# Thesis Proposal

## EMD Serono Research Center - existing | Billerica, MA



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Prepared For:

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# 1 Executive Summary

The purpose of this proposal is to clearly explain the scope of the redesign project on the EMD Serono Research Center – existing lab building and provide justification based on the existing condition of the facility. The existing mechanical system of this building is evaluated. Alternative systems are selected based on the objectives of this building design: provide environmental comfort, healthy indoor air quality and be energy responsive.

The EMD Serono Research Center – existing lab building consists of 17% vivarium space, 35% office space, and 48% laboratory space with a gross area of 56,700 square foot. Both the laboratory and vivarium areas are critical spaces that generate hazardous contaminants. As a result, 100% outdoor air system was selected as the mechanical system for those spaces to ensure contaminated air does not recirculate and transfer inside the building. The existing system has a chiller plant and a boiler plant. Chilled water is generated by a water cooled chiller and an air cooled chiller to provide summer cooling. Steam is generated by two gas fired boilers and it is used for summer reheat, winter heating and humidification.

In an effort to optimize the mechanical system, three analyses will be performed involving the possibility of reduce building load by putting solar shading, the implementation of Heat Recovery System, and the application of Dedicated Outdoor Air System(DOAS) with Chilled Beam. For all of the analyses the effect of the systems on building space coordination as well as first cost and lifecycle cost will be investigated. Comparison of the alternatives will be done based on the system's impact on energy consumption, thermal comfort, indoor air quality, space requirement, and cost.

Since all the supply air for the laboratory and vivarium spaces is 100% outdoor air, large amount of energy is consumed to condition the outdoor air. The mechanical redesign proposal will replace the 100% OA AHU units with units containing a heat recovery system. Different heat recovery systems will be investigated: enthalpy wheel, plate heat exchanger, heat pipe, and runaround loop. Comparisons based on the total effectiveness, energy saving, potential cross contamination issue, and maintenance can be made to decide which system is best suited for this building. The other alternative is to utilize the DOAS system to supply only ventilation air to the space and use chilled beams as the parallel system to meet to rest of the sensible load inside the space. Both passive and active chilled beam systems will be investigated.

In addition to investigate the heat recover systems and the DOAS system with chilled beam, two breadth areas will also be developed. The first breadth will look into the solar shading device and the building envelope to determine the optimal building construction to reduce building load. The other breadth area will be the electrical analysis. Electrical analysis will be done to determine the power distribution requirements for the facility as compared to the existing design with respect to energy consumption and additional cost.

To analysis these topics, several tools are needed. Trane TRACE, a building energy modeling software will be used along with Engineering Equation Solver (EES) and Microsoft Excel to calculate the necessary information needed for system redesign. Autodesk Revit and Adobe Photoshop will also be used to render the solar shading and building envelope material in the architectural breadth.

Lifecycle cost analysis will be performed for all proposed redesigns. The life cycle cost analysis will be used to determine the economic feasibility of the redesigns.

# 2 Building Summary

EMD Serono Research Center – existing lab building was constructed as the research and development building. This building has 2 stories, a basement, and a penthouse, with gross area of 56,700 square foot. The building program contains management office, research and development laboratories, and vivarium rooms. Mechanical rooms are located on the basement floor and in the penthouse. Vivarium facilities, research lab rooms, support rooms are located on both the 1$^{st}$ and 2$^{nd}$ floor.

# 3 Existing Mechanical System

There are a total for 3 air handling units in this building. AHU-1 provides 45,000 cfm to all the research and development labs and AHU-2 provides 19,000 cfm to all the administrative offices. Both units are located in the penthouse. AHU-3 is located in the basement and provides 5,000 cfm to the vivarium rooms and the mechanical room in the basement. Since both AHU-1 and AHU-3 serves laboratories and animal spaces, both AHU-1 and AHU-3 provides 100% outside air to the space.

The mechanical system of the EMD Serono Research Center – existing lab building has a chilled water cooling plant and a gas fired central heating plant. The cooling plant consists of a 350 ton water cooled centrifugal chiller, a cooling tower, and a 60 ton air cooled chiller. The heating plant consists of two low pressure steam boilers (175 hp and 50hp) and two heat exchangers. Air is distributed throughout the building by variable and constant volume terminal boxes in each space. There are three air handling units in this building. Inside each air handling units, there is low pressure steam pre-heat coils to precondition the outside air in the winter time, cooling coil are located downstream of the preheat coil to cool the air in the summer time. Conditioned air is then distributed into the spaces. In the winter season, pre-conditioned air from AHUs is conditioned again by the hot water heating coils in the terminal boxes prior to entering the space. Hot water inside the heating coils is coming from the heat exchangers.

# 4 Mechanical Design Objectives

EMD Serono intended for this research and development facility to contain the highest quality materials and systems practical for its designed uses. Getting the best value for dollars spent was essential, but cost must not take precedence over quality. The guiding principal governing selection of systems and design was to maximize comfort in a practical way for the scientists and staff to do their work. The main mechanical design objectives for the EMD Serono Research Center - existing lab building were environmental comfort, energy responsiveness, flexibility for future changes, durability, ease of maintenance, reliability, and modular approach.

Since laboratories and vivarium rooms are critical spaces that generate potential hazardous contaminants, air handling units need to provide 100% outside air into the spaces to ensure contaminated air does not recirculate and transfer inside the building.

High efficiency filters and have 100% exhaust air rate are also required for those spaces.

# 5 Mechanical System Evaluation

The mechanical system for the EMD Serono Research Center – existing lab building was designed adequately for its purpose of reducing the spread of contaminates, maximizing comfort.

## 5.1 Air Distribution System Evaluation

The air distribution system designed in the way that contaminated air from the labs and the vivarium rooms does not circulate inside those spaces and transfer to other spaces in the building. Critical spaces such as laboratories and vivarium rooms were designed to maintain negative pressure relative to surrounding area. Conditioned air is distributed to space through variable volume or constant volume boxes. Terminal boxes in vivarium areas are constant volume boxes; boxes in laboratories and office areas are variable volume boxes. Since majority of the terminal boxes are variable volume boxes, it is difficult to maintain relative negative pressurization in critical spaces.

## 5.2 Heating System Evaluation

The steam and hot water system in this building is an effective system. The gas fired boilers generates low pressure steam to provide preheat and humidification inside each air handling units. Low pressure steam is also delivered to heat exchangers to generate hot water for summer reheat and winter heating. The 50 hp boiler operates during the summer while the 175 hp boiler operates during the winter.

By utilizing hot water heating as the primary heating method; large pump energy is consumed to deliver hot water throughout the building. Another potential concern of this system is the energy consumption for hot water reheat during the summer. Since the 50 hp boiler is dedicated for summer reheat, generating steam to transfer heat through heat exchanger to supply hot water for reheat might reduce the overall efficiency of the system.

## 5.3 Cooling System Evaluation

The chilled water system consists of a water cooled centrifugal chiller, an air cooled chiller, and a cooling tower. The cooling system is designed as a parallel chiller-primary constant flow system. Both the water cooled chiller and the air cooled chiller are designed to operate at the same time. In general, air cooled chiller has a higher kw/ton value than water cooled chiller. Using an air cooled chiller in parallel with the water cooled chiller might decrease the overall efficiency of the system.

Pumping system in chilled water application is a significant energy consumer. Pumping system structure is a key design decision. Utilizing primary/secondary system or primary variable system may help reduce energy consumption.

A potential concern is the absence of the heat recovery or desiccant wheel for the 100% outside air AHUs. One of the issues found in the previous report is that there is a large latent load from the outside air. Since 2 out of the 3 systems utilize 100% outside air, large amount of energy is used to condition the outside air. This topic will be discussed in the Proposed System Alternatives section in this report.

# 6 Proposed System Alternatives

The mechanical system for the EMD Serono Research Center – existing lab building was well designed to meet the objectives of the building design. But as with any design, there can be alternative designs for improvement. The following is a list of alternatives that can be redesigned or investigated for potential system improvement in areas such as indoor air quality, energy consumption, carbon footprint, and construction cost.

- Investigate the pressure relationship between spaces to determine method to ensure contaminated air does not recirculate or transfer inside the building.
- Investigate heat recovery methods for the 100% outside air system by utilizing exhaust air stream.
- Investigate the dedicated outdoor air system with secondary cooling system
- Provide steam heating coil inside air handling units to eliminate heat exchangers and hot water distribution throughout the building to save hot water distribution pumping energy.

- Convert the 50hp steam boiler to high efficiency hot water boiler to provide summer reheat.
- Change the parallel water cooled chiller and air cooled chiller system to series water cooled chiller. Have the larger size chiller provide base load cooling and the smaller size chiller provide peak load cooling.
- Investigate changing the parallel chiller- primary constant flow system to primary/secondary or variable primary flow system.

The objective for alternative solution is to increase efficiency, provide thermal comfort, healthy indoor air quality as well as to reduce the operating cost and carbon footprint. Based on the objectives of this building design, two topics have been chosen out of the list above to be studied further: heat recovery system and dedicated outdoor air system with secondary cooling system.

## 6.1 Heat Recovery Systems

The EMD Serono Research Center – existing lab building provides its occupants with excellent indoor air quality by utilizing 100% outdoor air system in critical spaces. AHU-1 and AHU-3 provides a total of 50,000 cfm 100% outside air to both the lab and vivarium areas which made up 89 % of the total supply air. This building also contains a total of 9 exhaust fans, exhausting a total of 61,150 cfm air out of the building. In harsh summer and winter condition, large amount of energy is needed to condition the outside air. By employing a heat recovery system to retrieving energy from the exhaust air stream, large amount of energy can be saved.

| Ventilation System | | | |
|---|---|---|---|
| | System Type | CFM | % of CFM |
| AHU-1 | 100% OA | 45000 | 80% |
| AHU-2 | With RA | 6300 | 11% |
| AHU-3 | 100% OA | 5000 | 9% |
| AHU-1 + AHU-2 | 100% OA | 50000 | **89%** |
| Total | | 56300 | 100% |

**Table-1** Ventilation System

The proposed redesign is to utilize heat recovery system to recover heat from the exhaust air stream to precondition the outside air. This heat recovery process can be achieved by using different methods such as enthalpy wheel, plate heat exchangers, heat pipes, and runaround loops.

Enthalpy wheel rotates between the supply air and exhaust air streams and picks up heat energy from the exhaust air stream and releases it into the supply air stream. Both sensible and latent energy are being transferred. The total cooling load of this building consists of 65% sensible load and 35% latent load. Therefore, system that can reduce latent load during the heat recovery process is very attractive. However, contaminated exhaust air might leak into the supply air stream causing cross contamination problem. As a result, other heat recovery system will also be investigated.

| Sensible Load vs. Latent Load | | | | | |
|---|---|---|---|---|---|
| | Sensible Load (Mbh) | Latent Load (Mbh) | Total (Mbh) | % Sensible Load | % Latent Load |
| AHU-1 | 1895 | 1350 | 3245 | 58% | 42% |
| AHU-2 | 800 | 239 | 1039 | 77% | 23% |
| AHU-3 | 157 | 150 | 307 | 51% | 49% |
| Total | 2852 | 1739 | 4591 | 65% | 38% |

**Table-2** Sensible Load vs. Latent Load

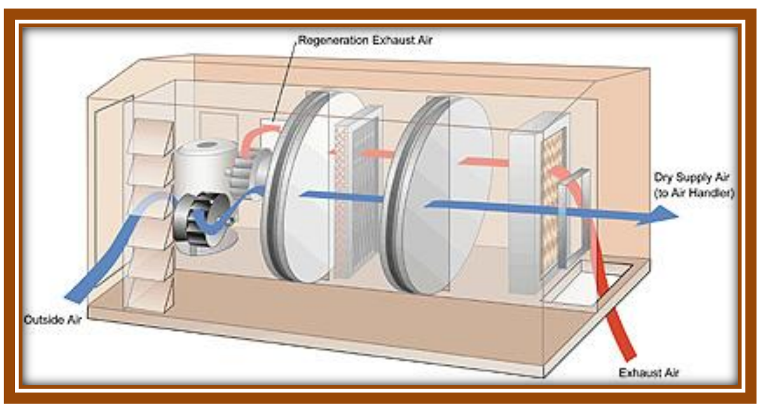



**Figure-1** Heat Recovery System – Enthalpy Wheel

Plate heat exchanger consists of alternating layers of plates that are separated and sealed. Plates are arranged for cross flow or counter flow of supply and exhaust airstreams. Since plates are solid and non-permeable, only sensible energy is transferred, therefore, no cross contamination issue.

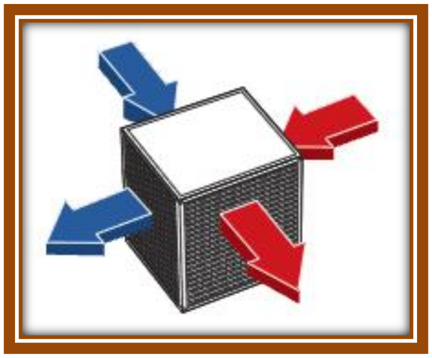


**Figure-2** Heat Recovery System – Fixed Plate Heat Exchanger

Heat pipe heat exchanger is constructed of individual heat pipes. A partition divides the exchanger into 2 sections to ensure the separation of supply and exhaust air flows. Supply and exhaust air are ducted in counter flow direction across each other to transfer heat.

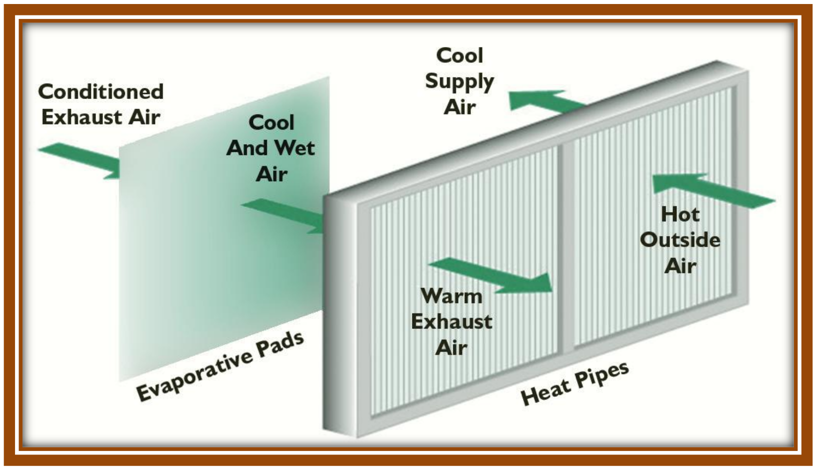



**Figure-3** Heat Recovery System – Heat Pipe

Runaround loop system consists of finned tube water coils in the supply and exhaust air streams. The coils are connected in a closed loop via counter flow piping through which an intermediate heat transfer fluid is pumped.

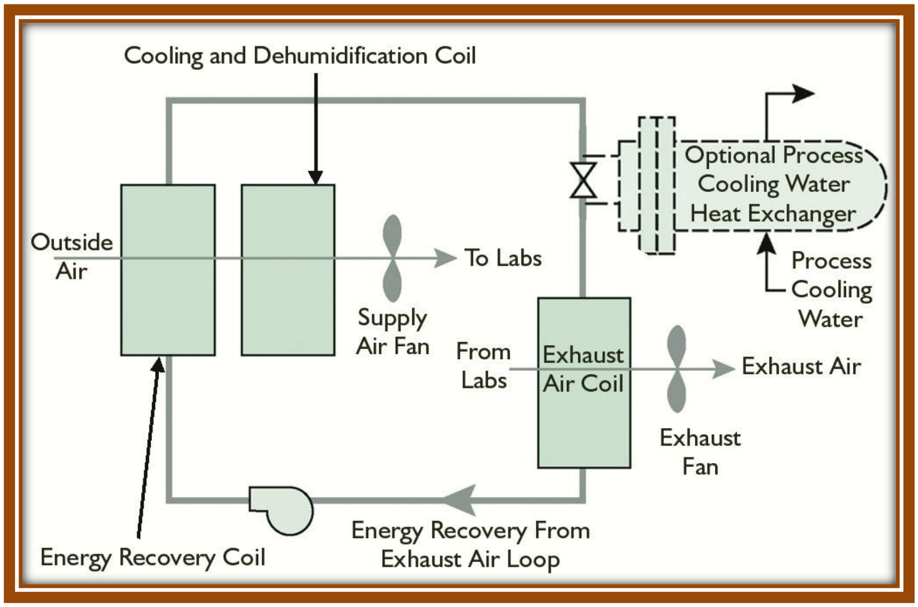



**Figure-4** Heat Recovery System – Runaround Loop

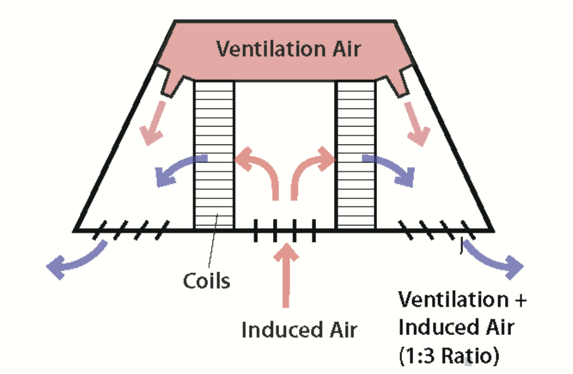
Analysis will be done for all 4 heat recovery systems. Comparisons based on total effectiveness, energy saving, cross contamination issue, and maintenance can be made to decide which method is best suited for this building.

## 6.2 Dedicated Outdoor Air System with Chilled Beam

The building utilizes 100% outside air system for the laboratory and vivarium area to ventilate and conditioned the space. Dedicated Outdoor Air System uses 100% outside air to ventilate the space. Since DOAS system only delivered ventilation air, the rest of the load is met with a parallel system such as fan coil units, chilled beams, radiant floor, etc. The latent load must be met at the air handler units while the sensible load can be picked up in the space.

By employing DOAS system in the EMD Serono Research Center – existing lab building, significant energy saving may be achieved. Air handing units and duct sizes can also be reduced due to the smaller volume of supply air to the space. On the other hand, DOAS system consumes more energy in a few areas such as pumping. Therefore, analysis will be done to calculate the total energy usage of the system when compared to the 100% outside air supply system.

Chilled beam will be investigated as the parallel system for the DOAS system. Both active chilled beam and passive chilled beam will be analyzed. In active chilled beam system, ventilation air from DOAS system is injected into the space through small air jets in the beam. Both induced air and ventilation air is conditioned by the cold water pipe inside the beam. Passive chilled beam only induce room air to cool it, ventilation air must be provided by other means. Both summer cooling and winter heating can be achieved by either two-pipe or four-pipe chilled beams. A potential concern for the chilled system is the condensing water issue; therefore, humidity must be controlled in the space.



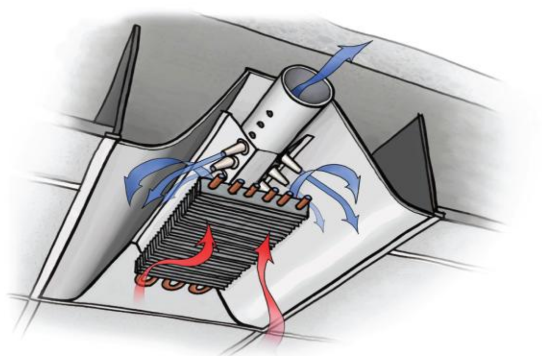
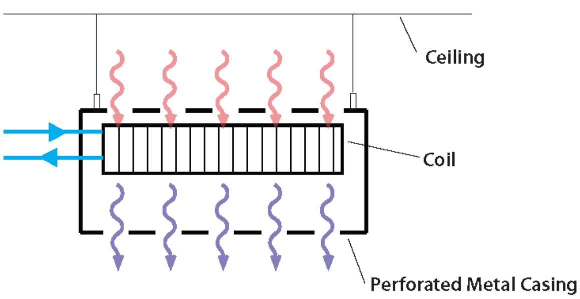



**Figure-5** Active chilled beam systems use air supplied from an air handling unit.



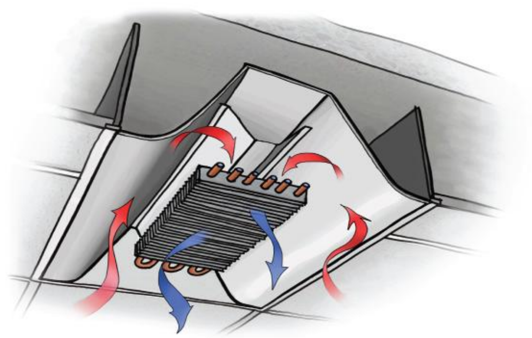



**Figure-6** Passive chilled beam systems use the natural convection in a room and have no direct air supply

# 7 Breadth Topics

## 7.1 Architectural

An analysis on the solar shading will be done. The existing building contains a total of 37% glass areas as analyzed in Technical Report 2. This high percentage of glass leads to a high solar load on the building. An analysis will be performed to see the load reduction possibilities for external solar shading. An energy model will be performed using Trane Trace to evaluate the solar shading effect on internal load.

External aluminum solar shading was constructed on the North West corner of the building. To evaluate the architectural impact of solar shading on all four sides of the building, an architectural model will be constructed using Autodesk Revit and Adobe Photoshop. Different types of solar shadings will be modeled in Revit to determine which type is the most aesthetically pleasing. This will be also accomplished by researching different solar shading products in the market today such as aluminum shading and electronically controlled shading.

| Fenestration Area | | | |
|---|---|---|---|
| Façade | Gross Wall (sf) | Glass (sf) | Fenestration % |
| East | 6565 | 2542 | 38.7 |
| South | 10927 | 4082 | 37.4 |
| West | 4695 | 910 | 19.4 |
| North | 4274 | 2288 | 53.5 |
| Total | 26461 | 9822 | 37.1 |

**Table-3** Fenestration Area

## 7.2 Electrical

The changing of the building mechanical system will have an impact on the design of the electrical system. Implementing the dedicated outdoor air system with chilled beam will possibly reduce the size of the chillers because less amount of air will be conditioned. However, by adding chilled beams into the system, more electricity will be needed to power the chilled beams. The other design alternative is to implement heat recovery systems to reduce the energy needed to condition the outside air. At the same time, energy is needed to power the heat recovery systems. Therefore, an electrical analysis will be done to determine the power distribution requirements for the facility as compared to the existing design with respect to energy consumption and additional cost.

# 8 Tools for Analysis

In order to provide a complete analysis on all of the potential system changes, numerous tools are needed to be utilized.

Trane TRACE is a load and energy modeling software that is able to model in depth various mechanical systems with different configurations. A detailed room by room load model will be done by Trane TRACE to accurately determine the building load. Another Analysis will also be done by TRACE to see how different solar shadings and different envelope material will affect the building load.

Energy models will be done through Trace TRACE for the different heat recovery systems, the dedicated outdoor air system as well as the passive and active chilled beam systems. Problems in this area could arise from insufficient modeling capability of cutting edge systems. In order to determine the validity of the findings, results will be compared to the building energy use data found on the Energy Information Agency’s (EIA’s) Commercial Building Energy Consumption Survey (SBECS).

In addition to Trance TRACE software, both the Engineering Equation Solver (EES) and Microsoft Excel programs will be used to do load and energy analysis. EES will be used to solve for large sets of simultaneous equations with exact state property values. Microsoft Excel will be used for this project in setting up large spreadsheets of data with numerous equations and values built within each cells.

CONTAM is a multizone airflow and contaminant transport analysis software. Indoor air quality is a significant concern in this building. Contaminant is generated in the laboratories and vivarium spaces. By using enthalpy wheel heat recovery technology, exhaust contaminated air might leak into the supply air stream. CONTAM will be used to analysis how leakage in heat recovery systems will affect the indoor air quality in this building.

Autodesk Revit and Adobe Photoshop will be used to provide rendering for solar shading device as well as the new building envelope materials.

Lifecycle cost analysis will be performed for all proposed redesigns. The life cycle cost analysis will be used to determine the economic feasibility of the redesigns.

# 9 MAE Course Related Study

As part of the MAE Requirement, graduate level classes must be incorporated into the proposed redesigns. Material taught in AE 555: Centralized Heating Production and Distribution System, AE 557: Central Cooling System as well as AE 552: Indoor Air Quality in Building will be used to analysis the heat recovery system and the dedicated outdoor air system with chilled beams.

# 10 Conclusion

In conclusion, two mechanical system redesigns were chosen to analyze further: employ heat recovery systems in the existing system and implement dedicated outdoor air system with chilled beams. In the heat recovery system analysis, four systems will be investigated: enthalpy wheel, plate heat exchanger, heat pipe, and runaround loop. In the DOAS with chilled beam system, both active and passive chill beam systems will be investigate.

In addition to mechanical system redesigns, two breadth area analyses will be developed. The first breadth topic is to determine how solar shading device and building envelope construction will affect or possibly reduce building load. The other breadth topic is to determine the impact of redesign systems on the building mechanical space coordination.

# Appendix A Preliminary Research

## Heat Recovery System

1. Otto VanGeet, Sue Reilly. "Ventilation Heat Recovery For Laboratories" ASHRAE Journal Vol. 48. March 2006.

   This article covers how energy recovery can reduce the mechanical heating and cooling requirements associated with conditioning ventilation air in laboratories. It focuses on air-to-air energy recovery using enthalpy wheels, heat pipes and runaround loops in new construction.

2. Air2Energy(2009) Intelligent FRESH AIR Systems, from http://www.air2energy.com.au/exchangers.html

   The Air2Energy Company prepared a comprehensive description for different heat recovery systems such as flat plate heat exchanger, enthalpy wheel, and heat pipe heat exchanger systems.

## Dedicated Outdoor Air System with Chilled Beam

3. Mumma, Stanley. "Overview of Integrating Dedicated Outdoor Air Systems with Parallel Terminal Systems." ASHRAE Transactions. 107. AT-01-7-1 (2001): 545-552. Print.

   This article discusses the benefits of using 100% outside air as opposed to a conventional VAV system. It explains the different applications of DOAS in buildings. Different types of terminal units to be used in DOAS applications are also discussed in this article.

4. Peter Rumsey, Neil Bulger, Joe Wenisch, Tyler Disney, Rumsey Engineers. "Chilled Beams in Laboratories: Key Strategies to Ensure Effective Design, Construction, and Operation." Laboratories for the 21$^{st}$ Century. June2009

   This article presents the practice strategies for designing, constructing, operating, and maintaining chilled beam systems in laboratories.

# Appendix B Work Schedule

# Appendix C

## List of Tables



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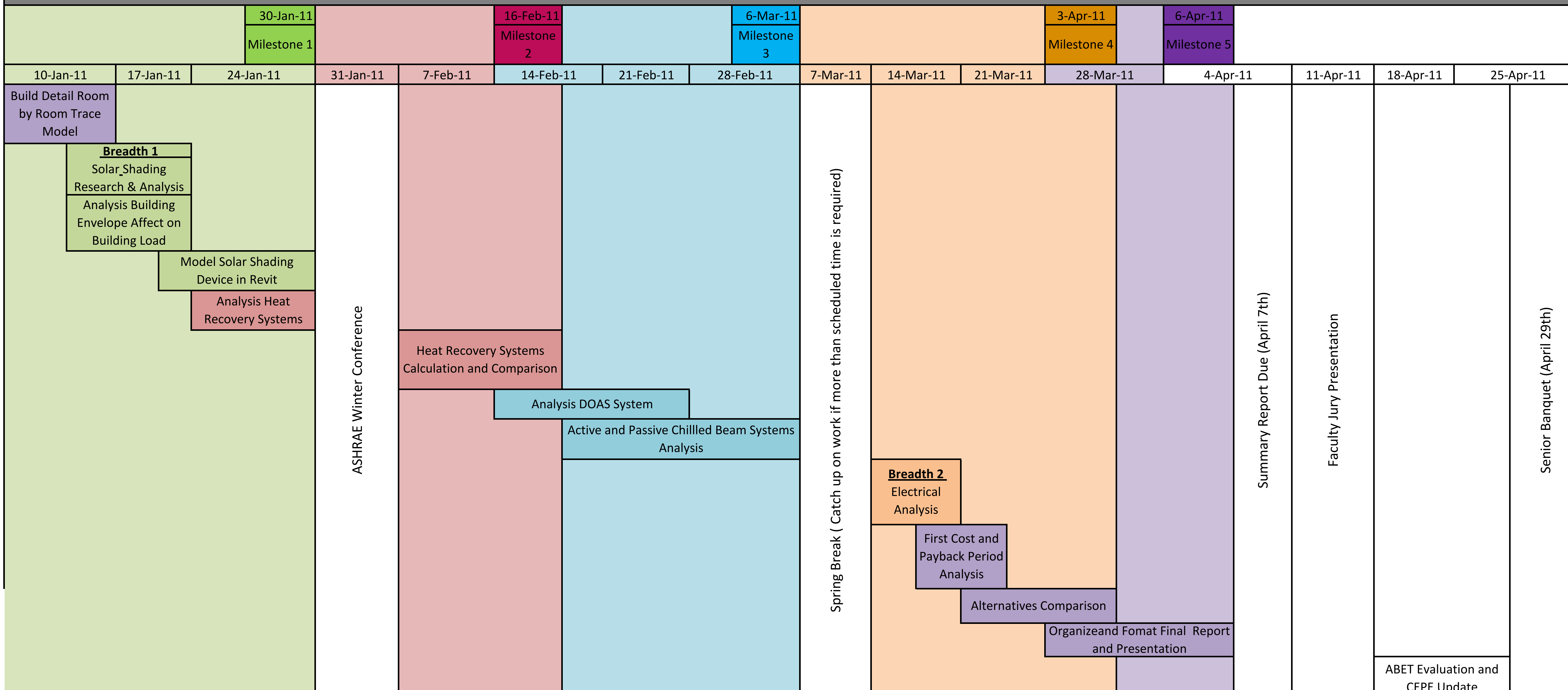
# Proposed Thesis Semester Schedule




| Milestones | |
|---|---|
| 1 | Analysis on building load with different solar shading and building envelope |
| 2 | Analysis on heat recovery systems |
| 3 | Analysis on Dedicated Outdoor Air System with chilled beam systems |
| 4 | Alternatives' coordination and cost analyses; System Comparison & Conclusion |
| 5 | Finalize the final report and presentation |

| Complete | | |
|---|---|---|
| General Information | General Information Needed for Design | |
| Alternative Topic 1 | Heat Recovery Systems | |
| Alternative Topic 2 | DOAS with Chilled Beam Systems | |
| Breadth Topic 1 | Solar Shading and Building Envelope | |
| Breadth Topic 2 | Electrical Analysis | |