THESIS PROPOSAL

LANDSCAPE BUILDING

AT

JANELIA FARM
HOWARD HUGHES MEDICAL INSTITUE

ASHBURN, VIRGINIA

PREPARED

BY

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MEHCANICAL OPTION

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EXECUTIVE SUMMARY

The Landscape Building at Janelia Farm Research Campus is a 546,436 square foot world-class biomedical research facility owned by Howard Hughes Medical Institute located in Ashburn, Virginia

The building is supplied air by 15 air handling units which feed into one plenum that serves the entire building. There are 2-50,512 MBH and 2-20,125 MBH (one future) boilers The majority of the load is used for the air handling unit's steam coils. The remaining steam is used at various shell and tube heat exchangers. The chiller plant has seven chillers and seven cooling towers (one back-up) each rated at 1200 tons. The portion of the load that does not go to the air handling units serves various equipment within the building.

The primary goal is to modify the existing HVAC system to reduce energy consumption and yearly utility costs. This will consequently reduce emissions as well. Secondary goals include optimizing the artificial lighting in the laboratory spaces and office pods located on the second and third floors as well as resizing affected electrical system components throughout the building.

MECHANICAL REDESIGN

In order to achieve the desired energy reduction, a heat recovery system which prevents losing a large amount of energy in the conditioned air will be incorporated into the current mechanical system. The integration of a plate-type heat exchanger will be analyzed for effectiveness and amount of energy saved. The heat exchangers must be able to transfer both sensible and latent energy, but the air streams remain completely isolated from each other. This is the critical feature due to the high risk of contamination.

BREADTH ANALYSIS

While it is important to design a system that is capable of maximizing its energy usage, it is also important to minimize the amount of energy required. To aide in this, an analysis of the lighting in the laboratory spaces and office pods will be performed. Lighting can be one of the largest loads in a commercial building. Therefore, a well designed lighting system can provide adequate lighting and also conserve energy for the owner.

The integration of the plate heat exchangers may have a noticeable impact on electricity demand. Optimizing the lighting of the laboratory and office pods will have a significant impact on the electrical load as those spaces occupy the majority of the second and third floors of the building. Therefore the electrical system to these spaces will need to be updated with new loads.

BACKGROUND

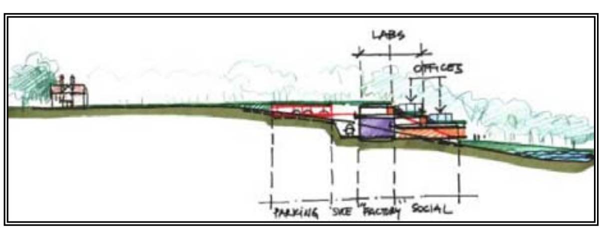
BUILDING CONCEPT & DESIGN

Janelia Farm Campus is designed to be a world-class biomedical research facility to achieve the long-term goal of promoting unconstrained scientific research. It is located on the outskirts of the Washington Metropolitan Area in Ashburn, VA. Howard Hughes Medical Research Medical Institute was chartered in Delaware on December 17, 1953. The charter states: "The primary purpose and objective of the HHMI shall be the promotion human knowledge within the field of the basic sciences (principally the field within the field of medical research and medical education) and the effective application thereof the benefit of mankind." The institute provides grants for international research scholars world-wide. $49.7 million in grants to strengthen education programs were awarded to colleges and medical schools, as well as to public schools, grades K-12. After 52 years of conducting research on over 70 university campuses across the United States, HHMI decided to build its own facility. The design is guided by four principles:

- Understand the researchers' needs versus their preferences
- Focus the planning effort on what will or could happen versus what is happening today
- Keep work spaces standardized and rational
- Make the work spaces adaptable over time to accommodate changes in research

In order to realize these goals, HHMI conceptualized a facility where scientists, engineers, and information technology professionals from all over the world could gather and reside. There are three buildings on campus, the Landscape Building, the short-term stay Conference Center, and Long-term housing townhouses, all of which are located surrounding a pond. The focus of this thesis project will be the Landscape Building.

As a result of the historic requirements for the site, the architect RVA designed the building to be an extension of the hill on which the Mansion is built. The requirement calls for the view of Sugar Loaf Mountain to be maintained. As a result, the building is completely underground and can only be seen from the northperspective. It is a three-story structure with two upper lab floors and a meeting-service floor at the bottom level. The lab floors are stepped back creating terrace space on which the office pods are located. Two glass-encased stairs radially cross the building connecting the ground floor to the roof terrace. There is also a 300 car-parking garage located behind the labs on the third floor underground.



The entire length of the 900ft façade runs a glass corridor giving daylighting and picturesque views to the labs spaces opposite the corridor. The building is based on the idea of the strong relationship between lab and office space. RVA placed the office pods on the terraced roofs, each one having three exterior glass walls to provide more natural ligh. Behind these pods are large lab spaces designed to be common space for the different research groups to share. The biochemistry lab spaces are designed to be extremely flexible, with lab equipment and chemical and gas connections easily moved around without costly renovations. Adjacent to the labs are smaller support rooms such as cold rooms, dark rooms, isotope labs, chemical storage space, along with general rooms of various sizes. Behind this support belt is the equipment service corridor that runs the length of the building. Along this corridor is a 6ft band housing all MEP equipment. It was designed so that when maintenance is necessary; all work can be done outside the lab space. This is beneficial for both the maintenance crew and scientists. The draw back is the cost to set such a great amount of space aside for MEP services. There are also large areas that will be used as future expansion space on the first floor.

Figure 1: Example Laboratory/Office Pod Floor Plan

MECHANICAL SYSTEM

SYSTEM LOCATION

The need to separate the mechanical and electrical systems and equipment from the laboratory, office, and other primary occupied spaces was the principal design consideration. HHMI researched and studied many other scientific campuses around the world, such as the Medical Research Council Laboratory of Molecular Biology (MRC LMB) in Cambridge, England, Cold Spring Harbor Laboratory, the European Molecular Biology Laboratory, the Carnegie Institution of Washington's Department of Embryology, and AT&T's Bell Laboratories in Murray Hill, New Jersey. After concluding existing building studies, HHMI determined that in order for the scientists and researchers to perform at the highest levels, it would be necessary to locate all mechanical and electrical equipment and controls to isolated areas. This allows maintenance to be done without entering laboratory or office space and therefore, research can be continued uninterrupted.

As seen in the first floor rendering below, the light gray band below is the service corridor. All rooms below that corridor are mechanical space and the majority of rooms shaded gray are mechanical space as well.

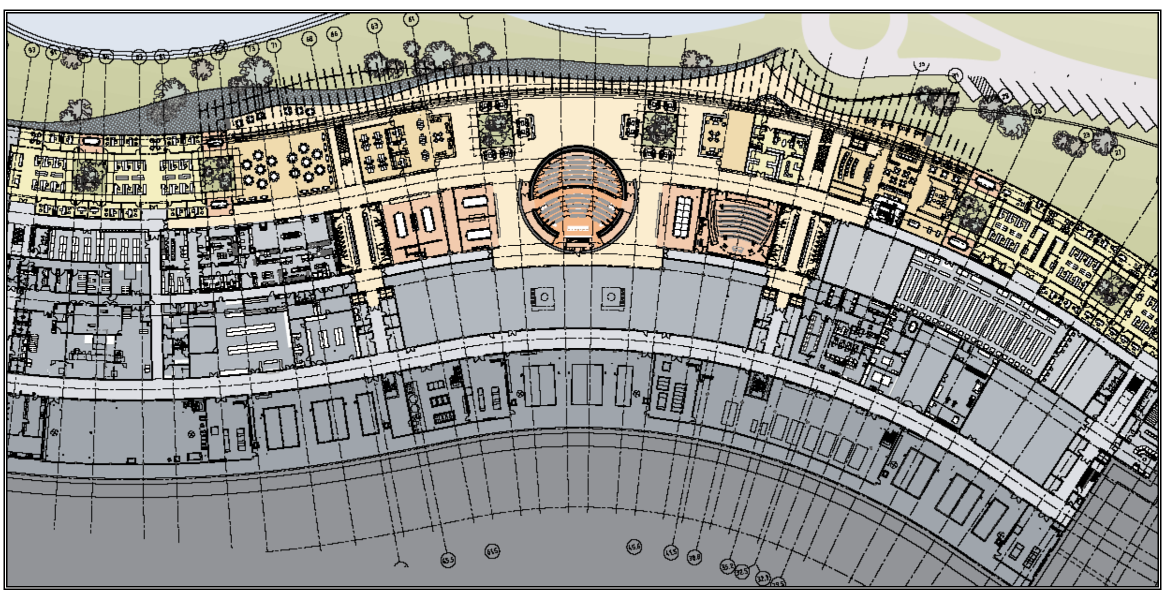


Figure 2: First Floor Architectural Rendering

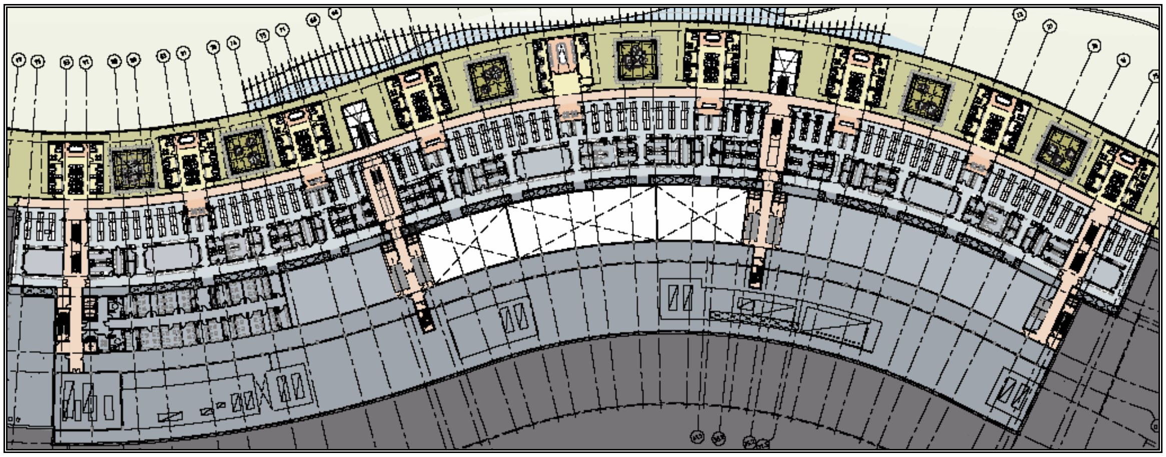


Figure 3: Second Floor Architectural Rendering

The bottom fourth of the second floor is completely dedicated to mechanical systems. The third floor is almost identical to the second. Some of the spaces are two stories in height. Approximately 220,235 square feet of useable space is dedicated to mechanical systems. This is 49.5% of the building's total area. Clearly HHMI was more concerned about providing an excellent working environment for the medical experts than the cost of using so much space for systems.

Floor	Mechanical Area [sf]	Total Area [sf]	Percent Lost
First	147,773	240,461	61.5
Second	46,049	122,649	37.5
Third	26,413	82,013	32.2
Total	**220,235**	**445,123**	**49.5**

Table 1: Mechanical Space

AIR SYSTEMS

The mechanical system uses a variable air volume (VAV) distribution system. Due to the nature of the building, 100 percent outdoor air is required to decrease the risk of contamination. It is designed to maintain the proper temperature, humidity, differential pressure, outdoor air exchange rate, and acoustic criteria within the building.

The building is served by 15 identical custom type 45,000cfm air handling units; 14 primary and one back up. All 15 air handling units feed into one plenum which will maintain a minimum of 67% capacity in the case of equipment failure or maintenance shut-down. This large plenum serves the entire building. AHU-1 and AHU-2 are separated from the rest of the air handlers by mechanical dampers. They serve the Vivarium during typical operations with AHU-3 serving as back-up. AHU-4 thought AHU-15 serve the rest of the building through one plenum. If needed, AHU-3 can also be connected in parallel with the rest of the units. Lab and Vivarium spaces will receive 100% outdoor air and pass through 30% efficient prefilters, 95% efficient final filters, energy recovery coils, direct injection steam humidifiers, chilled water cooling coils, and single plenum0type fans. The supply fans operate at 88.5 BHP and the AHU supply temperature is 45.8^{o}F. The system has pressure-independent hot water terminal reheat devices and individual laboratory and office area temperature zone control.

Outdoor air inlet dampers in each plenum open to bring in outdoor air to mix with exhaust air to maintain a constant discharge velocity from each exhaust stack with exhaust air volume demand decreases. Each exhaust plenum will maintain at least 67% efficiency in the case of equipment failure. All radio-chemistry or perchloric acid hoods are located on the third level of the Landscape Building and are equipment with dedicated direct exhaust to the roof.

All occupied spaces are equipped with climate control which is accomplished by variable air volume terminal unit and reheat coil. Air volumes are throttled to minimum flow rate before the reheat coils are activated to heat the space. Fan powered air terminal units with reheat coil are installed in the office areas where occasional, minimal cooling requirements would result in air flows that are sufficiently low to cause air quality problems.

CHILLED WATER & STEAM

The estimated demand for each utility is 23,210 kW (6600tons) for chilled water and 26,000 kW (100,000 lb/hr) for steam. The chilled water and steam enters the lower level of the Landscape Building via the utility tunnel. There is a two-stage pressure-reducing station that supplies medium pressure steam for sterilizers, washers, and other scientific equipment. Secondary chilled water and return chilled water from air handling unit cooling coils are used for lab equipment cooling and environmental room condensers.

HYDRONIC HEATING

Heat exchangers provide hot water for variable and constant air volume terminal reheat coils and cabinet heaters and convectors. These are used for secondary heating throughout the building. There are dedicated circulation variable frequency drive for each heat exchangers as well as one redundant heat exchanger/pump combination.

BOILER PLANT

The boiler plant contains three boilers and room for an addition of a fourth. Two have a capacity of 50,210 MBH and on is 30,125 MBH, a total energy input is 163,181 MBH, and an efficiency of 80%. They make 80 lbs steam and convert it to 15 lbs steam when needed. In general, two boilers run in any combination to meet desired load. The majority of the steam generated by the boilers is used by the air handler steam coils. Any remaining steam is used with the shell and tube heat exchangers (see TableA.8) XR-1 and XR-2 (back-up) are used to heat water that is pumped to reheat coils in the VAV boxes and XR-3 and XR-4 (back-up) used to heat water that is pumped to the radiant flooring in the lobby area.

CHILLER PLANT

There are six w/c centrifugal chillers and one back up that have full load capacity of 1,200 tons. The full load LCHWT and ECWT are 42.0°F and 85.0°F respectively. The full load power is 0.670 kW/ton. The condenser flow rate is 2,400 gpm and pressure drop of 13.0 ft. Remaining capacity is used for various equipment, such as the fan coil units in the data center room.

SPECIFIC ZONE REQUIREMENTS

The laboratory spaces are arranged with supply air distributed by multiple air handlers to ensure that fresh air is supplied 100% of the time. This concept is also applied to the exhaust fans. If one piece of equipment is not working properly or needs to be serviced, the load can be transferred to other equipment. The ventilation rates must be sufficient to remove volatile compounds present in the laboratory spaces. Concentrations can be determined using methodology found in National Institutes of Health's (NIH) HVAC Requirements.

The multimillion dollar mice are the center of ground-breaking bio-medical research. Their living environment must be maintained with precision to ensure their health and accurate test result.
The required air flow to the Vivarium spaces is not based on occupancy or space type, but the necessary air changes per hour. In addition, the animals housed in the Vivarium require warmer temperatures than do people. Individual control is provided to each holding room, treatment room, procedures room, and operating room. The Vivarium facilities are serviced by AHU-1, AHU-2, and AHU-3(back-up) that run in parallel to heat, ventilate and provide air-conditioning. The arrangement with stand-by equipment ensures continuous operation during equipment failure and scheduled maintenance.

The space requires HEPA filters because the animals will be involved in chronic testing. Supply air is introduced 24 hours a day through high-volume and uniformly drawn across the holding areas to provide uniform mixing. It is important to ensure that the system does not create drafts on the animals. Ventilation Design Handbook on Animal Facility and Animal Facility design published by NIH and ASHRAE Application Handbook were used to design the Vivarium system.

PROPOSAL OBJECTIVE

The results of this thesis will suggest alternative solutions to the design of the Landscape Building at Janelia Farm. All modifications are for academic purposes and do not imply flaws in the original design (old e-studio disclaimer). All modifications are simply alternative solutions which will include one extensive modification to the mechanical system and resulting changes to the other building systems.

The primary goal is to modify the existing HVAC system to reduce energy consumption and yearly utility costs. This will consequently reduce emissions as well. Secondary goals include optimizing the artificial lighting in the laboratory spaces and office pods located on the second and third floors as well as resizing affected electrical system components throughout the building.

The system modifications must be done without unfavorably changing the current system. As found with Techical Assignments One and Two, the Landscape Building meets ventilation requirements outlined in ASHRAE Standard 62 and lighting power allowance and building envelope compliance as outlined in ASHRAE Standard 90.1. All changes shall maintain the highest standards of the original design.

CONSIDERED ALTERNATIVES

COGENERATION

The design team at Burt Hill considered the feasibility of a cogeneration system to provide power and steam for the Janelia Farm Research Campus. The following three buildings on the campus were incorporated in this study:

- Landscape Building: 546,436 square foot research facility.
- Conference Housing: 42,000 square foot hotel facility with 107 guest rooms.
- Transient Housing: 48-two bedroom apartments for long term visitors.

The conceptual design included a turbine generator with adequate capacity to satisfy the minimum continuous electrical power demand for the campus. The continuous demand ranged from 2.5 to 3.0 mega-watts. The design featured 500kW gas micro-turbines that could be staged on/off to meet demand. The system was more efficient when all the turbines operated continuously. Enough heat could be recovered to operation 1-1200 ton absorption chiller which is equivalent to one of the seven current chillers. The waste heat could have met the majority of the winter heating requirements.

This study concluded an annual savings of $195,640 for the 2.5 mega-watt cogeneration system. The estimated first cost was $4,720,000. Based on this, the simple payback period would be 24 years. This was deemed beyond the limits of a reasonable payback period on such an investment.

A second study utilizing the 3.0 mega-watt system resulted with an annual cost savings of $214,400, system first cost of $7,080,000, and a 33-year pay back period. Again, this is beyond reasonable for a payback period.

No further analysis was done. In order for cogeneration to be feasible for the Janelia Farm research campus, equipment and installation costs will have to be greatly reduced.

Note: All dollar values are from 2002.

ENERGY RECOVERY WHEELS

Another energy saving option that the design team considered was the use of enthalpy wheels or desiccant wheels. During the cooling system when outside air is hot and humid, the wheel transfers both heat and humidity from the outdoor air to the exhaust air. This decreases the amount of cooling needed by the air handlers. During the cooling season when outside air is frigid and dry, the wheel transfers heat and humidity to the incoming air from the exhaust air. This decreases the amount of heating and humidification needed from the air handlers.

There are two drawbacks to including a wheel in the mechanical system in the Landscape Building. The primary reason is the risk of cross contamination. As the building is a medical research laboratory, there is a always a chance of chemicals, gases, or infectious material becoming air-borne in a space and consequently the mechanical system. One way the system manages this issue is to provide 100 percent outdoor air to all critical spaces and exhausting 100 percent of that air directly out of the building. Energy recovery wheels are able to recover energy and moisture because they are able to effectively mix the exhaust and supply air streams. Given this, contaminants will also transfer between air streams. As a result, the concept of using an enthalpy wheel was not pursed.

Desiccant wheels on the other hand do not transfer air-borne contaminants. The wheel is flushed with supply air that is deflected by a damper in the purging section of the rotor. This further helps reduce the risk of contamination. While this may work well in theory, the chance that the equipment may not work properly was a risk the owner was not willing to take. Using a desiccant wheel was not pursued.

The second more minor drawback is Howard Hughes did not want to pay for the equipment and additional space it would take up in the mechanical rooms.

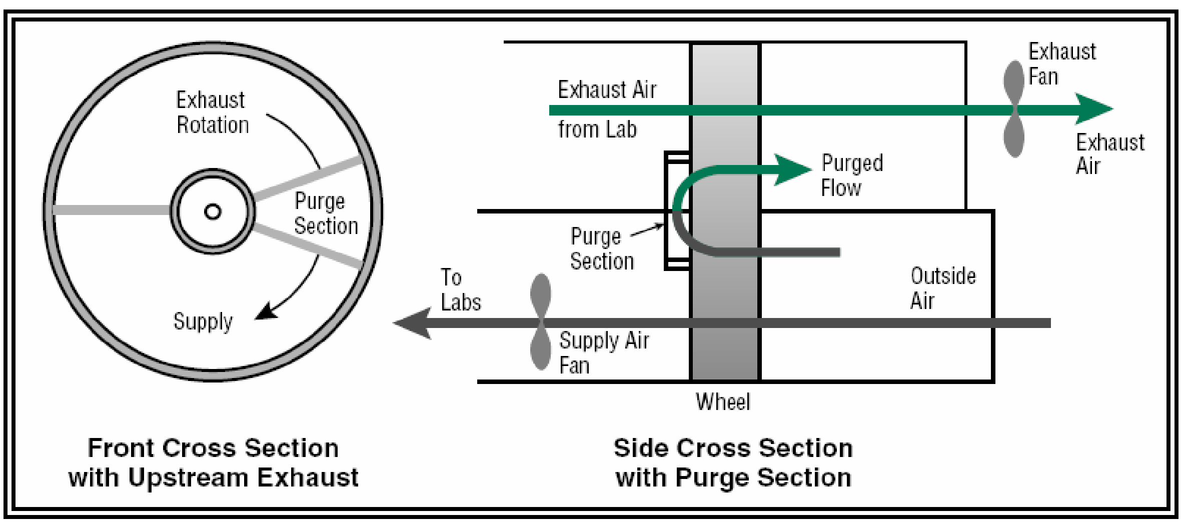


Figure 4: Desiccant Wheel Schematic

PROPOSED REDESIGN

The Landscape Building will have an estimated yearly utility bill of $3,530,000. This is a direct result of the size of the building as well as the building type. Laboratory spaces have requirements that will directly increase the cost of operation. Providing 100 percent outdoor air to all laboratory spaces will increase fan energy and equipment energy because such a large amount of air must be conditioned. As a result, all of the air in the labs must be exhausted out of the building. As stated in a case study of R.W. Johnson Pharmaceutical Research Institute, "Fume hoods are directly responsible for a large amount of fan energy, and they are indirectly responsible for vast amounts of heating and cooling energy because of the volume of conditioned air they continually exhaust from the labs."

The goal of this thesis report will be to reduce energy consumption and energy costs for the owner.

The primary goal is to utilize a heat recovery system to prevent losing a large amount of energy in the conditioned air. The integration of a plate-type heat exchanger will be analyzed for effectiveness and amount of energy saved. As stated in the product description, the exchanger "is a plate-type heat exchanger wherein the plates are constructed of ionomer membranes, such as sulfonated or carboxylated polymer membranes, which are capable of transferring a significant amount of moister from one side of the membrane to the other side." In other words, it is effectively a plate-frame heat exchanger, but instead of using metal or paper, a polymer membrane separates the two air streams. These membranes are able to transfer both sensible and latent energy, but the air streams remain completely isolated from each other. This is the critical feature which makes this a feasible addition to the mechanical system in the Landscape Building. The square box in the left side of the figure below is the actual exchanger in one of the many possible configurations.

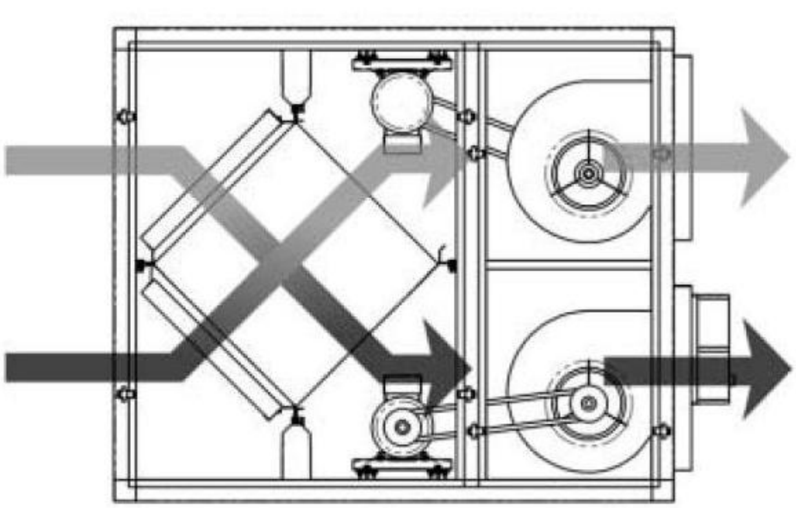


Figure 5: Membrane Heat Exchanger Schematic

BREADTH AREAS

LIGHTING

While it is important to design a system that is capable of maximizing its energy usage, it is also important to minimize the amount of energy required. To aide in this, an analysis of the lighting in the laboratory spaces and office pods will be performed. Lighting can be one of the largest loads in a commercial building. Therefore, a well designed lighting system can provide adequate lighting and also conserve energy for the owner.

The Landscape Building uses primarily T8 florescent lamps in office and laboratory spaces. It may be beneficial for the T8 lamps to be exchanged with fewer T5s. It is possible for fewer T5 lamps to produce the same amount of lighting and maintain the same color characteristics with a smaller wattage. It is also possible that the chosen T5 lamps have a longer rated average life. This can have a direct savings in electrical consumption and indirectly save on ballast cost and operation because fewer are needed. Even though T5 lamps are more expensive than T8 lamps, the possible saving may make the equipment cost worth the investment.

Another option would be to replace many, if not all, the incandescent lamps in the building. Incandescents typically are less efficient, produce more heat, and have a shorter rated average life than compact fluorescents. This leads to a higher electricity requirement, a larger cooling load, and, and higher maintenance costs. These factors contribute to a higher utility demand and annual cost. There are now compact fluorescents with the same color characteristics as incandescent, which are much more efficient. Replacing incandescent with compact fluorescents may result in an economic savings for the owner.

One other consideration are the ALTO-series lamps from Philips Lighting. These lamps are designed with sustainability in mind. "Philips Alto fluorescent lamps combine the lowest mercury with long life and energy efficiency. The lamps contain up to 70% less mercury than other lamps. This is beneficial for the environment because mercury is a highly toxic substance. On average, the ALTO-series lamps consume 25% less energy over a longer life. This benefits the owner with a decrease in annual operating costs as well as being environmentally friendly with less waste and less pollution with energy generation (due to less consumption).

ELECTRICAL

The integration of the membrane plate heat exchangers may have a noticeable impact on electricity demand. While normally exchangers would reduce the size of the air handlers due to decreased required cooling and heating capacity, the air handlers in the Landscape Building may not be downsized due to outdoor air requirements. Instead, the capacity of the coils would be reduced. This in turn would have an impact on the size of the chiller and a reduction in pump power.

Optimizing the lighting of the laboratory and office pods will have a significant impact on the electrical load as those spaces occupy the majority of the second and third floors of the building.

As a result of the change in electricity usage, the feeders, circuits, and panel boxes will need to be resized with the new loads. Again, this will reduce first costs as well as operational costs.

INTEGRATION & COORDINATION

The major issue with the integration and coordination of the proposed redesign is space reallocation. The addition of the membrane plat heat exchanger will alter the supply ducts and exhaust ducts as well as take up space in the mechanical room. Fortunately, the mechanical rooms are over-sized to ensure added equipment will fit without difficulty. Also, the supply and exhaust ducts are currently adjacent to each other which is extremely convenient because the exchangers require this.

PROJECT METHODS

The proposed redesign of the Landscape Building will go through multiple iterations and sequences. The most important component is the mechanical design as its alterations will affect the electrical system. This analysis will be performed first and for the duration of the semester. The modified system will be modeled using Carrier's Hourly Analysis Program (HAP) and compared to the analysis performed for Technical Assignment One.

The breadth portion of this proposal will be carried out after a preliminary mechanical design is completed. In order to optimize the lighting effectiveness and lighting power of the laboratory and office pod spaces, extensive research on lamp and ballast data. In addition, space modeling using Lexicon lighting analysis software will be carried out to ensure an adequate amount of light in the space.

At this point in the redesign process, a new HAP simulation should be done to recalculate the heating and cooling loads. This will be done to make sure all the equipment sizes are correct with the new loads.

The last design step will be to resize the electrical system that was affected by the redesign. This will include updating feeders, branch circuits, and panel boards.

Lastly, and life cycle cost analysis will be performed for each individual alteration and for the entire redesign as a whole. This will determine if the redesign is economically practical or not.

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Note: Thesis Proposals were used to aid in the format and content of this report.

SPRING SEMESTER PROPOSED SCHEDULE

The calendar on the following pages is a preliminary outline for the redesign process over the spring semester for the Landscape Building at Janelia Farm. This is only a rough estimate of how long individual design components will take and the order in which they are accomplished. Modifications will occur in light of other course work and unforeseen events.

January 2006

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
						1
2	3	4	5	6	7	8
9 First day of class.	10 - Begin In-Depth Consultation with Professors	11 - Begin Heat Exchanger Analysis	12	13	14	15
16 No Classes – MLK Day	17	18 Last Day to Drop/Add	19	20	21	22
23	24	25	26	27	28	29
30	31 - Complete Exchanger Design					

February 2006

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
		1 - Begin Lighting Research	2	3	4	5
6	7	8	9	10	11	12
13 -Complete Lighting Research	14 - Begin Lighting Layout & Total Power Calculation	15	16	17	18	19
20 -Complete Lighting Layout and Power Calc	21 - Begin Electrical Redesign	22	23	24	25	26 Final Exam Conflict Deadline
27	28					

March 2006

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
		1	2	3	4	5
6 Spring Break	7 Spring Break	8 Spring Break	9 Spring Break	10 Spring Break	11	12 - Complete Electrical Redesign
13 - Begin HVAC final calculation	14	15	16	17	18	19
20 - Complete HVAC Redesign	21 - Begin LCC Analysis	22	23	24	25	26
27 - Complete LCC Analysis	28 Write the Report	29	30	31		

April 2006

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
					1	2
3	4	5 Final Report Due	6 - Create the Presentation	7 Late Drop Deadline	8	9 - Complete the Presentation
10 Presentations	11 Presentations	12 Presentations	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28 Last Day of Classes	29	30

May 2006

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
1 Finals Week	2 Finals Week	3 Finals Week	4 Finals Week	5 Finals Week	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				