2013

Proposal

American Art Museum

Mechanical Systems Project Proposal

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Executive Summary

American Art Museum (AAM) will be a 9 story building located in New York. AAM will be built with advance lighting and HVAC control systems to remain the thermal environment for art storage purpose. And, the design of AAM specifies the required efficiency of HVAC equipment in order to shorten the payback period. So, this proposal provides the ideas about designing a cost effective mechanical system and room layout.

Steam/Hybrid System

The in-depth mechanical project is to replace some of the electric chillers with absorption chiller(s). Since the electric price is increasing today, a steam or hybrid system may be a better option to save utility cost. A hybrid system is a combination of steam and electric chillers. This system is also suggested, especially when the budget of fist cost is limited without applying a full absorption chiller system. Because AAM will be located in the area where the district heat system is provided, the waste steam can be used in a hybrid/steam cooling system during cooling months to lower the electric cost.

Rearrangement of Mechanical Equipment

Another proposed project with structural and acoustics consideration is to rearrange the mechanical equipment closed to the served areas. The goal of this arrangement is to minimize the energy loss in piping and ductwork. There will be a mechanical and electric room on 9th floor, where will be on top of a large gallery. In order to shift the mechanical equipment to 9th floor, the acoustical and structural impact will be considered, such as improving the acoustical treatment and resizing the structural components. The impact may raise the capital cost. The new rearrangement should be cost effective and cost balanced with the acoustical and structural impact.

In conclusion, the general goal in the proposal is to speed up the payback period by reasonably increasing the capital cost. This goal requires conducting a trial and error analysis in order to find an optimized solution.

Project Background

Name	American Art Museum
Location	New York, NY
Occupancy Type	Group A-3 Museum
Size	195000 sq. ft.
Function	Gallery, Classroom, Office, Auditorium, Restaurant
Floors	9 levels with cellar mezzanine and cellar level underground
Construction	Start in February 2012, End in late 2014
Main Architectural Feature(s)	1. Cantilevered entrance 2. The Biggest column-free gallery in New York 3. Ground floor restaurant and top floor café 4. Rooftops on Multiple levels for outdoor exhibition 5. Glazing system, pre-cast concrete, and stud wall as façade
Sustainability	Goal: LEED Gold Certification

Figure 1 Courtesy of the owner

Figure 2 Courtesy of the owner

Figure 3 Courtesy of the owner

Mechanical overview

Cooling System	2 branches of air conditioning system: <u>3 air conditioning systems as cooling systems</u> • Located on the cellar Level (-1) • Handle 1/3 of the load • Manage the air in floors C through 7. <u>Another AC system</u> • Located in Level 8 • Manages the air condition in 8th floor. The main refrigeration plant • 3 electrically driven centrifugal refrigeration machines 5 cooling towers • On the roof • Hold 200 ton cross-flow or counter-flow typed cells Fluid-applied roofing and green roofs
Heating System	A hot water heating boiler plant • Located on cellar level • 5 condensing water fire-tubed boilers • Built-in water treatment • A combustion chamber with gas filters Finned tube convector along the exterior walls Unit heaters and fan coil type heaters • Provide heat on all mechanical rooms, exits and entrances. Fan coil units along the glass façade walls • Heat and cool the lobby areas
Ventilation	Several main zones with different ventilation distribution: • Galleries served with VAV system • Lobbies served with VAV system • Restaurant served with constant air volume (CAV) system • Auditorium served with CAV system. Both branches of AC system • Fogged-typed humidifier systems. • Flirtation with 95% efficient filters
Control System	Direct Digital Control (DDC) Modes of setting: • Unoccupied Mode • "Summer" Occupied Mode • "Winter" Occupied Mode • "Auto" Mode

Evaluation of Existing System

The building design of American Art Museum is very energy-efficient with different advanced technologies. Also, AAM will be LEED Gold certified. Most of the LEED points will be obtained from Energy and Atmosphere (35 possible points) and Sustainable Sites (26 possible points).

After analyzing heating system, cooling system, and ventilation system of AAM, the cooling system is the most potential and flexible for a new design. The design heating system is less flexible, because a generator for cogeneration purpose will also be connected with a fuel tank for emergency use. Next, the ventilation system of AAM will be with a set of complex control logics for the high sensitivity of environmental needs. To lower the coil loads, the mechanical system will consist of different sub-heating and cooling systems, for example, the fan coil units will cool and heat the exterior walls. Comparing to these two systems, the cooling system of AAM is less complex. The cooling system contain (find other wordings) five cooling towers and a free cooling heat exchanger. Therefore, the primary cooling system is mainly considered in this proposal.

The alternatives of the cooling system in AAM describes in the next sections.

Alternatives Considered

The Alternatives of Mechanical System

In this section, the three alternatives of cooling system are about cooling towers, a thermal storage, and a steam cooling system. The description of these three alternatives is the following table with the limitation of each design.

Table 1 descriptions of three mechanical alternatives

Ideas	Description	Benefit to the System	Limitation
Cooling Tower			
Optimizing a cooling tower	Lowering the power consumption	Adjusting the operations of fan and pumps	Difficult to obtain the data of a DOE 2 polynomial model.
Replace cooling tower	Embracing the view of New York Public Park	Finding other sources for heat rejection	Ground heat rejection is unavailable, because AAM is located on a landfill site. A river in New York is also unavailable, because of environmental impact and Clean Water Act (US Environmental Protection Agency, 2012).
Thermal Storage			
Adding a thermal storage	Lowering power consumption during peak hours	Adding a containerized ice storage/packaged glycol chiller	Requiring a precise prediction of electricity consumption
Steam Cooling System			
A steam chiller supplied steam from a local district heating system	Lowering the electricity consumption by using steam.	Adding a steam compressor Replace the original electric chiller(s) with steam turbine driven/absorption chiller(s)	Space restriction, because an absorption chiller generally is 50% bigger than an electric chiller.

After listing the benefits and the limitations of the new design, it concludes that the ideas about cooling towers and adding a thermal storage are difficult to be conducted. Therefore, arranging a steam cooling system should be a rightful choice.

Other Alternatives

In the BAE/MAE Capstone Mechanical project, it requires to have the design(s) related to mechanical and two other disciplines. Table.2 shows the considered alternatives.

Table 2 descriptions of the alternatives with two other disciplines

Ideas	Discipline	Description	Limitation
A New Design of Façade			
Integrating the design with New York Public Park	Landscape	Building a new pond on the terrace shared with the New York Public Park	The discipline is not valid to a Mechanical project.
Replacing the motorized Shading devices with a new shading design	Lighting + Architecture	New shading devices associated with the solar angle calculation, such as shading fins and overhang.	It requires using day lighting software.
Rearrangement of Mechanical Equipment			
Moving some mechanical equipment from lower levels to 9th floor mechanical room	Structure + Acoustics	Moving the equipment closed to the loads to minimum losses. Find a cost effective arrangement based on the impact of acoustics and structure	It requires to find the pricing and performance data of acoustical components, which is not included in RS Mean.

Since a steam cooling system is more complex than an electric cooling system and the project is time restricted, an easy alternative is recommended in order to balance out the work load. The rearrangement of mechanical equipment is a preferred alternative.

Proposal Topics

This proposal consists of one mechanical depth analysis and one structural and acoustical breadth analysis. The depth analysis is to create a hybrid system, which produces cooling to the building with the original electric chillers and new steam chiller(s). The breadth analysis is to arrange the ventilation equipment from cellar level and cellar mezzanine level to the mechanical room on the 9th floor to lower the friction loss through ductworks and the power consumption of fans. Also, the arrangement will be analyzed with the structural and acoustical impacts.

Mechanical Depth – Absorption Chiller

Most of the HVAC engineers don't consider the application of steam cooling, which are a steam compressor, a steam turbine driven chiller, and an absorption chiller (Spanswick, 2003). It is because the COP of any steam chillers is lower than a typical electric chiller, and an absorption chiller is generally bigger than an electric chiller. However, because of the utility rate of electricity getting higher, there is a potential saving of energy consumption and utility bill on the application of steam cooling system or hybrid system.

Utility Saving and Absorption Chiller

In this Mechanical project, the only steam cooling system will be studied is absorption chillers. The ASHRAE Journal, Advances in Steam Cooling, mentions that selecting between an absorption chiller and a steam turbine-driven chiller, the absorption chillers generally are more cost effective at capacities less than 1,000 ton (Spanswick, 2003). Since each chiller in AAM is at 300 ton capacity, it suggests that an absorption chiller is more suitable to the cooling system.

Incentive Program

Another reason of having a double stage absorption chiller is that ConEdison, the utility company provides district steam heating system in New York, offers some incentive programs for installing and maintaining a steam turbine driven chiller or/and a double stage absorption chiller. The following tables are the customer benefits of steam cooling provided by ConEdison (Con Edison of New York, 2012).

Table 3 Incentive program of installing a steam cooling system

Incentives

Steam AC Equipment Type	Capacity Range	Incentive Level ($ per ton)	Incentive Limit
Steam Turbine Chiller	Less than or equal to 1700 tons	$525	Up to 65% of the delivered equipment cost*
	Greater than 1700 tons	$470	
Double Stage Steam Absorption Chiller	All	$430	
Single Stage Steam Absorption Chiller	not eligible for incentives		
Notes:*Delivered equipment cost represents the total invoiced cost associated with purchase of the chiller equipment. This cost includes all delivery, labor, equipment, and taxes associated with purchasing the chiller equipment and delivering it to the property. Any additional customer costs including but not limited to site preparation, rigging, demolition, and equipment removal are not to be included in the total invoiced cost.			

Table 4 an annual maintenance incentive of a steam cooling system

Maintenance Incentive Type	Incentive Level ($ per ton)	Incentive Annual Limit*	Term Limit
Maintenance Service Contract	$5	up to $3000	Up to ten years on an annual schedule
Remote Monitoring Bonus	$2	Up to $1000	
**Or up to the amount of the actual service contract, whichever is less* Notes: The maintenance incentive funding shall only be used to maintain the applicable chiller included under the Steam AC Chiller Incentive Program. The funding can be used for any and all maintenance activities associated with the particular chiller.			

Based on Table.2-3 and the journal, the better choice based on the capital saving and potential payback is to have double effect absorption chiller. However, in order to ensure the relationship between the capital cost and the energy consumption of both absorption chillers, a detail comparison of both chillers should be conducted in the early stage of the project.

Hybrid System vs. Capital Cost

During summer, the steam price is relatively low, but the cost of an absorption chiller is high. An ASHRAE Journal in 2002, Economic Analysis of Hybrid Chiller Plants, recommends that since absorption chiller is not as efficient and low cost as an electric chiller, it is better to have a cooling system with a combination of both types of chillers. So, it can achieve the goal of energy cost with the budget of the owners. In conclusion, different chiller combinations of energy model should be generated to find the most cost effective solution.

Impact of Mechanical Space

The drawbacks of an absorption chiller are (HVAC Absorption Chillers vs Electric Chillers, 2012):

- An absorption chiller takes 50% more floor area than a typical electric chiller.
- It weights at least twice as much the equivalent electric chiller.
- It requires more piping for steam supply and return.

It is difficult to conclude if the area of mechanical room is enough. Placing absorption chillers may require an enlarged mechanical room, which should be analyzed after selecting chillers.

Conclusion

After analyzing the advantage and impact of absorption chiller application, it concludes that a steam cooling system can flatten the peak electric load during peak hour in order to reduce the total utility bills. And, the hybrid system is also highly recommended, since the capital cost of an absorption chiller is relatively high. In conclusion, this project will analyze the cost effectiveness of this steam system based on the incentive program of ConEdison and the utility saving from steam.

Structural and Acoustic Breadths – Rearrangement of Mechanical Equipment

The rearrangement of mechanical equipment is another analysis in the project associated with the building structure and acoustical performance. This analysis is to seek for a potential saving by moving mechanical equipment closed to the location of load severed. There are two types of potential saving considered:

1. Minimizing the energy loss in piping and ductwork, such as friction loss.
2. Lowering the capital cost, because of less piping and ductwork.

However, the rearrangement might impact the structure and acoustical performance. Therefore, the goal is to find a piping and/or ductwork layout that is well balanced with the cost and performance impacts of structure and acoustical.

Potential Location of Mechanical Equipment – Mechanical Room on 9th Floor

The ideal location of shifting the ventilation equipment from cellar levels is the mechanical room in 9th equipment. Since the mechanical equipment on 9th floor will mainly serve for the 8th floor and 9th floor, enlarging the mechanical room and locating more equipment is a possible and easy solution.

Change of Mechanical Equipment – Air Handling Unit

On cellar level, there will be 3 air handling units (AHUs) serving the galleries from 1st to 7th floor. Each air handling unit will size 31.5' x 15' x 11' and weight about 1500 lbs.

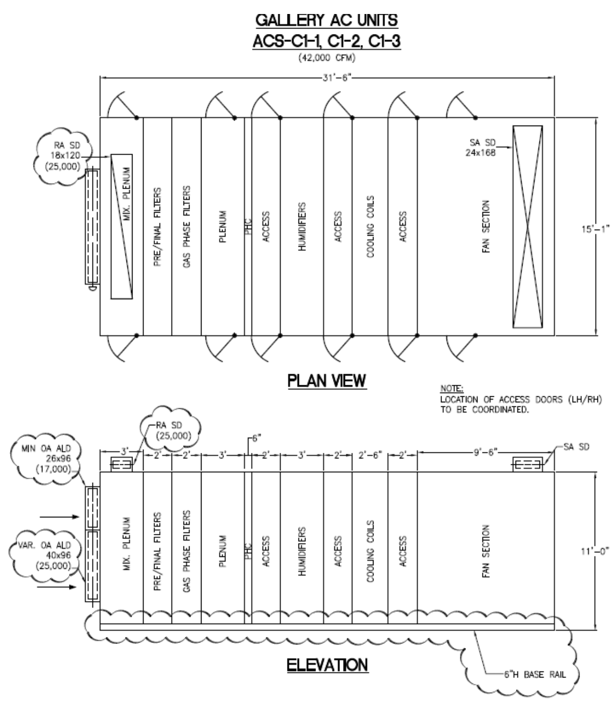


Figure 4 Dimension of a typical air conditioning system in AAM

One of these AHUs, which will serve the load on 6th and/or 7th floors, should be moved to the 9th floor mechanical room for minimizing the energy loss and the amount of ductwork.

Change of Mechanical Shaft

This change also will be associated to the size of mechanical shaft. The following image shows the location of two main mechanical shafts.

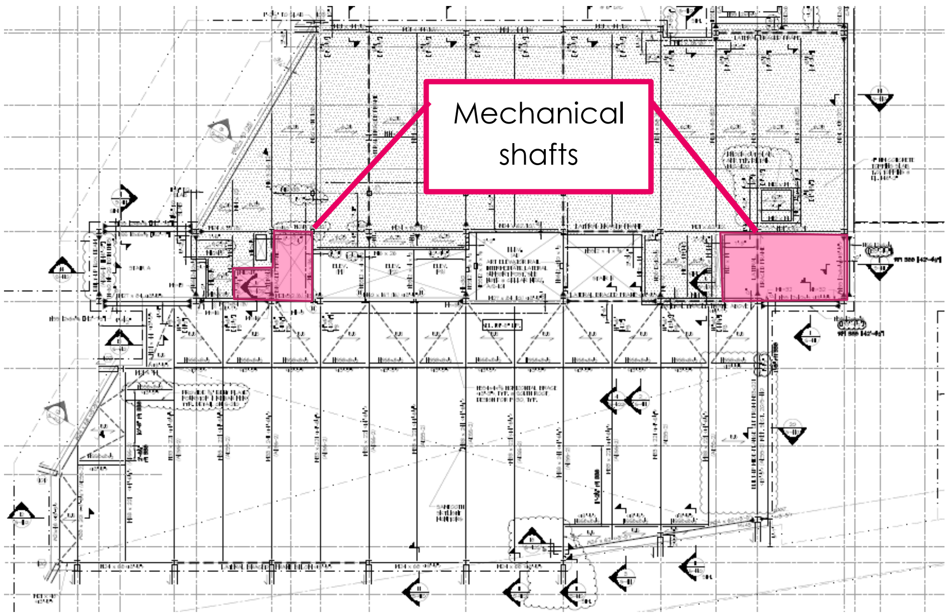


Figure 5 The location of mechanical shaft on 9th floor (S-109)

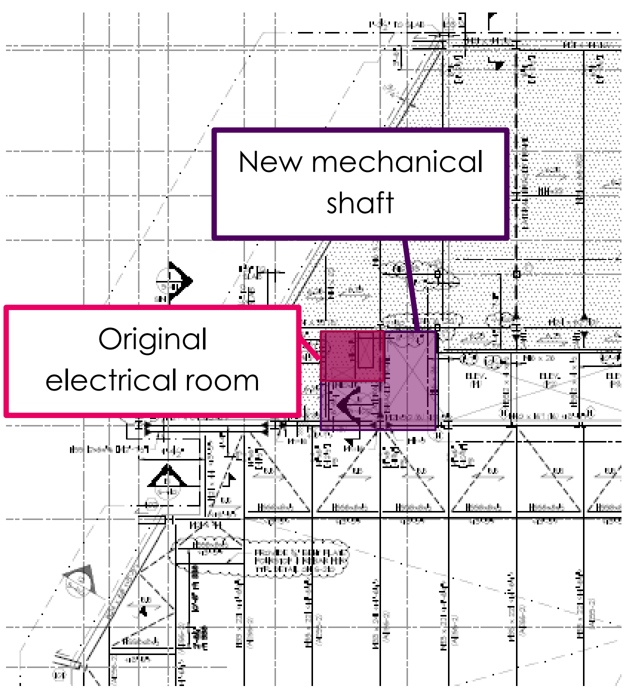


Figure 6 The proposed mechanical shaft

An air handling unit will be added on this floor on the West side, because the 56,000 cfm outdoor intake louver will be located in the West side of 9th floor. The size of the louver and the size of the mechanical shaft (Left side of Figure.4) may be increased. The potential solution is to shift the electric room next to the mechanical shaft and changing the shape of mechanical shaft like Figure.5.

Conclusion: Acoustical and Structural Impact of AAM

This proposed rearrangement will affect the building design structurally and acoustically. It is because of the following factor and changes:

- A new air handling unit and its corresponding ductwork will be added to the mechanical room.
- The size of mechanical shaft may be changed.
- There will be a large open-spaced office below the 9th floor mechanical room The area of 8th and 9th floor may be increase.

The arrangements might require extra acoustical treatment, because an office space is a noise sensitive zone. The extra treatment will be referenced from the specification, but the minimal requirement of acoustic treatment should also be considered in order to achieve the cost balancing goal. According to the structural change, since there will be a change of mechanical shaft and dead load on 9th floor, some of the structure of AAM, such as column(s), metal decks and slabs, will be checked and resized if needed.

These rearrangements of acoustical design and structural components will increase the capital cost. Therefore, several version of the new mechanical room layout should be conducted. Then, the acoustical treatment should be well designed based on the cost perspective. Also, the basic calculation of sizing structural part will also be conducted to ensure if any part of structural system needs to change, such as increasing the depth of beams and thickness of slabs.

Tools and Methods

The software used in this project is Trace700, STAAD and Dynasonics AIM. But, some other energy stimulation software is considered in the project, because Trace 700 doesn't provide life cycle cost analysis.

Table 5 Software used in the project

Software	Functions	Drawback
Trace700	Since the original energy model is done in Trace700, it is suggested to use Trace 700 to conduct this further analysis. Trace700 has the functions of analyzing the cost with different utility bills and the power consumption of absorption chills.	Trace700 will be used to conduct a quick analysis of different combination of a hybrid system. However, it doesn't support a detail economic analysis, such as life cycle cost.
STAAD	It calculates the tension force of trusses. This function helps to re-size the components of truss around a mechanical shaft.	-----
Dynasonics AIM	It is acoustic software. It helps to calculate the NC and A-weighted values of a room with different types of acoustical treatment.	-----

Table 6 Software considered using in the project

Considered Software	Function	Drawback
Energy Plus	It consists of detail energy management analysis and lifecycle cost program. It can be used in the later stage of project.	It is required to use other software to build the room layout, since the layouts and shapes of rooms in AAM will not be uniform.
HAP (Hour Analysis Program)	It consists of simple lifecycle cost analysis. Also, unlike Energy Plus, it doesn't require any other software.	

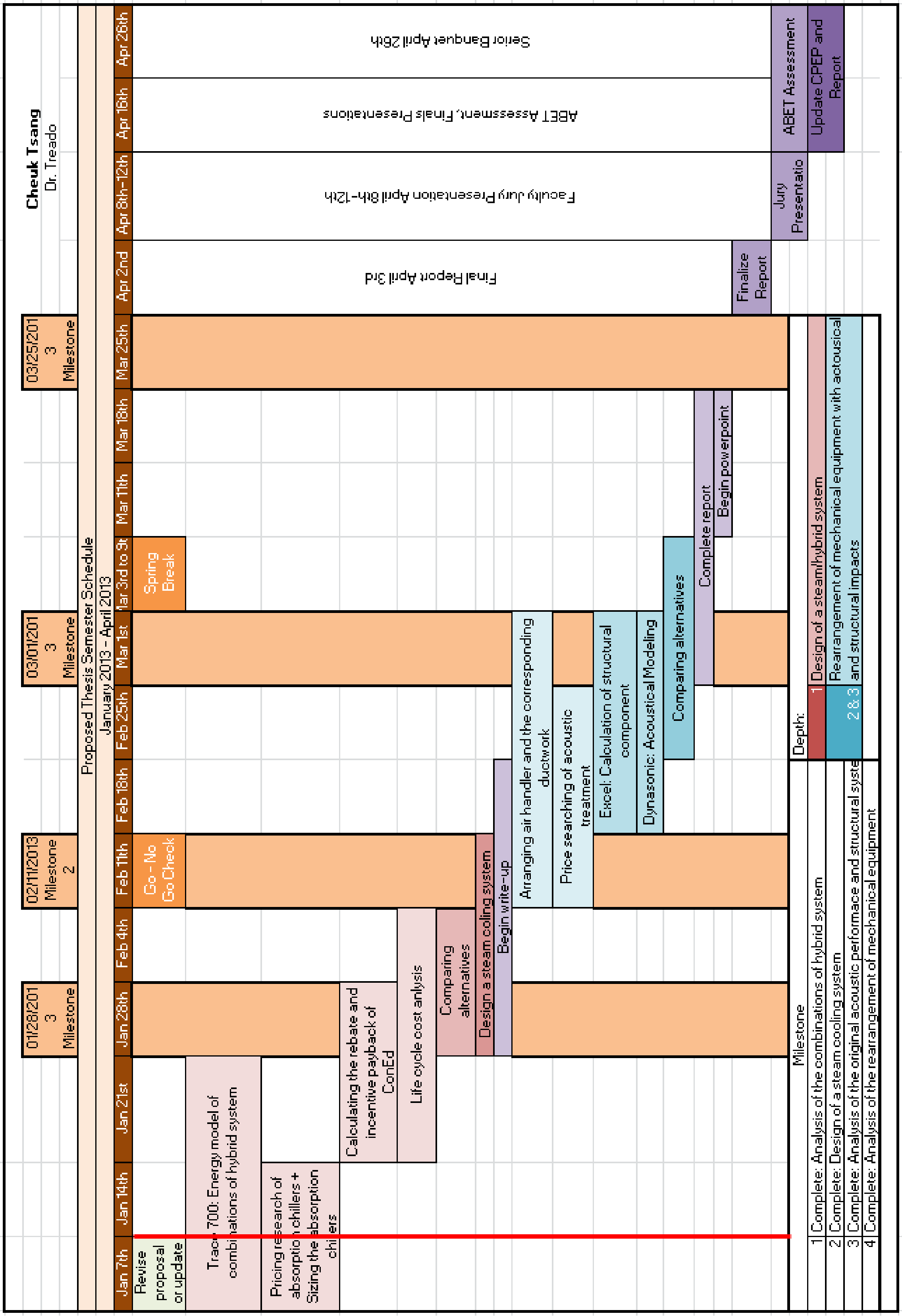
MAE Course Relation

The MAE courses related to this project are:

- AE 557 Centralized Cooling System: The ideas of absorption refrigeration in this course help to understand the impact to other mechanical components and the installation requirement of absorption chillers. Also, the lecture of AHRI Standard 550/590 and ASHRAE Standard 90.1 explains the potential energy saving of operating with multiple chillers instead of one.

- AE 555 Building Control System: This course provides different search methods that can be applied on HVAC operation, such as increasing the efficiency of HVAC system by changing the combination of mass flow rates, temperature setpoints, and part load ratios. This concept helps to find the cost effective combination of electric and absorption chillers, and also the well balanced layout of the mechanical room on 9th floor.

Schedule of Work Plan



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