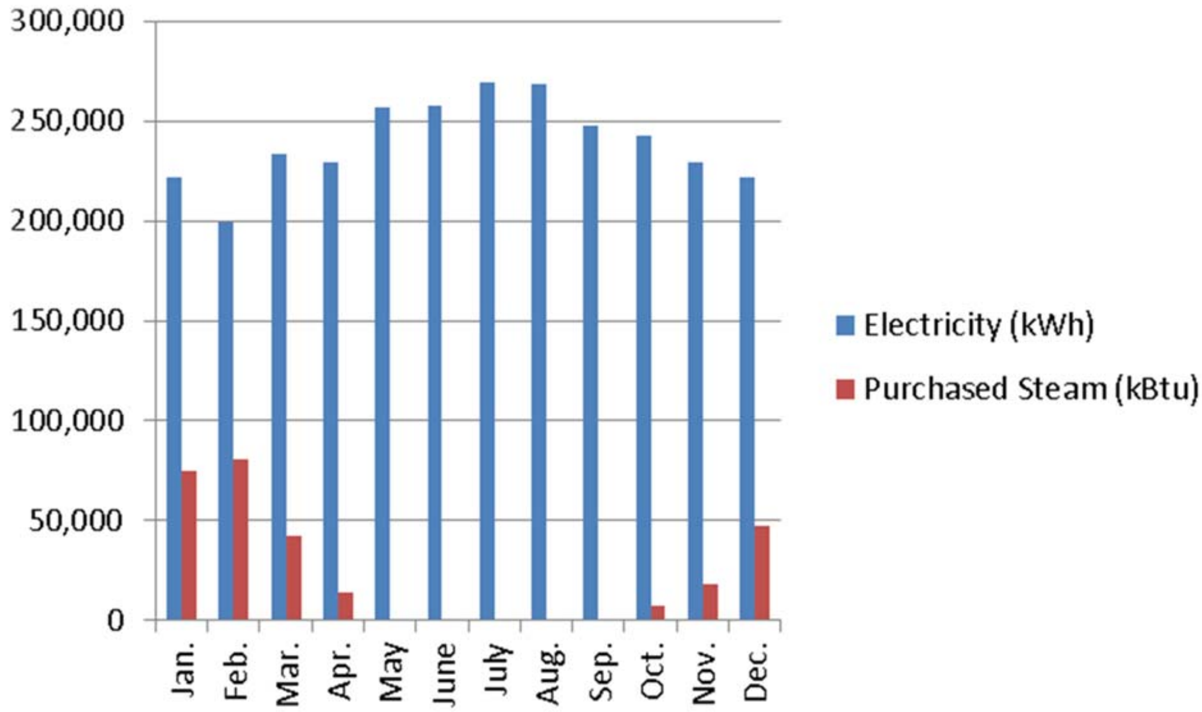


Using Trane Trace 700 the monthly energy consumption was calculated for electricity use and purchased steam total, these values can be seen in Table 14 and in Figure 2. Figure 2 is a graphical representation for usage per month.

Table 14- Monthly Energy Consumption Electricity & Purchased Steam

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Electricity (kWh)	222,089	199,515	233,795	229,135	256,651	257,323	269,448	268,688	247,377	242,935	228,835	222,047
Purchased Steam (kBtu)	75000	80400	42500	14100	900	400	200	400	500	7700	18500	47400

Figure 5- Monthly Energy Consumption



As can be seen in the graph the purchased steam has a near zero energy consumption during the summer months since it is used for heating only. The electricity is at its highest during the summer months as this is the peak cooling load for the Science and Technology Building.

Energy Costs:

The energy cost calculations were done in Trace using the cost rates provided by the designer in the LEED EA CR-1 submission. The cost for the individual energy consumptions can be seen in Table 15, and the percent of total cost is the same as the energy consumption percentage. This occurs since all the energy uses are based on the same cost, except for the space heating which depends on the cost of steam and does not affect the overall percentage. The results obtained from Trace are nearly identical to those calculated by the design engineer for total energy cost for electricity and purchased steam as can be seen in Table 16. The percentage of total cost for each use can be seen where receptacles are 39 percent with space heating the lowest percent at 2.8. A monthly cost analysis can be seen in Figure 3 including both the cost of electricity and steam. Table 17 has the calculated cost per month for electricity and purchased steam.

Table 15- Energy Cost per Year Each Load Type

Energy Use	Modeled	Cost	% of Cost
Space Heating	334,000 (kBtu)	$3,996	2.8
Space Cooling	289,042 (kWh)	$13,874	9.8
Auxiliary (Fans, Pumps)	1,132,269 (kWh)	$54,349	38.2
Lighting	302,358 (kWh)	$14,513	10.2
Receptacles	1,153,669 (kWh)	$55,376	39.0

Table 16- Energy Cost Building Total Comparison

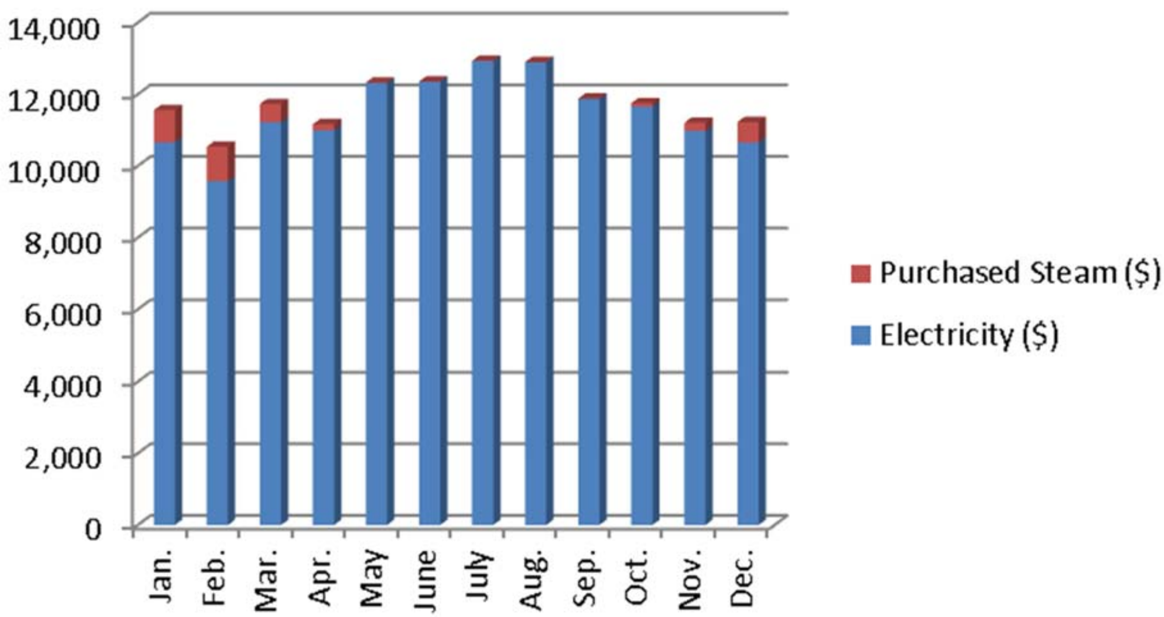
Utility	Modeled Building Energy Cost	Designed Building Energy Cost
Electricity	$ 138,143	$ 134,949
Purchased Steam	$ 3,965	$ 10,893
Total	$ 142,108	$ 145,842
Cost per Square Foot	$ 1.39	$ 1.43

The total energy cost for the building is similar, but individually the electricity is slightly more than as-designed since the receptacles and space cooling have greater energy consumption. The reduced cost of steam is due to the energy consumption of the heating being less than the design value calculated by the engineer. The total cost per square foot for the Grunenwald Science and Technology Building came out to $1.39 similar to the design value of $1.43. The integration of the micro turbine and photovoltaic panels saves on average $6,800 dollars a year as calculated by the design engineers, even offsetting the cost of purchasing natural gas to operate the micro turbine.

Table 17- Monthly Cost Electricity and Purchased Steam

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Electricity ($)	10,660	9,577	11,222	10,998	12,319	12,352	12,934	12,897	11,874	11,661	10,984	10,658
Purchased Steam ($)	896.25	960.78	507.875	168.495	10.755	4.78	2.39	4.78	5.975	92.015	221.075	566.43

Figure 6- Monthly Cost Analysis



The cost for the steam is shown to be nearly negligible compared to the cost for electricity for the entire building. During every month the electricity dominates the cost of the total energy consumed in the building. The highest monthly cost is in July at $12,936, with the lowest monthly cost occurring in February at $10,538.

Actual Utility Bills:

The building has been open since June 2009, but utility bills could not be obtained within the past few months from Clarion University for the single building located on their campus. The reason that the building has been implemented in an integrated control system with various buildings therefore the utility data is not available for the Science and Technology Building.

LEED Assessment for Mechanical System

A LEED assessment was done by the design engineers using LEED-NC 2.1 for the Grunenwald Science and Technology Building. There are two areas of LEED that are relevant to assessing the buildings mechanical system, which are Indoor Environmental Quality, and Energy and Atmosphere categories. LEED-NC 3.0 was used for the evaluation of the criteria based on calculations made by the design engineers. The changes that were made to LEED include an increase in the emphasis on the reduction of energy consumption and greenhouse gas emission for the various credits that can be achieved. The Indoor Environmental Quality (IEQ) has 2 prerequisites and 5 mechanical system applicable areas to earn credits; while Energy and Atmosphere (EA) has 3 prerequisites and 6 areas that possible credits can be earned. The credits that are associated with the mechanical system for IEQ are credit 1, 2, 6.2, 7.1, and 7.2, as the rest are related to construction practices, electric, and day lighting systems.

Indoor Environmental Quality:

IEQ Prerequisite 1requires the design to meet Sections 4-7 of ASHRAE Standard 62.1 and is required for this section, which was met based on the calculations done for the previous version of LEED by the engineers. The calculated values for Technical Assignment 1 were not 100 percent accurate as the engineers did not have two critical spaces that did not meet the ventilation requirements.

IEQ Prerequisite 2 is to prevent or minimize exposure to environmental tobacco smoke (ETS) and is required for this section. This was achieved since the Grunenwald Science and Technology Building is non-smoking.

IEQ Credit 1is the installation of permanent monitoring systems to ensure that the ventilation systems maintain the specified design requirements. This was achieved by installing devices to measure the CO_2 differentials in all of the return ducts for the laboratory, classroom, and office spaces. The measured differential controls the dampers for the economizer and verified through air flow meters in order to maintain the minimum differential. This was worth one point for achieving the credit.

IEQ Credit 2 is to provide additional outdoor air ventilation to improve the indoor air quality; this was not done for the building as this would have increased the energy consumption.

IEQ Credit 6.2 is to provide 50 percent of the building with comfort controls. This was not achieved as the building has set temperature controls for the different spaces, and is an educational building with constant changeover of occupants.
IEQ Credit 7.1 is the design of thermal comfort by meeting the requirements of ASHRAE Standard 55- 2004. The calculations done by the design engineers do comply with the standard, therefore one point can be earned for this credit.

IEQ Credit 7.2 is the verification of thermal comfort in the building. The engineers have put into place a permanent monitoring system to ensure that the thermal comfort designed is being met. This is worth one additional point.

Energy and Atmosphere:

EA Prerequisite 1 is the fundamental commissioning of building energy systems, which is required for EA credits. This was done by the design engineers to achieve this prerequisite.

EA Prerequisite 2 is the minimum energy performance for the building, which was achieved by the design engineers as the building does comply with all the required sections in ASHRAE Standard 90.1-2007 and all energy costs were included.

EA Prerequisite 3 is the CFC reduction in the mechanical system which is achieved since no CFC based refrigerants where used.

EA Credit 1 is the optimization of energy use in the building using the described method used in prerequisite 2. The engineers were able to reduce the energy consumption by 40.9 percent over the baseline design which would earn 15 points for this credit.

EA Credit 2 is the on-site renewable energy percentage. The Grunenwald Science and Technology Building does have photovoltaic panels, and the points for this category range from 1 to 7 based on the percent of the total energy produced. The percent produced by the photovoltaic panels is less than 1 percent therefore no points were earned for this credit.

EA Credit 3 is the enhanced commissioning of the building worth a total of 2 points. The Science and Technology Building will only use basic commissioning practices not achieving this credit.

EA Credit 4 is the enhanced refrigerant management to help prevent the depletion of the ozone, which is achieved since the buildings mechanical system does not use refrigerants.

EA Credit 5 is the measurement and verification of the building energy consumption over time. At this time the 3 additional points were not required, therefore the engineers did not pursue them for their LEED certification.
EA Credit 6 is the owner's choice to purchase over 35 percent of the buildings electricity from renewable resources for at least 2 years. This is worth 2 points, but Clarion University does not plan on entering into a contract to purchase renewable energy.

Overall Evaluation

The mechanical system for the Grunenwald Science and Technology Building is well designed and implements various sustainable technologies. The use of energy efficient equipment keeps the energy consumption of the mechanical system to a minimum. The use of high efficiency chillers, along with the VAV systems can be very effective when implemented properly. The use of produced steam from the central campus boiler plant is required by the university, and the plant has recently been upgraded to provide energy efficient boilers that burn natural gas rather than coal.

The use of economizers along with CO2 measurement devices allows the mechanical system to reduce the energy consumption further. The designers also incorporated a micro turbine into the design as the university received a grant to purchase this technology, it will provide electricity and the heat will pretreat outdoor air. The chillers used for the mechanical system are variable flow centrifugal chillers, which does make them more efficient than constant flow chillers and reduces the number of pumps along with their associated cost of installation. The cooling towers do not utilize free cooling in the initial design and if implemented savings in energy could be seen for a slight increase in upfront costs.

The VAV system used to supply the laboratories with 100 percent outdoor could work with a dedicated outdoor air system since the laboratories do not require that high of a ventilation rates. The use of the VAV systems keeps the installation and operating costs lower since it is typical of many new office buildings. If a DOAS was used only the ventilation would be provided by supply air while the rest of the load would be taken care of by radiant ceilings, chilled beams, etc., and may increase the first costs of the mechanical system. The cost of the mechanical system accounted for 18 percent of the total construction cost, and this is in the range of normal for construction projects of this type. The operational cost of the building is $1.43/sf. This is relatively low do to the on-site produced energy along with the use of energy efficient equipment.

The mechanical system utilized in the Science and Technology Building consists of chillers, cooling towers, pumps, AHU's, and VAV boxes, which is in the conventional systems installed in many of the new buildings. This will allow for many building engineers to know how to work on this system since there is no special equipment or training required to make repairs. Overall, the maintenance costs should remain low as the system is typical.
The laboratories are 100 percent outdoor air to prevent contaminants within the building, rather being captured by the large fume hoods and flexible snake exhaust ducts in each lab. There are 4 exhaust fans where redundancy is used with the implementation of an extra fan in case of failure of one of the other 3 fans. The exhaust for the building is released at high velocity to increase the throw above 60 feet to prevent contaminants to surrounding buildings.

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