Tech Report 3: Mechanical Systems Existing Conditions Evaluation

# PHARM CORP.

**Pills, Delaware**


**Advisor: Dr. Bahnfleth**

**Option: Mechanical**

**Ryan Schulok**


**11 November 2016**

# Table of Contents

## List of Figures

## List of Tables

# *EXECUTIVE SUMMARY*

Technical Report 3 is the third of three technical reports in the evaluation of Pharm Corp. This technical report discusses the existing conditions of the mechanical systems. From the design requirements of indoor and outdoor conditions, it was determined that all air-handling units and rooftop units supply more than the required ventilation air. The estimated heating and cooling loads calculated in Trane Trace 700 are 114% and 81% of the design document values, respectively.

A total of 1.7 million kWh of electricity and 2.1 million gallons of condenser water are required in annual building operations. Overall energy consumption within the building was determined to be 67% electricity, 29% of energy cost is from water, and the remaining 11% is the maintenance to operate the building. Electricity consumption is rather constant throughout the months, peaking toward December and January, while condenser water tends to peak in the summer months and decay in the winter months.

Mechanical systems are divided into indoor air units, outdoor air units and condenser water schematics. The cooling towers provide condenser water to condenser pumps, which is sent to water-cooled DX air-handlers. As for the outside system, RTUs send air to a dedicated conference room with demand control, which contributes to LEED credits. However, this credit cannot be received due to the rest of the building lacking demand response. The overall building did not receive any LEED credentials when the LEED-NC evaluation was conducted.

With system first costs being undisclosed due to the owner's request, the upfront cost is unknown. The rebates that can be awarded for this site, however, are crucial. It was determined that if this site used solar photovoltaics(PV), the site can receive a $240/kWh that is created by the solar PV system. With electricity costs being $170,000 for 1.7 million kWh, an arbitrary value of 1% of total electricity generated will result in rebates that can total to over $4 million dollars for each of the first 10 years.

Possible avenues to investigate based on this report are the reduction in mechanical space that is taken up on each floor by moving units to the roof, introducing a chiller that can control an active chilled beam system, which will greatly reduce the mechanical room size, and reducing the electricity consumption that the mechanical system consumes, primarily for heating. Installation of a boiler, with a chosen fuel for low emissions and high efficiency, will increase the cost of the heating system up front, but will greatly reduce the electric consumption responsible for heating. Enacting one or more of these possibilities may contribute to LEED accreditation, which can be a feasible goal if funds, life-cycle costs, and payback period are acceptable.

# *BUILDING OVERVIEW*

Pharm Corp. is located in Delaware and serves as the headquarters for the company. The footprint of the building is shaped like a bracket, with a core connecting a West and East wing. A symmetry line at 22.5° mirriors the footprint from the West to the East wing, shown in Figure 1 below. Upper floor walls tend to be slightly recessed back in reference to the floor below, creating green roof terraces. It creates a break in the continuous architectural façade of the building.

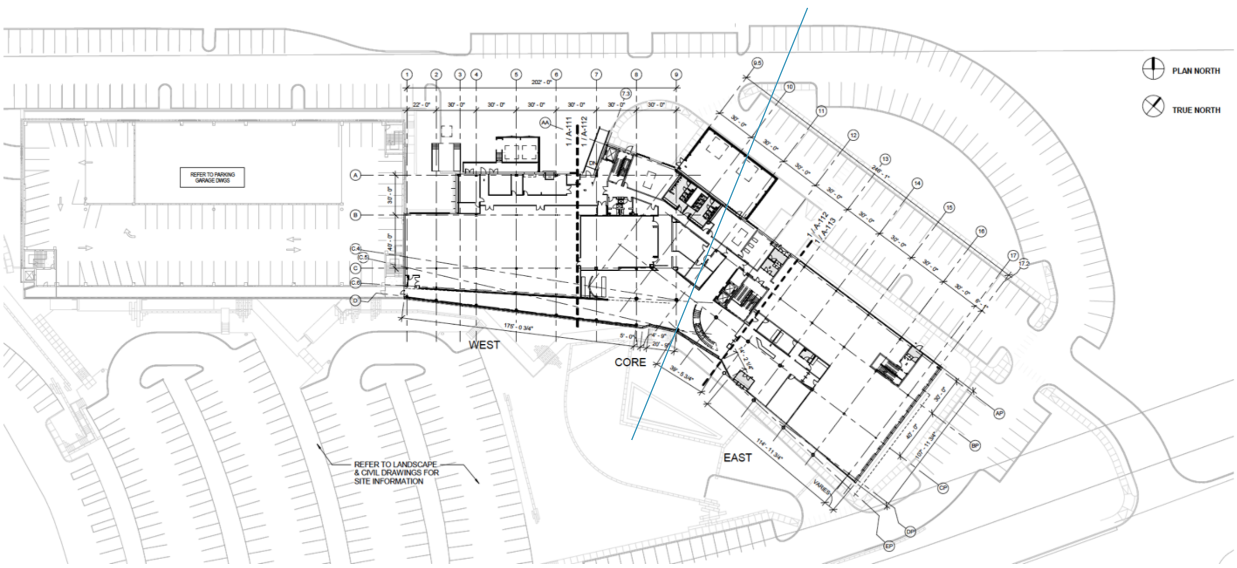


Figure 1. Site plan of building, illustrating West, Core and East, with mirror line of 22.5$^{o}$.

Architectural features such as a 4-story atrium with a grand curving staircase is the main focal point when entering the building. Curtain walls face a large percentage of the building, taking advantage of the natural light from the site. Utilizing the angle of the glass is a strategy within the building, with inward angled glass on the East façade and outward on the West. Light can then enter in the mornings, naturally heating up the space, while direct natural light is being repelled in the West to maintain the interior set point temperature.

As far as mechanical systems go, the main element that separates it from a generic variable air volume office system is the use of an enthalpy-based economizer, when ambient temperatures permit. Based on the climate of the site and the interior return air set point, the economizer is going to be utilized a sufficient amount of time. This will be discussed within the later sections.

Adjoined to the main headquarters building is a 4-story parking garage, recessed into the ground to create a 3-level offset from the main building. This creates parking space for the employees, that can easily enter the main building by a vestibule that connects the 4th level of the garage directly into the 1st floor atrium in the main building. It reduces the amount of run-off to the site and condenses the amount of landscape that has to be disturbed by creating parking lots.

Figure 2. Overall building view, illustrating the green roof on adjoined parking garage.

Using this space as entertainment and for events was the idea for the roof on the garage. It is a functioning green roof, with areas of pavers and walkways for people to walk around and not disturb the vegetation. This can be viewed in the image above. This roof is visible from the third floor dining area, so the employees can enjoy the view if they eat within the café. If they feel so desired, they can enjoy their breaks in this Zen area, away from the workspace.

# *DESIGN CONSIDERATIONS*

## Objectives

The purpose for the office design for Pharm Corp. was to provide an efficient office space layout for its employees. As for its goals that mechanical strategies have satisfied in the design, they are summarized in Table 1 below. The over-arching goals that can be taken away are that the cost of the system, along with the efficiency, are the highest interest of the mechanical system.

In terms of occupancy of the building, the main concern is thermal comfort, as well as no disturbances due to noise. The noise criteria that was selected to be met is NC-40 for all tenant spaces; NC-40 is the recommended NC level for open-office areas in design.

Table1. Owner Goals in Basis of Design for Pharm. Corp.

| Owner Goal | Mechanical Strategy |
|---|---|
| Reduce mechanical duct cost | Mechanical rooms placed on perimeter with OA louvers |
| | Use of ceiling plenum with transfer ducts |
| Minimal noise disturbance from HVAC system | Sound attentuation installed within ducts leaving mechanical room. |
| | Ducts are lined 15'-0" minimum downstream of all terminal units. |
| Reduction in energy consumption when possible | Economizer installation in air-side mechanical systems to utilize free cooling. |
| Make the workspace comfortable for all employees. | Carbon dioxide detectors installed in all high density areas to bring in proper outdoor air. |
| | Perimeter baseboard heating installed under all curtain wall systems |

Expanding on the energy consumption reduction, although the building did not apply to become LEED certified, all of the lighting density design criteria are met per ASHRAE 90.1-2010 and by LEED requirements. The exact values are shown in Table 3 in Indoor Design Conditions.

# Requirements

## *Outdoor Design Conditions*

Located in Delaware, Pharm Corp is designed to handle an assortment of climates, from hot and humid days throughout the summer to cold, snowy days throughout the winter. According to ASHRAE 90.1-2010, Pharm Corp is located in the 4A climate zone, susceptible to warm/moist climates. Figure 3 below shows the in weather fluctuation throughout the seasons that the mechanical system will have to overcome, with a maximum average high of 86°F and lowest average low of 25°F, and average rainfall of approximately 3.5" per month. Design outdoor temperature conditions are designed for

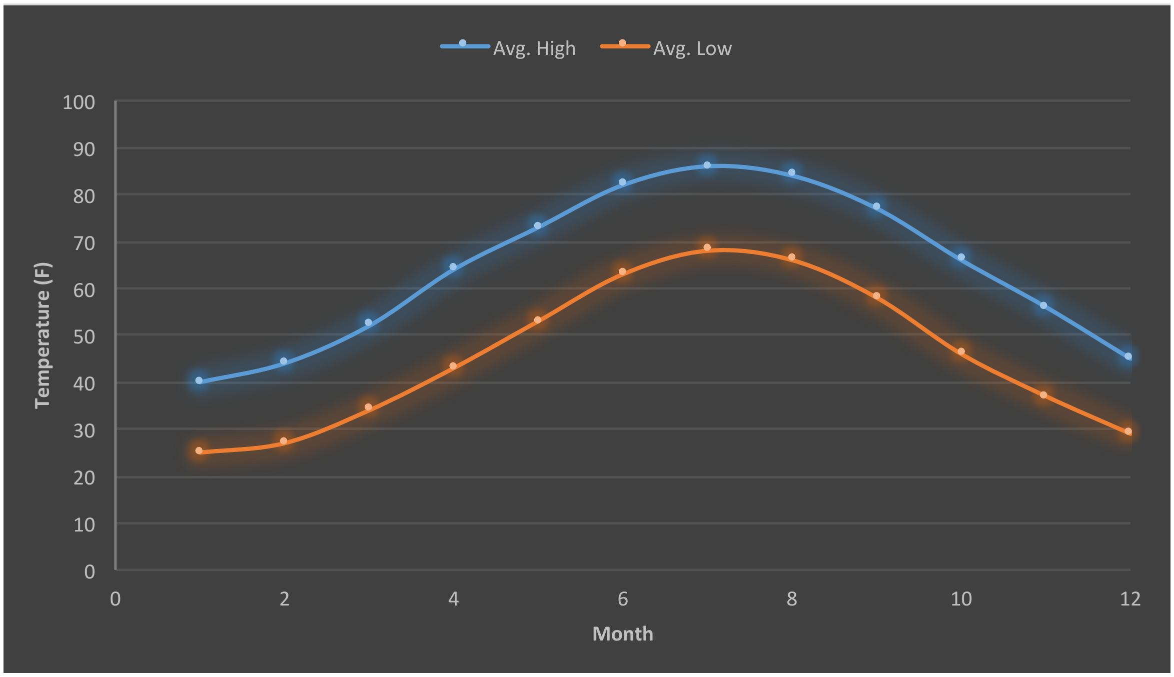


Figure 3. Annual average temperature fluctuation with precipitation.

the 0.4% and 99.6%. The exact temperatures that were input into load simulation software to determine zone loads can be seen in Table 2 on the right.

Table 2. Outdoor Air Temperature Conditions.

| Conditions | Temperature | |
|---|---|---|
| | DB | WB |
| Summer (0.4%) | 91.9 | 75.1 |
| Winter (99.6%) | 11.7 | - |

## *Indoor Design Conditions*

The indoor design conditions vary depending on the occupancy that is scheduled for that zone. Table 3 below shows the different spaces with their respective temperature set points and affiliated equipment and lighting loads that the interior zone must abide by. Recalling the objectives section above, the stated lighting power density values abide by LEED and ASHRAE 90.1-2010.

Table 3. Indoor Air Design Constraints.

| Space Type | AHU Equipment | Design Constraints | | | |
|---|---|---|---|---|---|
| | | Occupied | | Lighting | Equipment |
| | | Heating | Cooling | [W/SF] | [W/SF] |
| Food Prep/Dining | AHU-3-1 | 72°F | 80°F / 50% RH | 1.2 | 25 |
| Atrium | All Others | 72°F | 74°F / 50% RH | 0.6 | 0.5 |
| General Office Space | All Others | 72°F | 74°F / 50% RH | 1.0 | 2 |

All zones have the same heating set point, but the cooling set point for the kitchen can be set 6°F higher than the rest of the building. These different space types also use different lighting fixtures with different sensors, shown in Table 4 below. The spaces with daylight response dimming utilize the natural light from the outdoors as much as possible, reducing its overall lighting power density. Overall, the lighting and equipment loads are large influences of the indoor design set points for cooling.

Table 4. Space Lighting Type of Sensors.

| Space Type | Lamp Type | Load Type | Sensors |
|---|---|---|---|
| Atrium | 2"/4" LED Downlight | 0-10 V Dimming | Daylight Response Dimming |
| Café | 2" LED Downlight | 0-10 V Dimming | Timeclock Control |
| Dining Room | 2" LED Downlight | 0-10 V Dimming | - |
| Lobby | 2" Slot Lights | 0-10 V Dimming | Daylight Response Dimming |

## *Ventilation Requirements*

All of the air-handlings units that serve either offices, the kitchen, or the dining space all satisfy the minimum outdoor air requirement that was found using ASHRAE 62.1-2010. The increased outdoor air during normal operation allows for better indoor air quality within the zones. Several of the spaces supplied less actual supply air than was required from the ASHRAE 62.1-2010 zone design supply cfm, which may be due to a selected diversity factor. A summary of the air-handling units used within the space can be seen in Table 5.

Table 5. Air-Handling Unit Ventilation Schedule.

| System | Occupancy | OA Required [CFM] | Supply Air Required [CFM] | OA Supplied [CFM] | Actual Supply Air [CFM] | Percentage OA [ % ] |
|---|---|---|---|---|---|---|
| AHU-1-1 | Office | 2560 | 23920 | 3000 | 20000 | 15% |
| AHU-1-2 | Office | 1856 | 15425 | 2400 | 16000 | 15% |
| AHU-2-1 | Office | 898 | 9325 | 3000 | 20000 | 15% |
| AHU-2-2 | Office | 2031 | 20080 | 2700 | 18000 | 15% |
| AHU-3-1 | Kitchen | 4043 | 26470 | 9200 | 23000 | 40% |
| AHU-3-2 | Office | 1677 | 19390 | 2700 | 18000 | 15% |
| AHU-4-1 | Dining | 1630 | 12850 | 3200 | 16000 | 20% |
| AHU-4-2 | Office | 1544 | 16035 | 2400 | 16000 | 15% |

Table 6. Rooftop Unit Ventilation Schedule.

| System | Occupancy | OA Required [CFM] | Supply Air Required [CFM] | OA Supplied [CFM] | Actual Supply Air [CFM] | Percentage OA [ % ] |
|---|---|---|---|---|---|---|
| RTU-5-1 | Conference | 175 | 900 | 180 | 910 | 20% |
| RTU-5-2 | Conference | 175 | 900 | 180 | 900 | 20% |
| RTU-5-3 | Conference | 175 | 900 | 170 | 840 | 20% |
| RTU-5-4 | Conference | 175 | 900 | 180 | 900 | 20% |
| RTU-5-5 | Conference | 175 | 900 | 180 | 905 | 20% |
| RTU-5-6 | Conference | 175 | 900 | 200 | 990 | 20% |

Dedicated rooftop units (RTU) serve dedicated conference rooms. The outdoor air required and the outdoor air supplied are nearly equal, within five (5) cfm of the required cfm. This holds true for the supply air required in relation to the actual supply air sent to each conference room. Diversity of the conference room is 100%, as determined in ASHRAE 62.1-2010 Ventilation Tables, from Technical Report 1, resulting in the same values for required and actual. The summarized values in Table 6 are shown above.

## *Heating & Cooling Requirements*

With the use of Trane Trace 700, heating and cooling requirements were calculated for Pharm Corp, with inputs of the design requirements stated in the Requirements section. In addition to the inputs of temperatures and power densities, an occupancy schedule had to be determined to obtain values that would best estimate the heating and cooling loads. General office space was the template schedule used for the loads, assuming occupants are present within the building on a normal schedule of Monday-Friday, 8am to 5pm. The calculated load can be found in the first row of Table 7, below.

Table 7. Heating and Cooling Loads.

| Design Method | Cooling | | Heating | | Airflow | |
|---|---|---|---|---|---|---|
| | Peak Load [tons] | Per SF [SF/ton] | Peak Load [MBH] | Per SF [BTUh/SF] | Total Supply Air [cfm/SF] | Total Ventilation Air [cfm/SF] |
| Trane Trace 700 Computed Loads | 239.1 | 627.4 | 1355 | 9.0 | 0.60 | 0.14 |
| Design Document Computations | 296.9 | 505.2 | 1187 | 7.9 | 0.98 | 0.19 |

The second row of Table 7 shows the designed loads for Pharm Corp. from the mechanical designer. As for the discrepancies between the two values for the loads, the Trace model underestimated the peak cooling load by approximately 20% in comparison to the designed loads, while the deviation in the total ventilation air differs slightly from the Trace model, but is in accordance to the outdoor air percentages given in Table 6.

Possible variations in occupancy schedule can be the reason. Figures 4 & 5 show the schedule that was used by AKF Group in the determination of the loads. Their occupancy schedule calls for about 30% capacity of people and lighting and receptacle loads on weekends for a short duration of time, and normal weekday occupancy from 8am to 6pm, an hour longer than input into Trace.

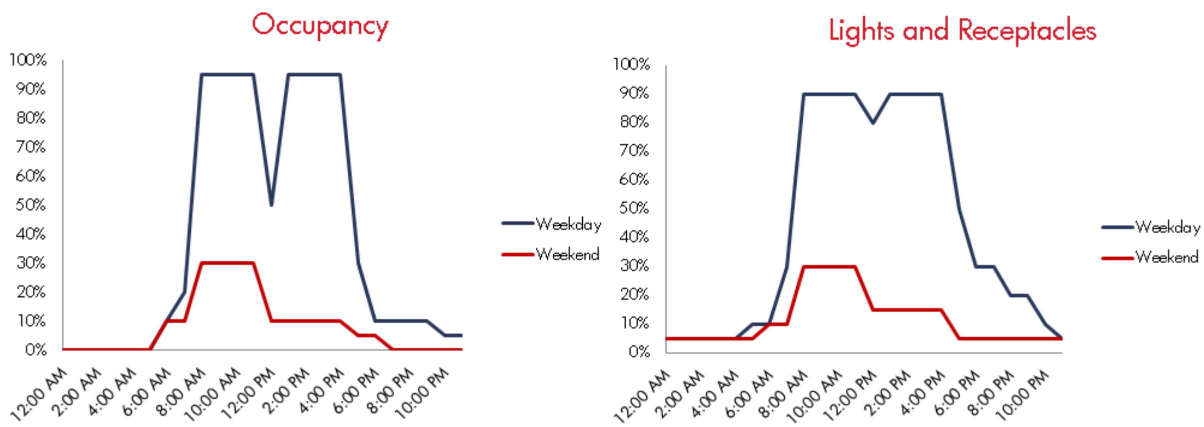


Figure 4 & 5. Schedules created by AKF Group in eQUEST.

The design heating loads are rather low, with being 9 BTUh/SF from Trace 700 and 7.9 BTUh/SF from the design documents. Reasoning for this is unknown, but from inspection, it may be due to the high internal equipment and lighting loads that were input within Trane Trace 700. An increase in the internal loads reduces the heating load for the units. It can also be due to the economizer. If the outdoor air temperature is low, the economizer can recirculate the return air, increasing the initial mixed air condition that the heating coil heats up.

Overall, the Trace model seems to underestimate the cooling and slightly overestimate the heating, resulting in a deviation from the design documents of approximately 0.3 CFM/SF for the entirety of the building.

## Energy Sources

### *Fuel Types*

The sole energy source that is used within the building is electric. There are no uses of fuels for the mechanical system. It is used in powering the lights, operating the cooling tower and air-handling units, runs the rooftop units and split air-conditioning units, and provides the resistance heating designed throughout the building.

### *Rates*

For the rates of energy sources within the building, it is the consumption of both electricity and water. Separate from sources consumed by the building, maintenance must be conducted to ensure everything is working as designed, equipment is cleaned and inspected, and complications can be resolved in a timely manner. Combining all of these different rates can be referred to in Table 8.

Table 8. Rates of Different Sources.

| Category | Maintenance Cost [$/(SF*yr)] | Electricity [$/kWh | Water [$/1000 gal] |
|---|---|---|---|
| Unit Cost | 0.50 | 0.1008 | 4.88 |

The rates for electricity is divided into five subcategories: heating plant, cooling plant, auxiliary fans, lighting and receptacle loads. Shown in Figure 6 is the cost per square foot for each of these subcategories, with the rates shown above.

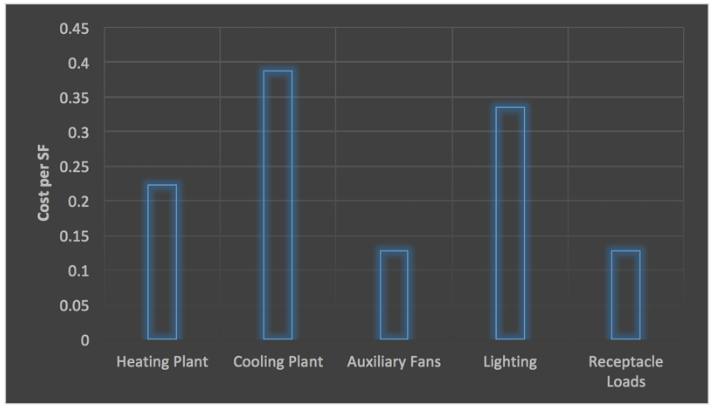


Figure 6. Cost per square foot per subsystem.

### *Annual Energy Use*

Overall, the building uses nearly 1.7 million kWh and 2.1 million gallons of condenser water per year. Maintenance also must be included in the overall energy input into the building, although it is not for the mechanical system. Table 9 and Figure 7 shown the broken down cost for each source of energy within the building, as well as the percentage of the total energy cost each source is responsible for. Electricity is the main source for heating and cooling within the building, totaling 2/3 of the total energy costs. As this building is still in construction, the actual energy usage has not been determined. These values are strictly from Trane Trace 700.

Table 9. Operating cost per system in building.

| Category | Maintenance Cost [$/(SF*yr)] | Electricity [$/kWh | Water [$/1000 gal] | Total Operating Cost [$] |
|---|---|---|---|---|
| Unit Cost | 0.50 | 0.1008 | 4.88 | |
| Multiplier | 150,000 SF | 1683206 kWh | 2,100,000 gal | |
| Cost [$] | $ 75,000.00 | $ 169,667.16 | $ 10,248.00 | $ 254,915.16 |

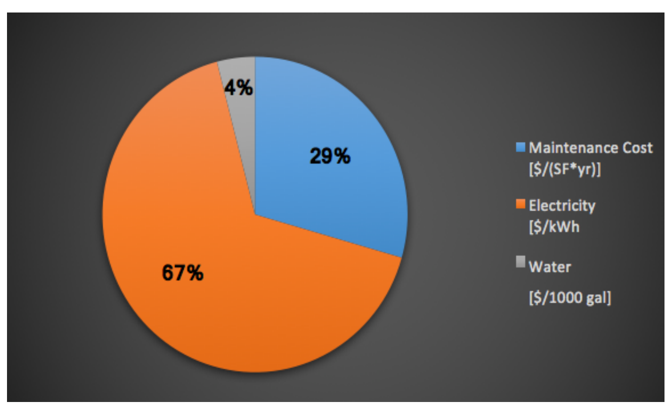


Figure 7. Overall energy used, by cost.

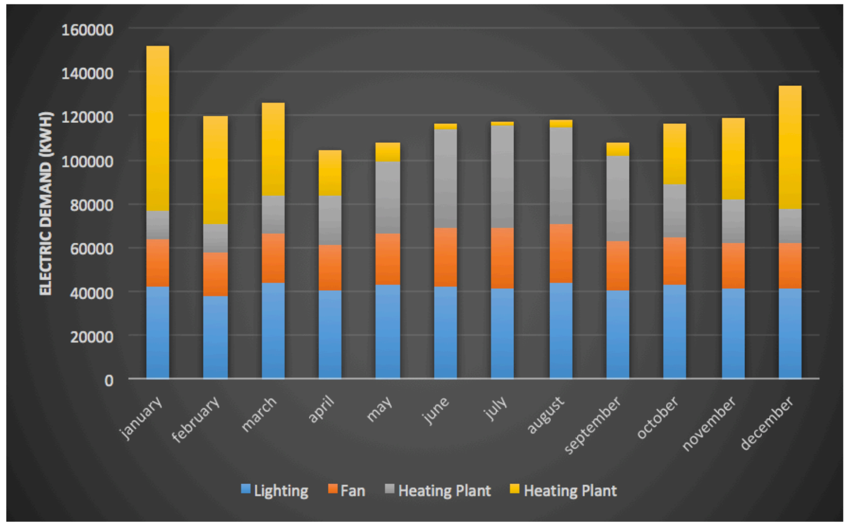


Figure 8. Monthly electric demand breakdown.

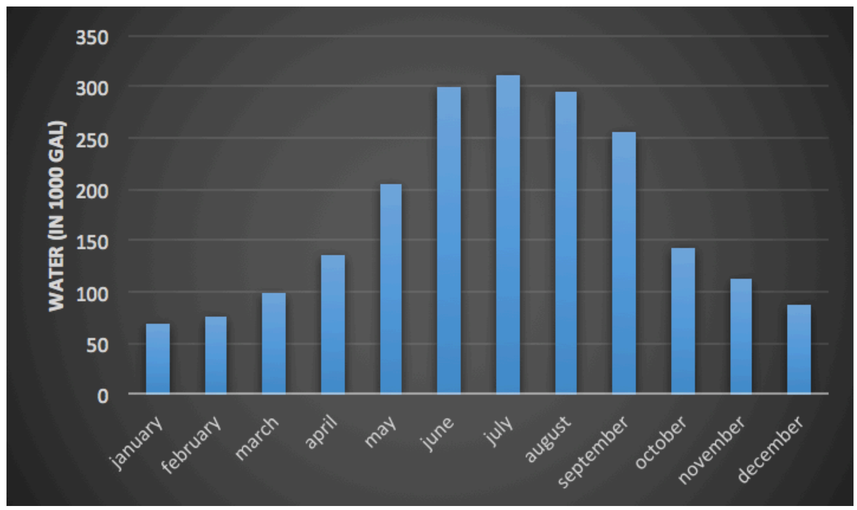


Figure 9. Monthly water demand.

Breaking down the electricity rates further into those subcategories explained above, Figure 8 shows how the electricity rates fare for each category over each month. The lighting load is approximately level throughout each month, as well as the fan operations. The heating and cooling plant operations are inverse of each other, with heating electric usage increasing in colder months while the cooling usage decreases. In the months of February through November, the building uses approximately the same energy usage, with increased energy usage in December and January, primarily due to the heating plant.

Water usage, on the other hand, depends greatly on the climate in a given month. Figure 9 is the condenser water needed to cool the DX water-cooled air handling units. It takes on a shape of a normal distribution bell curve, peaking from June to September, and then drastically decreasing to the right and left of these months.

### *Rebates*

Within the state of Delaware, it is encouraged to use some source of renewable energy source within a building, and by 2025-2026, buildings will be required to use a minimum of 25% renewable energy, with at least 3.5% of that being solar energy.

From renewable energy, if the use of solar water heat, solar space heat, solar photovoltaics (PV), wind, geothermal heat pumps, and/or fuel cells, rebates will be acquired as a function of utility usage. They can also acquire a rebate up to a 25% of total equipment cost for their use of a renewable listed above. None of these are used within the building, however. If net metering is used within the building for technologies such as solar PV, wind, biomass, hydroelectric and fuel cells, up to 110% of expected use costs can be gained as rebates.

For performance based rebates from solar panel installation, the owner can receive rebates up to $240 per kWh generated for its building for the first 10 years of operation. The rebate falls to $50 per kWh generated. From the 1.7 million kWh this building uses throughout a year, if 1% of that was received by solar energy, that rebate would be just over $4 million dollars, per year.

With the usage of both the main headquarters roof along with the garage roof areas, these rebates could be enormous, completely eliminating the cost of electricity within the building. After 10 years, that savings would drop to $850,000, which is still over four times larger than the electrical energy used within the building. These numbers are just arbitrary, as they depend on the solar panels installed, their design kWh generation per day, and the number of solar panels installed. Rebate values could be much less if limit solar panels are installed. The rebate values will also be offset in part by the initial cost of a solar panel system. The incentive is to install solar panels so that the grid can produce less electricity and the building can gather the electricity it needs.

# *EXISTING MECHANICAL SYSTEM*

## Equipment

### *Heating*

Being in climate zone 4A, Pharm Corp. is susceptible to cold winters and will require heating strategies due to the abundance of curtain wall systems. For any wall area that is comprised of a curtain wall system, electric resistance baseboard is installed below it. Capacities and sizes of these baseboard units are shown in the table below. The dense, colder air in the space will enter the bottom of the baseboard and be heated up. The hot, less dense air, rises parallel to the window, creating a barrier between the exterior cold temperature and the interior space temperature. This reduces the work that has to be done by the variable air volume reheat (VAVRH) boxes.

Table10. Electric Baseboard Schedule.

| Designation | Room Air DB [F] | Output [W] | Electrical Data | | | Type | Manufacturer |
|---|---|---|---|---|---|---|---|
| | | | Length | kW | Volt-Phase-Hz | | |
| EBB-A | 70 | 300 | 3'-0" | 0.9 | 277-1-60 | Recessed | Vulcan |
| EBB-B | 70 | 300 | 4'-0" | 1.2 | 277-1-61 | Recessed | Vulcan |
| EBB-C | 70 | 300 | 5'-0" | 1.5 | 277-1-62 | Recessed | Vulcan |
| EBB-D | 70 | 300 | 6'-0" | 1.8 | 277-1-63 | Recessed | Vulcan |
| EBB-E | 70 | 300 | 8'-0" | 2.4 | 277-1-64 | Recessed | Vulcan |
| EBB-F | 70 | 300 | 9'-0" | 2.7 | 277-1-65 | Recessed | Vulcan |
| EBB-G | 70 | 300 | 10'-0" | 3.0 | 277-1-66 | Recessed | Vulcan |

Shifting to the interior zones that will need heating, VAVRH boxes are provided. Electricity is sent to the boxes and the fins within the box are heated up to increase the leaving supply air temperature to the space. Primary heating that is sent through the VAV system is heated back at the air-handling unit heating coils. VAVRH is supplemental heating if the coil cannot heat the air to its desired temperature, or in a cooling condition, the air is too cold and will over-cool the space. A small percentage of the VAV boxes are scheduled below, as there are near 120 VAVs within the building. The selected boxes show the range of inlet size that the boxes can be within and their affiliated CFM for each size.

Table11. VAVRH terminal unit schedule.

| Designation | Inlet Size | Max CFM | Min CFM | Heating CFM | EAT [F] | LAT [F] | Controls | Manufacturer |
|---|---|---|---|---|---|---|---|---|
| VAV-1-08 | 10" | 1200 | 360 | 360 | 55 | 85 | Digital | Envirotec |
| VAV-1-09 | 8" | 625 | 188 | 180 | 55 | 85 | Digital | Envirotec |
| VAV-1-10 | 10" | 1020 | 306 | 305 | 55 | 85 | Digital | Envirotec |
| VAV-1-11 | 14" | 2040 | 612 | 610 | 55 | 85 | Digital | Envirotec |
| VAV-1-12 | 6" | 450 | 135 | 135 | 55 | 85 | Digital | Envirotec |

The final means of heating within the building are unit heaters (UH). Within spaces such as the fire pump room and electric rooms, unit heaters are installed to maintain a set point temperature within the space, compressed in Table 12. The equipment/pumps within these spaces need a minimum temperature to operate properly at, and the unit heaters provide this heat.

Table 12. Unit Heater Schedule

| Designation | EAT DB [F] | LAT DB [F] | CFM | Heating Capacity [MBH] | MHP | FLA | Volt-Phase-Hz | Manufacturer |
|---|---|---|---|---|---|---|---|---|
| UH-1-1 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-1-2 | 40 | 85 | 350 | 10 | 0.01 | 11 | 208-1-60 | Berko |
| UH-1-3 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-1-4 | 40 | 85 | 350 | 10 | 0.01 | 11 | 208-1-60 | Berko |
| UH-1-5 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-1-6 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-1-7 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-1-8 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-1-9 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-2-1 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-2-2 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-3-1 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-3-2 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-4-1 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-4-2 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |
| UH-5-1 | 40 | 85 | 350 | 17 | 0.01 | 6 | 208-3-60 | Berko |

Cabinet Unit Heaters (CUH), scheduled in Figure 13, are another kind of unit heater. They are installed within the stairwells of this building, either being recessed into the wall or ceiling ducted to not impede circulation in the stairs. They maintain the stairs desired set point temperature, as shown in the schedules below. The unit heaters have larger capacities because they are responsible for a single room, while the CUH work together in the stairwells, heating only a small portion of the volume.

Table13. Cabinet Unit Heater Schedule

| Designation | CFM | Heating Capacity [MBH] | Type | FLA | Volt-Phase-Hz | Manufacturer |
|---|---|---|---|---|---|---|
| CUH-1-1 | 250 | 10.2 | Ceiling Duct | 15 | 208-1-60 | Berko |
| CUH-1-2 | 250 | 10.2 | Wall Recessed | 6 | 208-1-60 | Berko |
| CUH-1-3 | 250 | 10.2 | Ceiling Duct | 15 | 208-1-60 | Berko |
| CUH-1-4 | 250 | 10.2 | Ceiling Duct | 15 | 208-1-60 | Berko |
| CUH-1-5 | 250 | 10.2 | Ceiling Duct | 15 | 208-1-60 | Berko |
| CUH-5-1 | 250 | 10.2 | Wall Recessed | 6 | 208-1-60 | Berko |

### *Cooling*

Office space within the building, along with the kitchen, dining areas and atrium spaces, are all cooled by water-cooled DX air-handling units accompanied by enthalpy-based economizers. A psychrometric chart has been drawn in Figure 10 below, showing when the economizer can be used. A differential enthalpy-based economizer has been drawn, which permits any temperature/enthalpy weather point that is left of the room air, at 74° F, and below the enthalpy line at 74° F, to be used to assist in the cooling or heating condition, depending on the season.

Interior conference spaces located on the 4th level are independently cooled by their dedicated rooftop units. Conference spaces are equipped with carbon dioxide detectors to increase the amount of outdoor air that is required as occupants are present in the space. Spaces separate from the main office areas, like IDF rooms, MDF rooms and AV closets, are cooled by individual split system air conditioners with condensing units located on the room. They have three operating conditions, low-medium-high depending on the condition within these spaces.

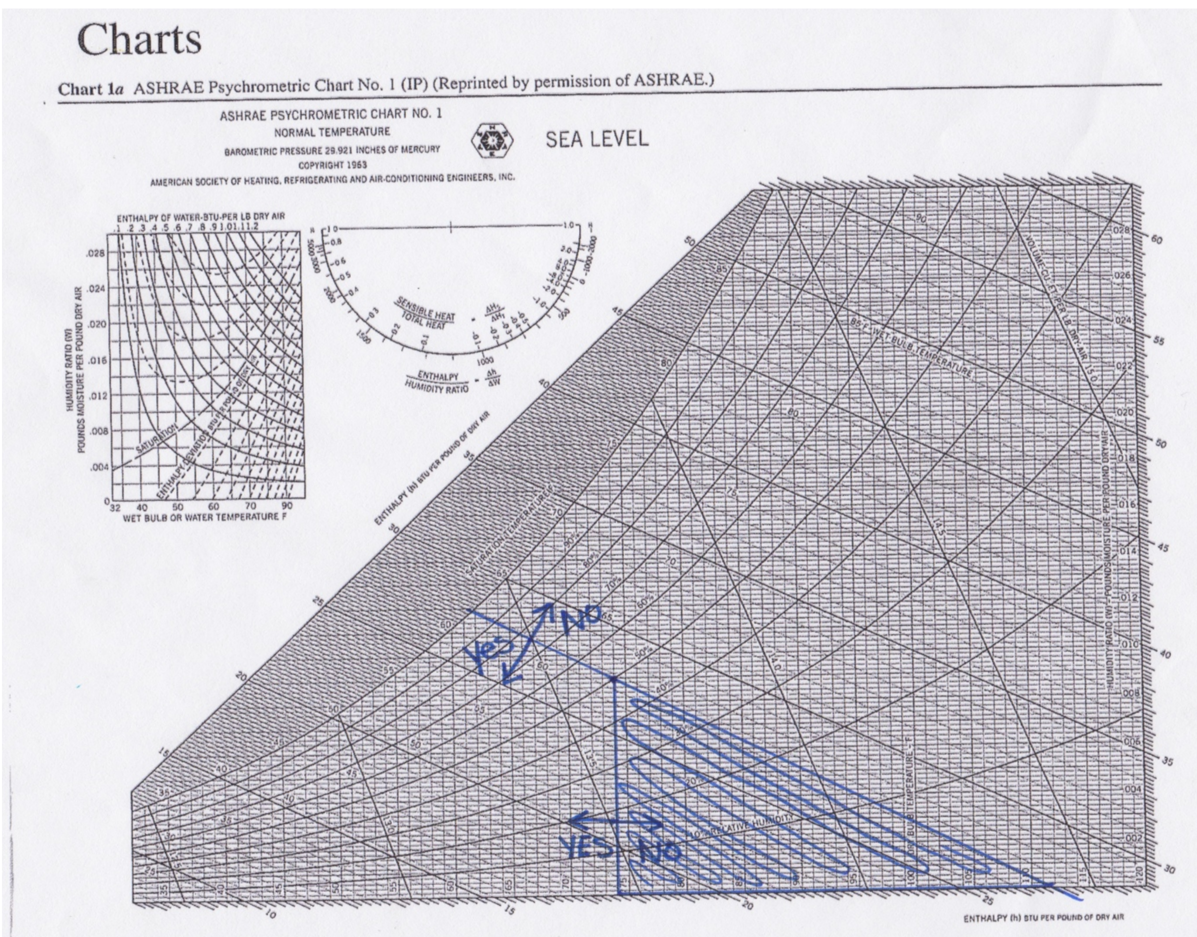


Figure 10. Differential enthalpy economizer psychrometric chart

As for how much the economizer will be utilized, a breakdown of average high temperatures and days per month are combined in Table 14 below. For the purpose of demonstration, if the average high temperature was more than 10°F lower than the room air, it was used every day of the month. If it was less than 10°F difference between the average high and the room temperature, only half of the days were used to be conservative.

The economizer will be in error in the months of June to September, so the economizer should be shut off within these months. The reason those months are generally in error is because the outdoor air is too high compared to the recirculating air. Therefore, it would only create a larger cooling load on the coils. Totaling the days of use to the days in a year, approximately 58% of the year the economizer will be used in assistance for cooling. Note that these are just temperatures, which is just one of the two criteria that has to be met. The assumption that the temperatures have abiding enthalpies was made, but actual weather bin data would be needed to confirm the accuracy of this.

Table 14. Economizer estimated usage per year.

| Month | Avg. High | Room Temperature | Use? | Days in Month Used |
|---|---|---|---|---|
| January | 40 | 74 | YES | 31 |
| February | 44 | 74 | YES | 28 |
| March | 52 | 74 | YES | 31 |
| April | 64 | 74 | YES | 30 |
| May | 73 | 74 | YES | 15 |
| June | 82 | 74 | NO | 0 |
| July | 86 | 74 | NO | 0 |
| August | 84 | 74 | NO | 0 |
| September | 77 | 74 | NO | 0 |
| October | 66 | 74 | YES | 15 |
| November | 56 | 74 | YES | 30 |
| December | 45 | 74 | YES | 31 |
| | | | Annual Percentage | 58% |

# System Operations & Schematics

## *Air Distribution – Indoor Units*

The air distribution system within Pharm Corp. consists of both units outdoors as well as units indoors. To understand the overall system better, it was broken up into two diagrams. In the diagram presented below, the indoor air-handling unit schematic is shown.

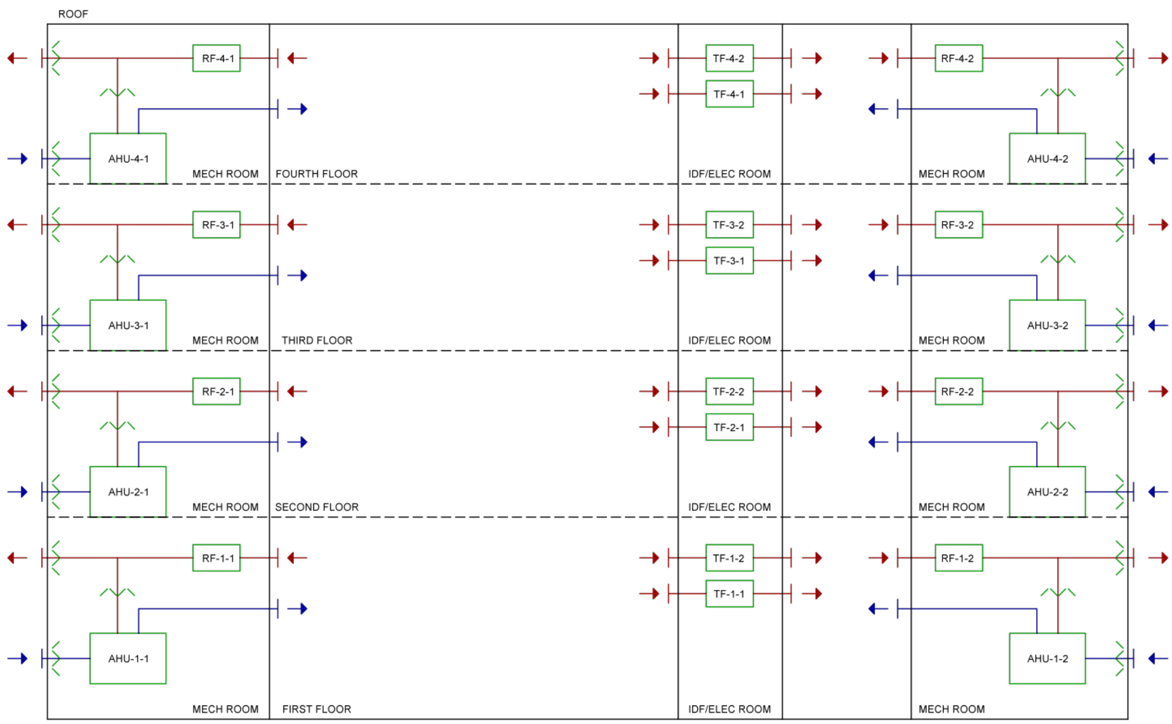


Figure 11. Indoor Air-Handling Unit Diagram.

Referring to the diagram above, the blue and red ducts are the supply and return air, respectively. Arrows indicate the flow of air from the equipment, which is denoted in green. The motorized modulating dampers are also in green, shown in the zig-zag configuration, while boxes labeled TF and RF are transfer fans and return fans, respectively. AHUs are also in green, and a compressed schedule is shown in Table 15 of all AHUs and their operating conditions. Not illustrated within this diagram are variable air volume (VAV) boxes and fan-powered boxes (FPB) as there are approximately 60 boxes, 30 of each, per floor, totaling near 240 total boxes.

As for the controls of the indoor system, thermostats are installed for each terminal box or FPB. This temperature determines the cooling demand that the zone requires to maintain its zone temperature set point. As the temperature of the zone increases above the temperature of the zone set point, a high temperature alarm signals and the VAV box is to open a designed percentage. This percentage is to increase the needed airflow to the space. As the damper in the box opens, the duct static pressure is reduced. The duct static pressure sensor then signals to the fan in the air-handling unit to increase its fan speed to maintain the duct static pressure set point. If too much cooling is being sent to the space, the electric reheat coils are to turn on and increase the supply air being delivered. This same control sequence is for heating as well, with the duct static pressure controls and VAV dampers. The alarm, however, would be a low temperature alarm, calling for more heating

Table 15. Air-handling unit schedule.

| Unit | Total CFM | % OA | OA CFM | ESP | COOLING | | Heating |
|---|---|---|---|---|---|---|---|
| | | | | | Total | Sensible | Total |
| | | | | | MBH | MBH | MBH |
| AHU-1-1 | 20000 | 15% | 3000 | 2 | 467.7 | 155.9 | 232152 |
| AHU-1-2 | 16000 | 15% | 2400 | 2 | 374.2 | 124.7 | 116076 |
| AHU-2-1 | 20000 | 15% | 3000 | 2 | 467.7 | 155.9 | 232152 |
| AHU-2-2 | 18000 | 15% | 2700 | 2 | 421.0 | 140.3 | 232152 |
| AHU-3-1 | 23000 | 40% | 9200 | 2 | 647.8 | 187.8 | 232152 |
| AHU-3-2 | 18000 | 15% | 2700 | 2 | 421.0 | 140.3 | 232152 |
| AHU-4-1 | 16000 | 20% | 3200 | 2 | 389.5 | 129.8 | 116076 |
| AHU-4-2 | 16000 | 15% | 2400 | 2 | 374.2 | 124.7 | 116076 |

In all operating conditions, a minimum outdoor air is to be brought in through the outdoor air damper shown in the schematic. The remaining percentage is from the recirculated air, and excess air is removed from the building. The return air fan (RF) tracks the outdoor air damper, and allows the building pressure to remain at its designed point. Due to all walls being full-height floor-to-floor walls, transfer fans, shown as TF, are installed to transfer air through the walls to get back to the unit. The transfer fan is to track the return air fan simultaneously so they operate at the same condition.

### *Air Distribution – Outdoor Units*

Conditioning the conference rooms located on the top floor are six rooftop units (RTU), one for each room. A basic schematic is shown on the next page, Figure 12, and scheduled in Table 16 of the RTUs. In operation, the RTU is to deliver the minimum outdoor air required to the space to keep it conditioned to design. Located inside of the space are both thermostats and carbon dioxide detectors.

Carbon dioxide detectors determine the amount of occupants within the space. As the carbon dioxide level increases in the space, the required outdoor air to be delivered increases, and the RTU outdoor air damper opens. To maintain the flow rate sent to the space, the mixing damper closes at the same rate, and relief damper exhausts that difference in air.

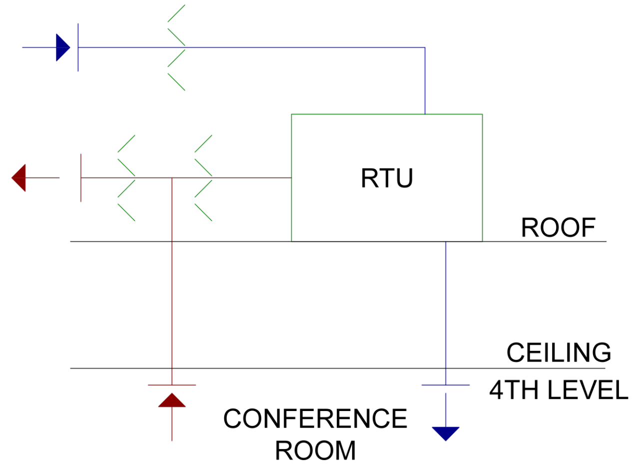


Figure 12. RTU schematic.

As for temperature controlled by thermostats, the thermostat reads the zone temperature and compares it to its set point. If the temperature is above a set high limit, the rooftop unit is going to increase its fan speed to satisfy the load. The same process is for the heating seasons, but a low temperature alarm will tell the RTU to increase the heating coil capacity.

Table 16. RTU schedule.

| Designation | Service | Min OA [CFM] | Total CFM | E.S.P [in w.g.] | Coil | Total [BTU/h] | Sensible [BTU/h] |
|---|---|---|---|---|---|---|---|
| RTU-5-1 | Conference | 180 | 910 | 0.5 | Heating | 64000 | - |
| | | | | | Cooling | 35.2 | 24.5 |
| RTU-5-2 | Conference | 180 | 900 | 0.5 | Heating | 64000 | - |
| | | | | | Cooling | 35.2 | 24.5 |
| RTU-5-3 | Conference | 170 | 80 | 0.5 | Heating | 64000 | - |
| | | | | | Cooling | 35.2 | 24.5 |
| RTU-5-4 | Conference | 180 | 900 | 0.5 | Heating | 64000 | - |
| | | | | | Cooling | 35.2 | 24.5 |
| RTU-5-5 | Conference | 180 | 905 | 0.5 | Heating | 64000 | - |
| | | | | | Cooling | 35.2 | 24.5 |
| RTU-5-6 | Conference | 200 | 990 | 0.5 | Heating | 64000 | - |
| | | | | | Cooling | 35.2 | 24.5 |

### *Exhaust System*

There are four different exhaust systems in the building. They all can be seen in the exhaust schematic in Figure 13 on the next page. All fans are scheduled on the next page as well, shown in Table 17. The system on the right is the exhaust system in the restrooms. EF-5-1 is to exhaust air for all the bathrooms. They are constantly running to remove class-2 air from the bathrooms.

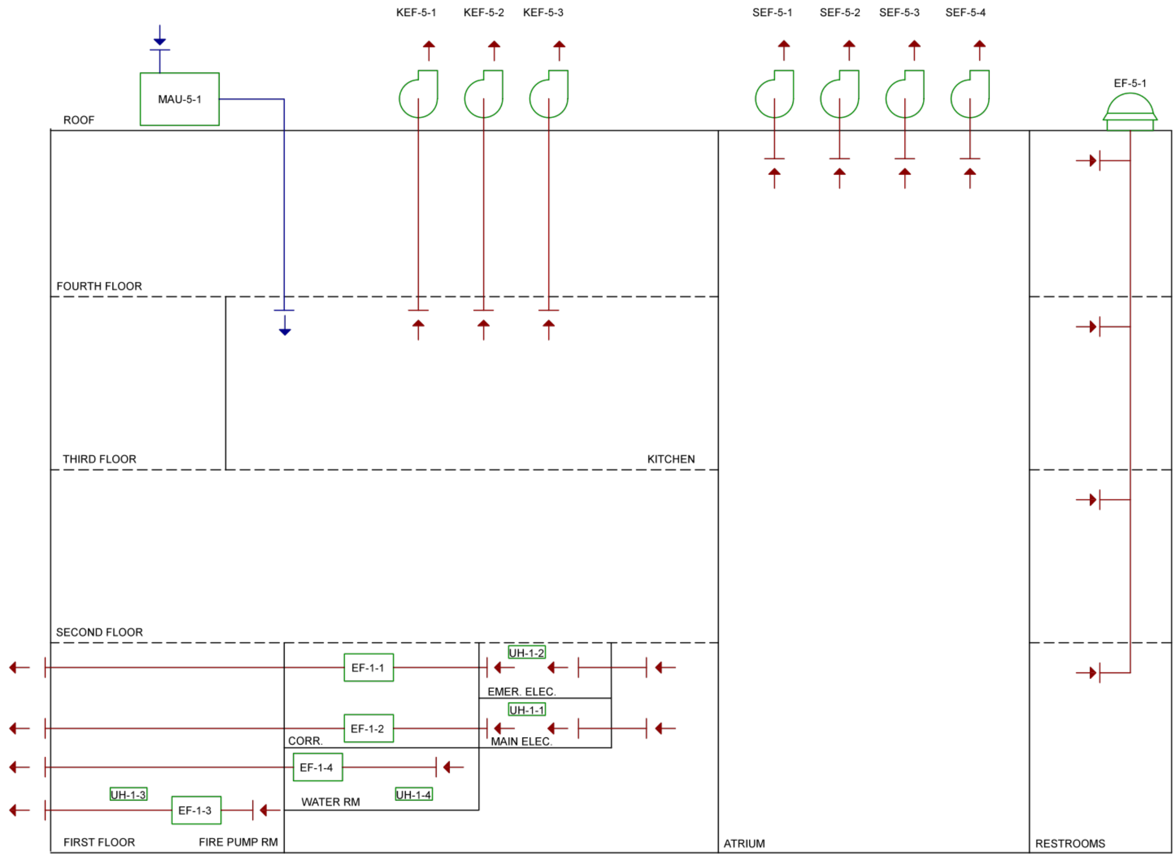


Figure 13. Exhaust air schematic.

SEF-5-1 through SEF-5-4 are for the smoke exhaust fan system dedicated to the atrium. In the case of a fire or smoke within the atrium, operable windows located in the atrium are to open. Their window opening area of all 22 windows is to provide 180,000 CFM into the space. This can occur as the smoke exhaust fans turn on, creating a negative pressure area, drawing large amounts of air through the windows. As the smoke is removed and the space returns to normal operating conditions, the fans ramp down and turn off. The atrium returns to its designed pressure set point, and the operable windows are closed.

The third exhaust system is dedicated to the kitchen, denoted as KEF in the schematic. These exhaust fans turn on when their dedicated equipment is operating. As the KEF turns on and removes air, the make-up air unit (MAU) shown on the roof, draws outside air in and sends it into the kitchen to maintain its design pressure. The three fans operate independent of each other, and they all send signals to the MAU as air is removed. The MAU tracks all the fans, so it sends the exact amount of air as is being removed.

The fourth system is the exhaust fans located in the fire pump, water room and electric rooms. These spaces have unit heaters in them, as shown in the schematic above, and they provide a certain amount of heat to the space to allow machinery to operate properly. As the unit heaters increase their airflow output, the exhaust fans detect the increase in air, and increase their fan speed to remove the air.

Table 17. Fan designation schedule.

| Designation | Service | Fan Type | Flow | Total SP [in. w.g] | MHP | Volt-Phase-Hz | Manufacturer |
|---|---|---|---|---|---|---|---|
| EF-1-1 | Emer. Elec | Inline | 150 | 0.20 | 0.17 | 120-1-60 | Cook |
| EF-1-2 | Elec Room | Inline | 450 | 0.20 | 0.17 | 120-1-60 | Cook |
| EF-1-3 | Fire Room | Inline | 250 | 0.20 | 0.17 | 120-1-60 | Cook |
| EF-1-4 | Water Room | Inline | 150 | 0.20 | 0.17 | 120-1-60 | Cook |
| EF-5-1 | Restrooms | Downblast | 3700 | 1.25 | 2 | 120-1-60 | Cook |
| RF-1-1 | 1st West | Inline | 20000 | 1.50 | 20 | 460-3-60 | Cook |
| RF-1-2 | 1st East | Inline | 16000 | 1.50 | 15 | 460-3-60 | Cook |
| RF-2-1 | 2nd West | Inline | 20000 | 1.50 | 20 | 460-3-60 | Cook |
| RF-2-2 | 2nd East | Inline | 18000 | 1.50 | 15 | 460-3-60 | Cook |
| RF-3-1 | 3rd West | Inline | 23000 | 1.50 | 20 | 460-3-60 | Cook |
| RF-3-2 | 3rd East | Inline | 18000 | 1.50 | 15 | 460-3-60 | Cook |
| RF-4-1 | 4th West | Inline | 16000 | 1.50 | 15 | 460-3-60 | Cook |
| RF-4-2 | 4th East | Inline | 16000 | 1.50 | 15 | 460-3-60 | Cook |
| SEF-5-1 to 5-4 | Atrium | Centrifugal Upblast | 45000 | 1.00 | 30 | 460-3-60 | Cook |
| TEF-1-1 to 4-1 | MDF | Inline | 450 | 0.20 | 0.17 | 120-1-60 | Cook |
| TEF-1-2 to 4-2 | Elec Room | Inline | 250 | 0.20 | 0.17 | 120-1-60 | Cook |

### *Water Distribution*

The use of water within this building for mechanical purposes is only seen on the condenser side. Below is a water riser diagram for the condenser water within the building.

Referring to the diagram on the next page in Figure 14, the blue and red pipes are the condenser water supply and return, respectively. As for the green items, they refer to equipment that requires power to operate, such as pumps and cooling towers in this diagram. Illustrated in black are valves that are used to balance and control the system operations. To understand their design operating conditions, refer to the schedules shown below in Tables 18 and 19.

The cooling towers are closed circuit, evaporative cooling towers. The cooling tower draws air through the tower with an axial fan while a basin pump transports basin water to the top of the tower and sprays it over condenser pipes that are also in contact with the draw-through air. Hot condenser water enters at the top of the tower and exits towards the bottom and is sent to the condenser pumps. Hot air that comes into contact with the

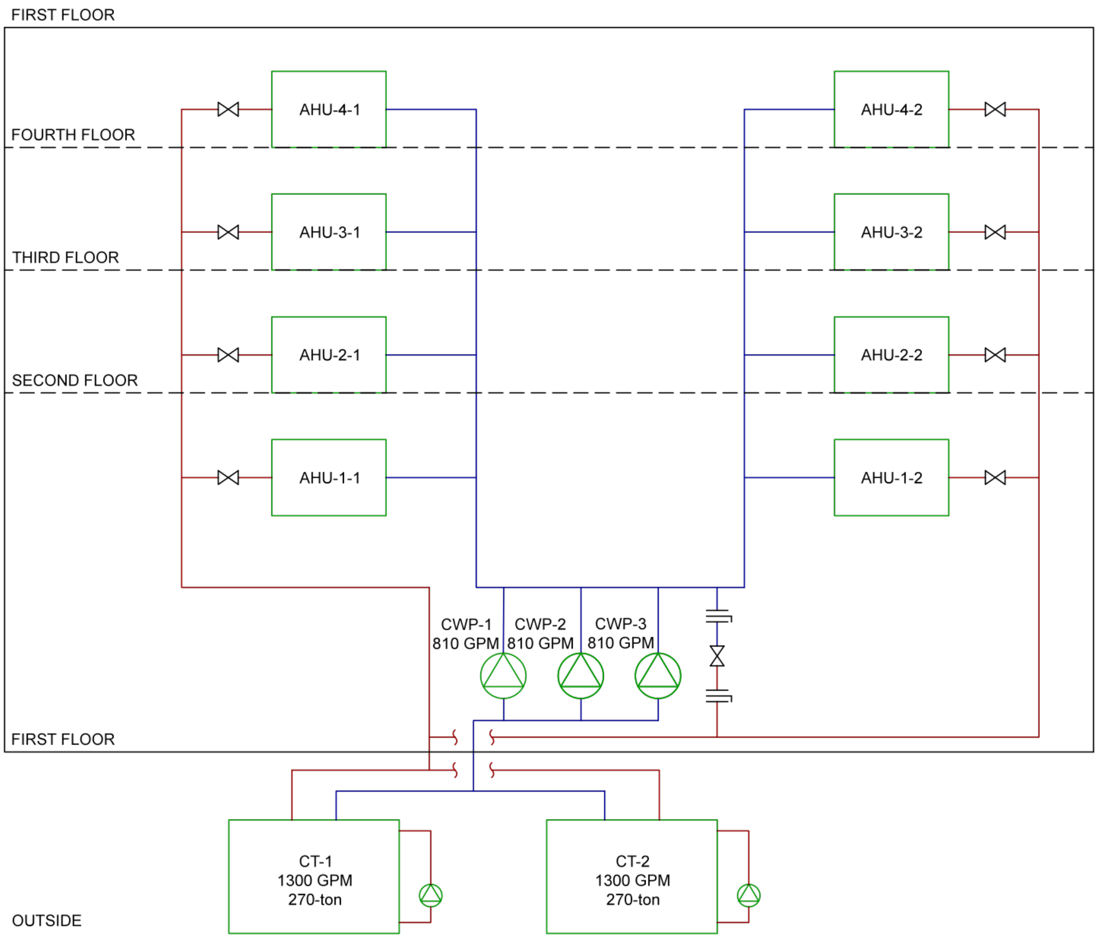


Figure 14. Condenser Water Riser Diagram.

cool water and drops in temperature. The lower temperature air comes into contact with the condenser piping, lowering its temperature and is sent to the condenser pumps. The image to the right shows what a closed circuit, evaporative cooling tower looks like with its components.

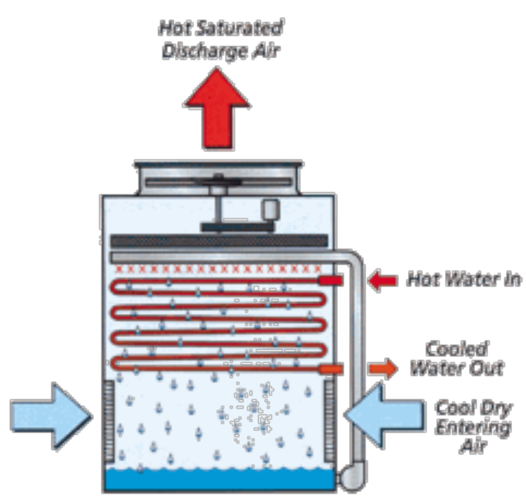


Figure 15. Evaporative Closed Circuit Cooling Tower.

This configuration has two main condenser pumps, and one standby pump, all with variable frequency drives. When an air-handling unit is online, it calls for condenser water to cool it down. At this point, the valve begins to open to the valve stem position that allows the correct amount of flow to that AHU. That pump is to be fully loaded to cool as many air handling units that the flow allows for.

Table 18. Evaporative Cooling Tower.

| Designation | Condenser Water Data | | | | | Fan | | | | Manufacturer |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water Temperature | | Max P.D | Ambient WB | | Airflow | MHP | | |
| | No. of Cells | EWT [F] | LWT [F] | ft $H_2O$ | [F] | No. Fans per Cell | [CFM] | | Starter Type | |
| CT-1-1 | 1 | 95 | 85 | 20.4 | 78 | 1 | 113720 | 40 | VFD | Baltimore Aircoil |
| CT-1-2 | 1 | 95 | 85 | 20.4 | 78 | 1 | 113720 | 40 | VFD | Baltimore Aircoil |

Table 19. Condenser Pumps.

| Designation | Fluid | Performance | | | | | Type | Motor | | Manufacturer |
|---|---|---|---|---|---|---|---|---|---|---|
| | | GPM | Fluid Temp [F] | NPSH | RPM | BHP | | MHP | Starter Type | |
| CWP-1 | Water | 810 | 90 | 9.10 | 1770 | 31.42 | Base Mount End Suction | 40 | VFD | Bell & Gossett |
| CWP-2 | Water | 810 | 90 | 9.10 | 1770 | 31.42 | Base Mount End Suction | 41 | VFD | Bell & Gossett |
| CWP-3 | Water | 810 | 90 | 9.10 | 1770 | 31.42 | Base Mount End Suction | 42 | VFD | Bell & Gossett |

Once the pump is at full capacity and the condenser water increases, the second pump is brought online. The flow is equalized and both pumps operate at the same speed. As the cooling capacity increases, the pumps increase at the same rate, at the same time. The pumps are to maintain the same differential pressure measured across them. If an operating point comes where the condenser water return is higher than its set point, a high set point limit will alarm, and the cooling towers fluid cooler fan will energize, to bring the condenser water back to its set point. Both towers have two fluid cooler fans, and once the speed of the one operating cooler fan reaches 90% of its maximum design speed, the second fan is to turn on.

When capacity begins to relax, a 15-minute operating time at minimum speed of the cooler fan will result in the shutdown of one fan. If capacity continues to relax, the second fan is to shut off under the same 15-minute minimum speed operating condition. When the load can be satisfied by only one pump, the valve to the second valve begins to close, shifting the flow to the primary pump. For pump life conservation, the pump with the higher run-hour time shall be the lag pump.

## Space Consideration

When considering the space that is consumed by mechanical-related items, the real-estate adds up quickly. With this building having eight (8) separate mechanical rooms, two (2) smaller plumbing chases and one (1) large plumbing chase per floor, the square footage accumulates rather quickly.

Shown in Table 20 on the right, the total mechanical space is approximately 7200 SF. With the overall square footage of Pharm Corp. being 150,000 SF, the percentage that mechanical-related space takes up is 5%. It is a lot of space, especially when office space for the headquarters is valuable. An average office of 200 SF, when compared to the mechanical space, would sum up to 36 offices.

Table 20. Breakdown of lost usable space.

| Level | Room | Square Feet |
|---|---|---|
| 1st | Mech-1-1 | 865 |
| | Mech-1-2 | 866 |
| 2nd | Mech-2-1 | 867 |
| | Mech-2-2 | 868 |
| 3rd | Mech-3-1 | 869 |
| | Mech-3-2 | 870 |
| 4th | Mech-4-1 | 871 |
| | Mech-4-2 | 872 |
| Summation of all | Plumbing Chase | 250 |
| | Total Area | 7198 |
| Percentage of Footprint | | 5% |

The reasoning for the increased mechanical footprint is to house indoor AHUs per each floor on the perimeter of the building. This reduces ductwork that is required when transporting air from the outdoors. This give-and-take for floor space versus duct cost was a valuable and important one, and the economics for duct cost outweighed the real-estate that mechanical rooms consume.

## System First Costs

As per the owner's request, the overall cost for the mechanical system is undisclosed. From investigating the overall footprint that the mechanical system takes, it appears the mechanical system and how it operates is of higher importance than the cost. They wanted the most efficient system, while being economical to not waste material. Since the building is still being constructed, there are no current operating history data for the systems. Therefore, it is undetermined of how the actual building would compare to the estimated energy usage.

# *LEED EVALUATION*

***Energy & Atmosphere Credits*** ***1/17 points***

*Fundamental Commissioning and Verification* *prerequisite* **MET**

A full commissioning plan has been provided for Pharm Corp. and will be conducted once construction is complete. Commissioning for the MEP systems is offered in house from AKF Group, the MEP Engineer.

*Minimum Energy Performance* *prerequisite* **MET**

All energy performance data has been assessed using ASHRAE 90.1 and has been met. A minimum amount of energy efficiency was established from the proposed building. All lighting power densities are in accordance to ASHRAE 90.1 as well as LEED criteria.

*Building-Level Energy Metering* *prerequisite* **MET**

Building energy metering is going to be installed as the building is constructed, so this prerequisite is satisfied.

*Fundamental Refrigerant Management* *prerequisite* **MET**

The refrigerant used is R410a, which is a Hydrofluorocarbon (HFC), which is not a Chlorofluorocarbon (CFC). It has zero ozone depletion percentage, meeting this prerequisite.

*Enhanced Commissioning* *1/6 points*

Commissioning is going to be completed for the Core & Shell portion of the project upon completion of that phase. A separate commissioning report will be filed for the Interior Fit-Out phase of the project. AKF is contracted to do the commissioning for all MEP systems.

*Optimize Energy Performance* *0/18 points*

The building has not been constructed fully at this point, and therefore there is no operation occurring within the building. Compared to the estimated energy usage, there is then no data of actual energy usage to compare to. At this point, this credit will not be met.

*Advanced Energy Metering* *0/1 point*

There is no plan determined by the owner to have monitoring of energy that can adjust energy consumption based on operation. Therefore, no points are rewarded.

*Demand Response* ***0****/2 points*

A demand response program was not set in place for Pharm Corp., therefore this credit is not satisfied.

*Renewable Energy Production* ***0****/3 points*

There is no renewable energy production on this site for the building. Recalling the Rebate section, it can be installed for large rebates and could then obtain these points.

*Enhanced Refrigerant Management* ***0****/1 point*

The refrigerant within this building is R410a. Although R410a has zero life cycle ozone depletion potential (LCODP), it has a high global warming potential (GWP) of 1725. Using the equation below determines the life cycle global warming factor (LCGWP):

$$LCGWP = [GWP * (L_r * Life * M_r) + R_c]/Life$$

where:

$L_r$=refrigerant leakage rate
GWP=global warming potential
Life=equipment life
$M_r$=end-of-life refrigerant loss
$R_c$=refrigerant charge

When using the default values provided from LEED-NC v2.2, the best possible LCGWP would be 82.5 and the worst possible LCGWP would be 132. In determining if the refrigerant is enhanced and less than the maximum allowable value to minimize emissions, the total $LCGWP+LCODPx10^5<100$, there is no clear vision to say this refrigerant is or is not within the constraints. Therefore, the point will not be awarded due to being conservative.

*Green Power and Carbon Offsets* ***0****/2 points*

There are no contracts established for two-year renewable energy sources. Therefore, this point is not acquired.

## *Indoor Environmental Air Quality Credit* *5/15 points*

*Minimum Indoor Air Quality Performance* *prerequisite* **MET**

Pharm Corp. was designed to meet the performance requirements that are covered by ASHRAE 62.1-2010. The outdoor air sent into the space is much larger than the required outdoor air flow. Therefore, this prerequisite is satisfied.

*Environmental Tobacco Smoke Control* *prerequisite* **MET**

Following the requirements in Option 1, smoking is prohibited within this building. This credit is then satisfied.

*Minimum Acoustic Performance* *prerequisite* **MET**

From the start of the project, the acoustical consultant as well as the MEP engineer had strict guidelines in maintaining NC-40 levels throughout all spaces. All mechanical equipment was approved by the consultant that met the design criteria.

*Enhanced Indoor Air Quality* *0/2 points*

This credit could have been obtained since the conference room rooftop units have carbon dioxide detectors to increase demanded ventilation air when the space was occupied. There is not demand control in the entire building, however. Therefore, no points were awarded.

*Low-Emitting Materials* *1/3 points*

Both the architect and the interior designer have specified that all materials are to be below the maximum volatile organic compound limit (VOC) as specified by LEED for the safety of the employees in the space. There is no record of if these materials are installed as specified since the building is not yet complete and commissioning has not taken place. Therefore, a conservative 1 credit will be awarded until commissioning is complete.

*Construction Indoor Air Quality Management Plan* *1/1 point*

With the MEP designer in contact with the owner, operations of the mechanical system and maintaining IAQ is of high interest. They have a plan to conduct air testing to ensure that contaminants are not above the maximum concentration. This point is then acquired.

*Indoor Air Quality Assessment* *0/2 points*

No plan was determined for this building once normal operation was to begin since LEED was not a goal for this building. This credit is not received.

### *Thermal Comfort* *0/1 point*

Thermal conditioning is only provided from the air-handling units. Thermostat control may be adjusted by the employees, either in enclosed offices or in open-office space. The regular office windows, however, are non-operable as they are part of the curtain wall system. Therefore, they cannot get outdoor air when they want.

### *Interior Lighting* *2/2 points*

All enclosed offices can operate their lights with given light switches. Open-office areas exposed to curtain wall systems, as well as the dining area and atrium, are equipped with daylight response lights to control the amount of artificial light being used when natural light is sufficient. Lights in those spaces can be overrode if occupants require more light than what natural light is available.

### *Daylight* *0/3 points*

Many offices on the perimeter are enclosed, restricting the amount of open-office space that is exposed to natural light. This constraint does not allow for this point to be received, as much less than the required 75% minimum floor area is exposed to natural daylight illumination.

### *Quality Views* *0/1 point*

As discussed in the Daylight section, since 75% of regularly occupied space is not able to receive the required natural daylighting, the quality view credit is also not received.

### *Acoustic Performance* *1/1 point*

This building project team has a hired acoustical consultant to ensure that the acoustic performance follows the strict guidelines to ensure the interior spaces have NC-40 for office space. Duct sizing, equipment selections and diffuser selections all went through this acoustical consultant to guarantee they are within acceptable guidelines.

## ***LEED Analysis Summary***

As expected, since the building was not originally designed to be LEED certified, only a few credits actually received points based on LEED criteria. Most of the points received were design decisions made by either the architect or MEP engineer that indirectly received points, based on good design techniques.

# OVERALL SYSTEM EVALUATION

With the mechanical system costs being undisclosed, there are no overall comments for the system costs. As for its space that the mechanical system consumes, housing eight indoor AHUs, two per floor, consumes a large amount of real-estate for each floor. The owner may have wanted additional office space that just was not feasible when the original mechanical design. Investigation on the impact of having units placed on the roof and distributing air into the floors may be a point of interest, while evaluating a change in mechanical cost and operating energy to the increased usable footprint.

Maintenance on these equipment is relatively simple with everything being inside and easily accessible, with the exception of the rooftop units, roof-mounted exhaust fans and outdoor air-cooled condensing units. This is an advantage with this mechanical system. Also, operating indoors can reduce the potential problems that the system could have, such as potential freezing problems. Heat tracing does not have to be used on indoor piping and ducts. There are very limited areas where heat tracing has to be used, such as the cooling tower and RTUs. Running a cost evaluation of heat tracing can be useful to further back-up the original design.

The one area that could be improved is the use of electricity. With the entire mechanical system being dependent on electricity, there is a large amount of energy, in kWh, that are being consumed. Incorporating a central boiler for the building can drastically reduce electricity usage, and therefore significantly lower the carbon dioxide emissions. It will also reduce the amount of equipment, such as electric baseboards, that need to be installed.

Referring back to the rebates section, there is a large incentive to install solar panels. If a boiler replaced the electric heating in the building and solar panels are installed, there is a significant increase in savings versus overall electric cost per year. There would be a new cost for fuel and the operating cost for the boiler, but with Delaware going to 25% renewable energy mandatory by 2025, this would be going in the right direction toward that goal.

An area that may also improve the mechanical system would be the installation of a chiller. Providing chilled water through the system will aid in the cooling capacity for the units. A possible avenue would be the installation of an active chilled beam system, which would combine both the use of the chiller, stated here, and the placement of the units on the roof, stated above. The potential that this redesign could offer is the decrease in duct sizes since less air has to travel to the space, the mechanical rooms now reduce in size so possible office space can be created at the owner's request, the electricity consumption would decrease. There is a large upfront cost for an active chilled beam system, but determining the life-cycle cost along with payback period can be the driving force to make this redesign change.

Overall, it is a relationship between the cost of the system to the overall payback period. The original design works as designed, with very limited fuel sources, a general VAVRH system and some demand control. If it can be shown to the owner that spending a larger upfront cost can later receive rebates of $240/kWh generated, or there is a reduction of electricity cost per SF of the building, it becomes more appealing to them. Life-cycle costs and payback periods should also be calculated to mathematically show it is or is not worth it.

# *REFERENCES*

ANSI/ASHRAE. (2010). Standard 62.1-2010, Ventilation for Acceptable Indoor Air Quality. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

ANSI/ASHRAE. (2010). Standard 90.1-2010, Energy Standard for Buildings Except Low Rise Residential Buildings. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

ASHRAE (2009). 2009 ASHRAE Handbook - Fundamentals. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

"Delaware Rebates and Incentives Summary." Clean Energy Authority, DigitalGreenMedia, 2016. Accessed 10 Nov. 2016.

Design Documents provided by AKF Group

LEED-NC Green Building Rating System for New Construction & Major Renovations v2.2

Rendering used by permission from Granum A/I

Trane Trace® 700 Version 6.3.0. for Academic Use