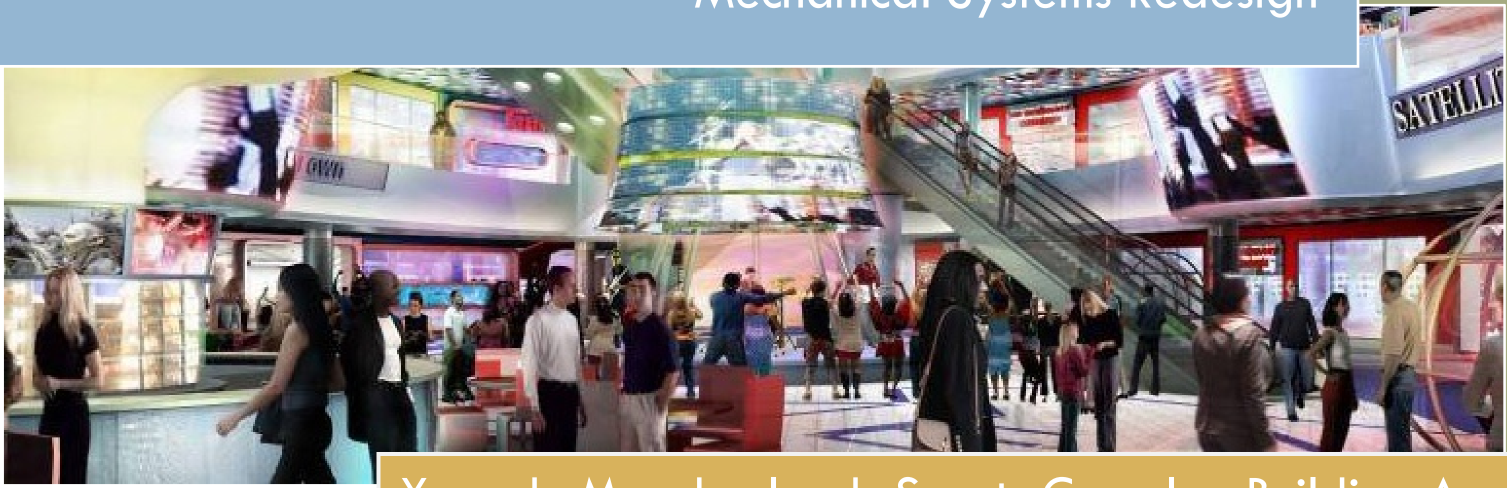
Thesis Proposal

Mechanical Systems Redesign



Xanadu Meadowlands Sports Complex Building A
East Rutherford, New Jersey

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Executive Summary

The Xanadu Sports Complex Building A is comprised of a retail section and an indoor ski resort called the Snowdome. Through the analysis found in previous technical reports areas of design improvement were found. Through the analysis the main areas of concern were found to be in the ventilation systems of both the retail section and indoor ski resort and the large amount of energy needed to run such a building. The contributing factor to these concerns can be linked to the use of the Building Officials and Code Administrators (BOCA) 1996 code.

The goal of the mechanical redesign is to address concerns of proper ventilation and energy use while maintaining a reasonable payback period. Other methods will be explored that may be too expensive to consider, however, will be used for the educational value.

The ventilation system redesign will reevaluate the system using ASHRAE Standard 62.1-2007. New rooftop units, ductwork, and diffusers will be selected to maximize the efficiency of the system. To address the concern of energy use and the various problems that result from the use of large amounts of energy, a combined power generation and heating/cooling system will be installed. The use of microturbines will generate electricity on-site using environmentally friendly gasses. The waste heat from the micorturbine combustion process can then be put to good use in other parts of the building, thus increasing the overall efficiency.

The introduction of the new mechanical system equipment will affect other building systems. The changes required due to the redesign will be addressed to fully analyze the feasibility of the new mechanical system. A structural analysis of the building's roof will be used to determine whether or not reinforcing is needed to support the new equipment. The electrical system will also be analyzed to determine whether feeders, panel boards, and the main distribution lines need to be resized in order to provide the proper capacity to the new equipment.

Finally, the redesigned system's cost will be estimated to determine the economic feasibility of such a system.

Building Design Summary

Building A of the Meadowlands Xanadu complex is designated as the sports district. All sports related retail stores and activities will be housed in this building. Building A has essentially two sections; the south side of Building A will contain all retail stores while the north side of the building will house the Snowdome indoor ski resort.

The retail section of Building A will contain a wide variety of sporting goods stores, a restaurant, and night clubs. The majority of leasable space will be used for retail sales; however, these retail spaces are not included in the current contract. Therefore, for these types of spaces an analysis will not be applicable. All work in retail spaces, night clubs, the ski resort lodge, and the restaurant will be fit out by the tenant near the end of construction.

The north section of Building A will house The United States' first indoor ski resort named the Snowdome. During normal operation the slopes will be comprised of snow laying flat over the distance of the run. However, during special events the slopes can be made into quarter pipes, and jumps can be added for competitions. Aside from skiing and snowboarding competitions the Snowdome is planned to be used for concerts, fashion shows, and parties with a wintery touch. The Snowdome will house 160,000 square feet of cold side space and will include a novice ski slope at 330 feet long by 120 feet wide and an advanced ski slope at 780 feet long and 150 feet wide. During times of normal operation the peak occupancy load is expected to be 300; while during special events the space is designed to provide enough fresh air for 999 people.

Figure 1 below shows the occupancy categories break down for the building.

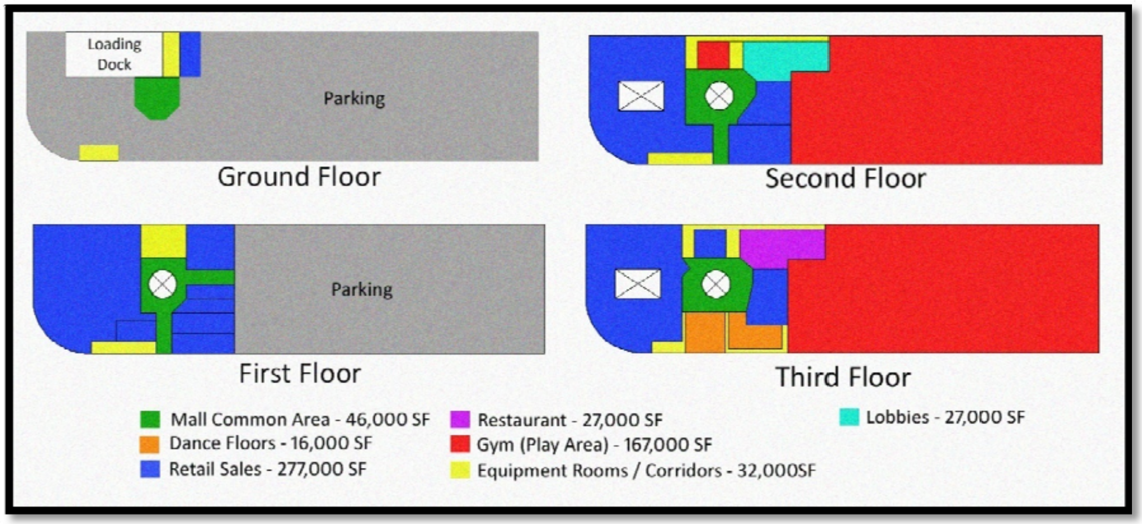


Figure 1: Building A Occupancy Category Distributions

Mechanical Systems Summary

Retail Mechanical System

The air side mechanical system for the retail section of Building A uses four roof top air handling units that serve all the common areas of the building. In Building A common spaces are comprised of walkways to the different stores and restaurants, restrooms, back of house rooms, and a large central area that will create a large atrium for all the levels of shopping. All tenant spaces will not have any mechanical work done at this time and will be finished by the leaser towards the completion of the building. All four common area rooftop units are controlled by variable frequency drives with two running modes: occupied mode during normal operating hours and unoccupied mode during the nighttime. A programmable time clock will control when the occupied or unoccupied mode begins to run. A thermostat will control the cycling of the supply fan and energize the electric heating coil to maintain the nighttime setback temperature during the unoccupied mode. During the occupied mode the supply fan will operate continuously. The use of an economizer to maximize atmospheric cooling will also be implemented for all four of the rooftop units.

RTU-1 serves the first and second floor common areas on the east side of the building, and RTU-2 serves the first and second floor common areas on the west side of the building. Both units supply 16,100 cfm of air each with 1,496 cfm of that supply air being outside air. Each unit's cooling coil has a capacity of approximately 38 tons and an electric heating coil capacity of 150 kilowatts. RTU-3 and RTU-4 serve the third floor common areas. Both of these units supply 31,000 cfm of air each with 3,037 cfm of that supply air being outside air. Each unit's cooling coil has a capacity of approximately 78 tons and an electric heating coil capacity of 190 kilowatts. A graphical representation of the atrium's ventilation system can be seen in Figure 3.

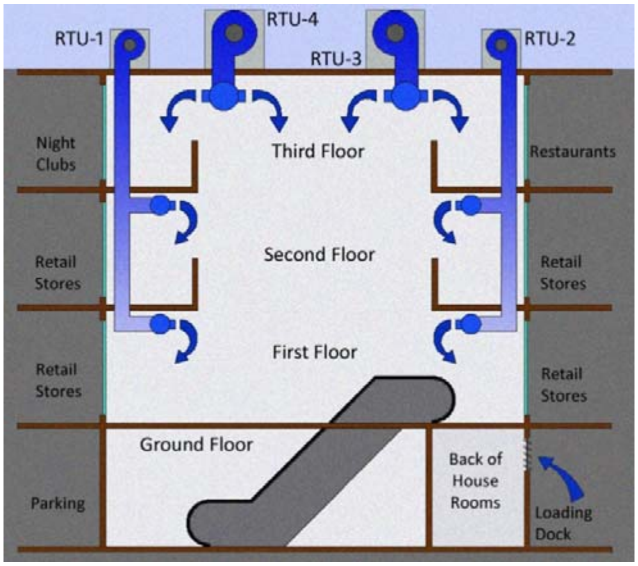


Figure 3: Retail Ventilation

In addition to the rooftop units, wall mounted electric unit heaters are used in mechanical spaces, entrance vestibules, and exit stairways to maintain thermal comfort. To ensure fresh air enters the back of house rooms, exhaust fans are installed to negatively pressurize the rooms. With the use of exhaust fans, fresh air that has been supplied to the walkways on the floor will be drawn to the rooms with negative pressure. Small air condition units are also used in elevator machine rooms and the main ground floor entrance to supply cooling when needed.

Snowdome Mechanical System

The challenge of an indoor ski resort is to ensure that snow can be maintained year round and to maintain a highly controlled environment. During normal day operation, temperatures must be maintained between 30°F and 32°F. However, at night fresh snow is made on a daily schedule, and temperatures must be cooled to approximately 24°F to ensure proper snow making. The Xanadu Snowdome plans to achieve ideal conditions by using cooled supply air, under floor glycol piping, recirculation coolers, and snow guns to provide the best skiing conditions every day of the year.

The Snowdome ventilation system is comprised of a single 30,000 cfm air handling unit with 15,000 cfm of the supply air being outside air. The unit uses a main common intake system with one primary and two secondary cooling coils. The air is pre-cooled by means of a thermal wheel and then cooled down to above freezing by the primary cooling coil. The air is then cooled below freezing by the secondary coils which are fed by a cold glycol system. A hot glycol system line is also fed to the secondary coils and will only be used when the coils need to be defrosted. The system is fully variable in volume, achieved by using inverters on the fans, to suit the current occupancy.

Two 222 ton electric screw chillers operating at 1.5°F leaving glycol temperature provide the cold glycol to the air handling unit's coils, under floor piping matrix, recirculation coolers, and snow guns. Both chillers operate in conjunction with an evaporative condenser located on the roof of the Snowdome mechanical mezzanine which houses all the mechanical equipment.

Mounted along the ceiling of the Snowdome are recirculation coolers and snow guns. Both devices will be run using the cold glycol system during normal operation. However, when the devices need to be defrosted, the cold glycol system will be shut off, and the hot glycol system will be turned on for defrosting. The snow guns also require compressed air for the use of snow making; therefore, a compressed air line will be provided to each snow gun.

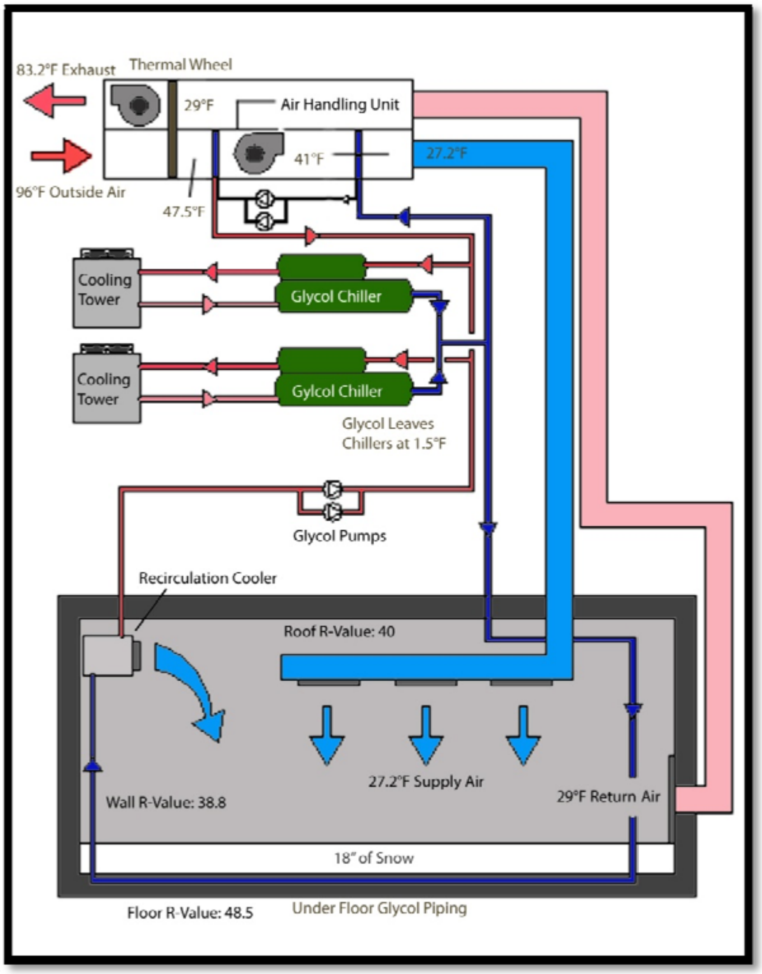


Figure 4: Snowdome Mechanical System

Proposal Objectives

The entire Xanadu Sports Complex including the mechanical system was designed to comply with Building Officials and Code Administrators (BOCA) 1996. Chapter 28 of the BOCA 1996 code covers the provisions of a building's mechanical system. The mechanical section covers topics such as acceptable pipe material, insulation requirements, and plenum sizes; however, prescriptive methods for designing ventilation systems and acceptable comfort levels are not present in the code. It is evident that the BOCA 1996 code is nowhere near as detailed as the current International Mechanical Code (IMC) regulations.

The use of an outdated code in the initial design of the Xanadu Sports Complex provides a great opportunity for areas of improvement. The largest area of concern comes from the amount of energy needed to supply proper skiing conditions throughout the year. From the beginning of the design the idea of an indoor ski resort has been controversial due to protests. The opponents of indoor ski resorts argue that the energy consumed does not warrant the construction of such structures. For this reason the main goal of the redesign will be to decrease the footprint Building A of the Xanadu Sports complex leaves. This will be achieved through decreasing the building's current dependency of electricity from the power grid, the use of efficient equipment, lower emissions, and overall efficient design.

Another objective is to redesign the ventilation system in the retail section of the building. Technical Report One discussed the results of an ASHRAE 62.1-2007 compliance report. Through the findings of the report it is evident that several areas are under ventilated. The under ventilated spaces are a result of poor diffuser location and in some case lack of proper distribution through ductwork. This problem can not only lead to improperly ventilated spaces, but also lead to areas not being conditioned properly.

The planned introduction of more energy efficient equipment will likely raise the first cost of the mechanical system significantly. While a large effort will be made to make the building more sustainable, the redesign must also be practical economically. For this reason a short payback period is desired. The new equipment will be more expensive at first; however through the savings gained from energy use reduction it is a goal to have a payback period of five years.

Proposed Redesigns

The areas of concern that were brought to light in the three technical reports will be addressed in the proposed building redesign. The two main areas of concern are the ventilation systems of both the retail and indoor ski resort and the large amount of energy used by the building. These two areas will be the main focus of the building mechanical system redesign.

Ventilation Systems

The results from the ventilation calculations in Technical Report One showed some potential problems in the mechanical system in relation to proper ventilation. The roof top units that serve the retail section of the building dump the majority of all the air from the units directly into the large atrium space and nowhere else. This design reduces the amount of ductwork needed and essentially uses the corridors as the duct to carry ventilation air to spaces. This can present a problem since in some cases spaces are relying on air to travel from the atrium though hundreds of feet of corridors to spaces that need ventilation. Another area of concern resulted from the Snowdome's air handling unit. The Snowdome's air handling unit was found to be undersized by about three times for the amount of ventilation that will be needed for such a large space. Finally, the natural ventilation analysis of the ground floor also showed some areas that can potentially be under ventilated. The free area of the louvers is very small in comparison to the minimum requirements presented by ASHRAE 62.1. Besides not meeting the size requirements, the louvered natural ventilation is within 25 feet of truck loading docks.

The three main areas of concern above will be the driving factor in the ventilation system design. The redesign of the retail ventilation system will ensure that all spaces receive proper ventilation rates based on the ASHRAE 62.1 Ventilation Rate Procedure. New air handling units will be selected to meet the proper flow rates. From the roof top units new duct work will be run to all spaces that require ventilation. All duct work will be sized to maintain a proper pressure loss to ensure maximum efficiency.

The Snowdome's single air handling unit which is already undersized according to ASHRAE Standard 62.1 will become multiple units in the redesign. As with the retail system redesign the ventilation rates will be prescribed by the Ventilation Rate Procedure. Not only will this provide the proper ventilation needed for nearly a thousand people to ski but also, it will ensure that if something goes wrong with one of the units, air can still be supplied to the space.

Finally, the ground floor natural ventilated spaces will now receive ventilation though the retail mechanical system. The reason for the elimination of natural ventilation is the lack of air that can be considered fresh. This is a result of the ground floor spaces being surrounded by a parking garage and truck loading dock.

Microturbine System

The energy analysis from the calculations found in Technical Report Two showed that the amount of energy needed to run the retail section and provide indoor skiing conditions year round will result in a large amount of energy use. This energy is obtained through electricity from the power grid which will result in a large amount of emissions. With growing electricity prices and environmental concerns, the drive for more sustainable buildings is at an all time high.

In an attempt to make the building more sustainable and energy efficient a combined power and heating/cooling system will be the focus of this redesign. Based on the amount of energy needed to heat, cool, light, and power other miscellaneous equipment microturbines will be sized to provide the proper energy needed. Microturbines produce electricity on the building site through the use of a combustion process. Since the electricity is produced on site, the electricity required from the power grid is greatly reduced and in times of on-site over production the excess electricity can even be sold back to the power grid.

The use of a microturbine system presents many alternative system solutions that will be researched in great depth to choose the best system. At this time the alternatives will be presented.

The first set of alternatives will take advantage of the waste heat produced from the microturbines combustion process. This waste heat can be harnessed to heat water to very high temperatures that can be used in other parts of the building, increasing the overall efficiency of the building. Ideally, this exhaust heat will be used to run a water-fired absorption chiller that will replace the screw chillers that run the glycol system in the indoor ski resort. A water-fired absorption chiller can run strictly from the hot water provided from the microturbine's combustion process; however, it is yet to be determined whether or not an absorption chiller can run at the -1.5 ° F leaving glycol temperature needed. If this is a feasible redesign, a great deal of electricity will be saved through the replacement of two large compressor chillers. However, if it is found that absorption chillers cannot run at the temperature needed, the waste heat can still be used elsewhere in the building. One alternative would be to not use direct expansion roof top units for the retail section and create a central plant comprised of a combined heating and cooling absorption chiller. The temperatures needed for the retail section will be able to be met through the use of the absorption chiller and will provide adequate energy to charge the coils in the units.

Another source of alternatives comes from the fuel used to power the microturbines. Microturbines can run on natural gas, methane, ethanol, or even landfill gas. While all the listed fuels are considered environmentally friendly, an even further step can be taken by introducing a bio reactor to the exhaust of the microturbine. A bio reactor uses algae to scrub the air clean of carbon dioxide, nitrous oxides, and sulfur oxides. However, the use of such a system is still in development and would be rather pricey; therefore, the use of bio reactors will be presented for the educational value.

Breadth Proposal

The redesign of the mechanical system will directly affect other aspects of the building's design. The goal of the breadth study proposal is to address the changes that will need to take place with other building systems to incorporate the changes to the mechanical system.

Structural Proposal

The introduction of new mechanical equipment on the roof will result in an increase in the dead load which will affect the roof's structural member size. Included in the redesign will be four resized roof top air handling units, multiple microturbines, and the possibility of a heating/cooling absorption chiller. Due to the increase of mechanical equipment weight on the roof the roof structural members will more than likely need to be increased in size. However, a study of proper equipment placement can reduce the overall reinforcement needed. For this reason the equipment location on the roof will be analyzed. If it is found that the structural members need to be increased in size, the price difference will be included in the mechanical redesign price to determine the overall feasibility.

Electrical Proposal

Similarly to the structural system, the changes in the mechanical system will directly affect the electrical system. The biggest change comes through the use of on-site electricity production. Research will be needed to determine how the electrical systems for a microturbine system are incorporated. The increase of mechanical equipment and replacement of existing equipment will greatly change the electrical design. With a change in electric load, new feeders, panels, and main distribution lines will need to be resized.

Project Methods

To fully evaluate the feasibly of the proposed redesign multiple engineering references and software will be utilized.

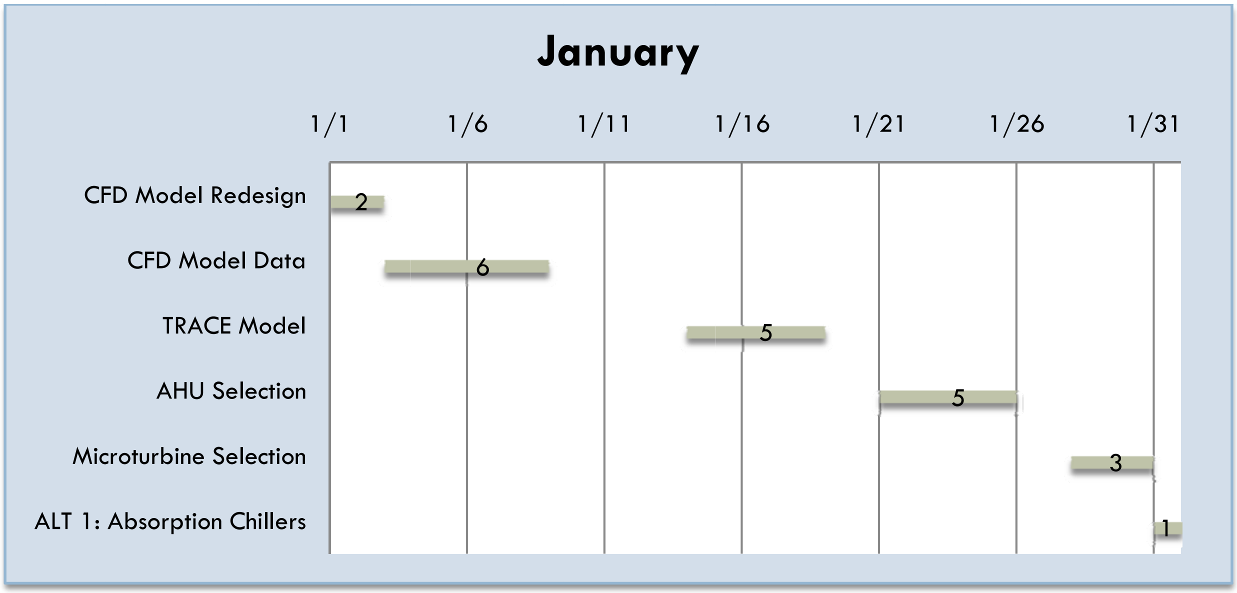
The computational fluid dynamics (CFD) software Fluent Airpak will be the first software used. This particular study will take place through the cooperation of CJL Engineering who is allowing the use of their software to be used for the use of this redesign. The CFD study will be used to evaluate the current air distribution and thermal properties of the current retail mechanical design. The retail section of Building A is a rather unique space with a large atrium and various corridors which require constant air supply. Due to the fact that the ventilation analysis from Technical Report One which indicated improper ventilation will be reinforced through the results of the CFD model, hence confirming the importance of a ventilation redesign. After the existing design model is completed a new model will be made to represent the ventilation redesign. The two models will be compared to determine the improvement of the system.

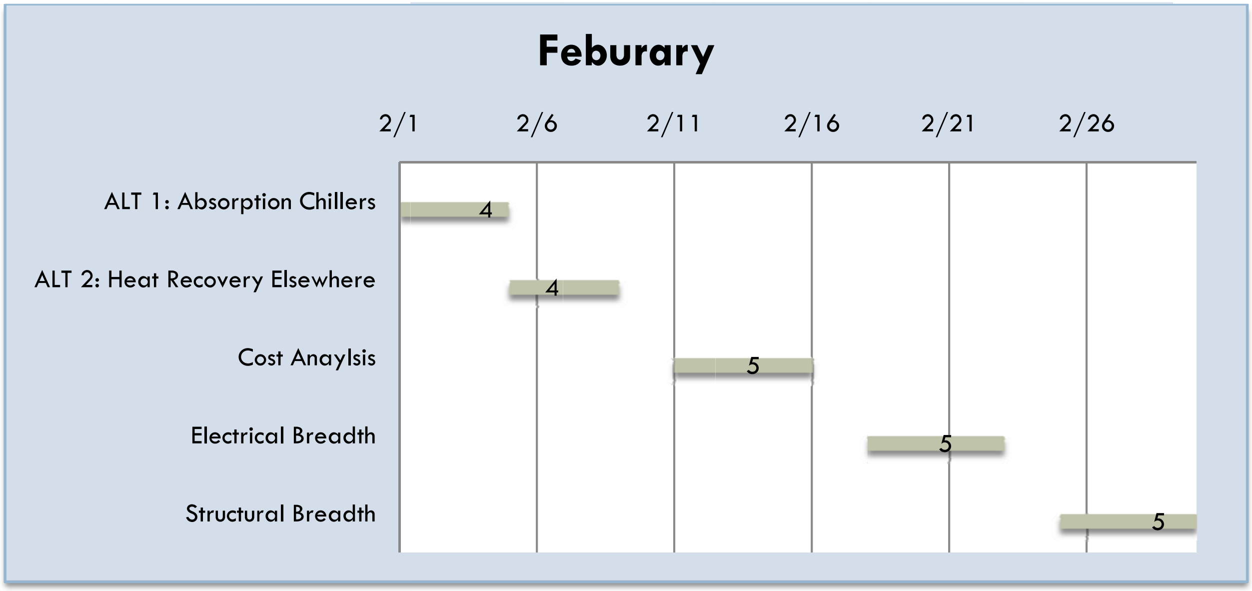
The TRACE 700 software will be used to size all new mechanical equipment accurately. The existing conditions TRACE model used for Technical Report Two will be used as the baseline case due to lack of designer information. Changes will be made to the existing model to represent the redesign. The two models will then be compared to estimate energy saving.

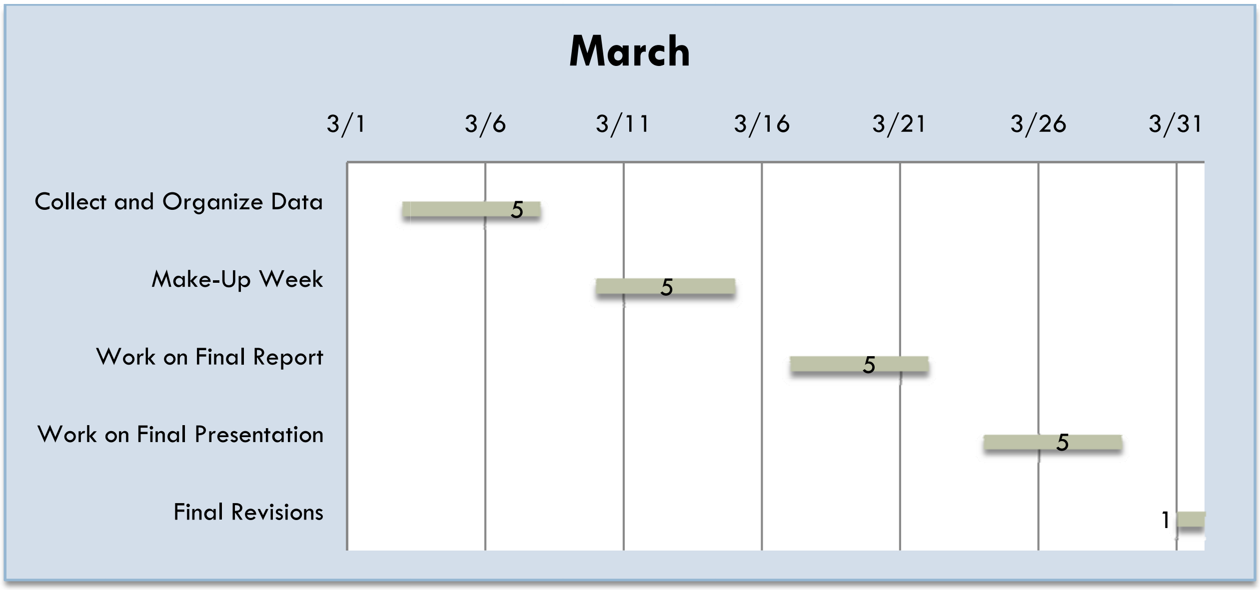
The cost of the redesign is an important aspect of the feasibility study of the proposed redesign. For this reason the latest R.S. Means will be used to estimate the overall price of all aspects of the redesign.

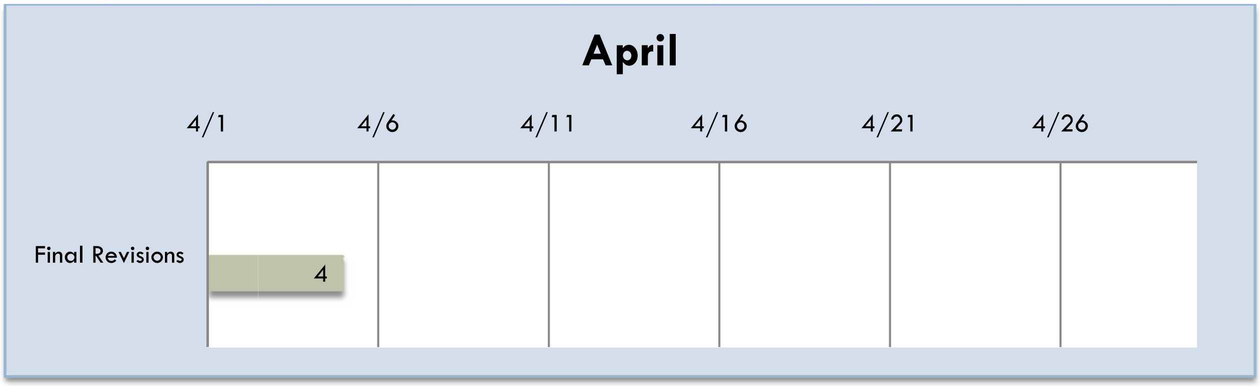
Schedule


December
12/1
12/6
12/11
12/16
12/21
12/26
12/31
CFD Model Existing
7
CFD Model Redesign
4


January
1/1
1/6
1/11
1/16
1/21
1/26
1/31
CFD Model Redesign
2
CFD Model Data
6
TRACE Model
5
AHU Selection
5
Microturbine Selection
3
ALT 1: Absorption Chillers
1


Feburary
2/1
2/6
2/11
2/16
2/21
2/26
ALT 1: Absorption Chillers
4
ALT 2: Heat Recovery Elsewhere
4
Cost Anaylsis
5
Electrical Breadth
5
Structural Breadth
5


March
3/1
3/6
3/11
3/16
3/21
3/26
3/31
Collect and Organize Data
5
Make-Up Week
5
Work on Final Report
5
Work on Final Presentation
5
Final Revisions
1


April
4/1
4/6
4/11
4/16
4/21
4/26
Final Revisions
4

Conclusion

The use of BOCA 1996 in the initial design of the Xanadu Sports Complex provides a great opportunity for areas of improvement. Throughout the past eleven years great strides have been made in energy efficiency and indoor air quality. The proposed redesign of the mechanical system is aimed to incorporate methods from current codes and standards to improve the current design. The redesign then aims to reach the next level of cutting edge systems to not only learn from new ideas but also demonstrate the feasibility of using such systems with different types of buildings.

Preliminary Research

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