Fall 2004
IPRO 328
Application of Solar Thermal Heating Technologies in Large Scale Buildings in the Urban Environment- Midterm
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GOALS:

To provide heating to the pool facility and surrounding spaces of Keating Sport Facility through the use of solar thermal collectors placed in the immediate area.

FACULTY MENTOR/ADVISORS

Advisor-Nancy Hamill-Governale

ORGANIZATION/TASKS:

Mechanical Team	Analysis Team	Enclosure Team
Jaesun Jeong	Sriram Mahadevan	Justin Odom
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ADDITIONAL DETAILS/HISTORY:

Primary Project Objective

To provide heating to the pool facility and surrounding spaces of Keating Sport Facility through the use of solar thermal collectors placed in the immediate area.

Secondary Project Objectives

- To discover which form or solar collector has the highest potential payback if used.
- To discover if modification of the building envelop has a potential to reduce the energy load produced by Keating Sports Facility.
- To study the possibilities of using sustainable system to provide for the cooling of Keating sports facility.
- To study the impact of solar thermal Technologies can have on Chicago as a whole.

PROJECT BACKGROUND

Solar thermal technologies have been in use since ancient times around the world. The use of solar collectors has been going for decades and having its greatest period of discovery in the 1970s. Though solar thermal impact has been limited to times of energy crisis the potential for solar thermal collectors to greatly reduce a buildings dependence on fossil fuels is great. The recent push by Mayor Daily to make Chicago a green city gives great cause to study the potential used of solar thermal collectors.

Though there are several types of solar collectors in use to today, the focus of the IPRO will be on the two most largely used types, evacuated tubes and flat plate collectors. These devices can be retro fitted to a current building or can be mounted in a separate structure. Though each collector has its own potential to succeed in Chicago, the combinations of factors will certainly make one type more viable then the other.

Keating Sport Facilities design has made it a perfect example of the use of solar collectors. The buildings energy use for climate control is great and still the climate achieved is not optimal for use. The pool facility needing to be warmer then other parts of the building to be used is a big factor in the amount of energy use.

RESEARCH METHODOLOGY

The past IPRO 328 groups have been focused on discovering which of the two collectors has the greatest potential for use in Chicago. Using gathered data of the groups the choice of the type collector to be used should be achievable in the first week. With this determined the focus will be on implementation of the solar collectors around Keating facility. The study will consist of:

- The mechanical system needed to incorporate with the solar collectors for proper use.
- The proper placement and attachment of the solar collectors to the site.
- The development of system to reduce the loss of energy gained.
- The analysis of gathered data to show potential energy saving and financial plans to show benefits of implementation.

Each of these aspects will be focused on by separate team that will work in tandem to achieve the project objective. The research will be handled by individuals who will submit what they have found to there individual group and then to the group as a whole once found pertinent by their group. There also will be information sessions for the whole group with specialists who will be able to help with there experience and knowledge of a specific field pertaining to the project.

EXPECTED RESULTS

Three different teams have been created to focus on different aspects of the project. Two teams will be working on the initial research of the two main aspects of the project while the third team will be doing analysis and verifying the factual nature of the predictions made by the other two groups of the proposed design.

Keating Hall Modification Team

The selection and installation process for an insulating pool cover. Information has to be gathered to verify the development and installation procedure of a mechanical system and secondary devices for the energy gathering system. The possible application of an integrated system that can be used for cooling in the pool incorporated in the heating system.

Enclosure Team

The integration and design a structure which a thermal solar collection system can be incorporated in to and place it properly on the site. Also research needs to be done to check the possibilities for a new curtain wall system for Keating hall that would help reduce energy load.

Analysis Team

To discover which system for solar collection has the best possible energy capabilities. To review the proposed design of the enclosure and Keating hall groups to discover the actual energy savings of the design system. The use of the gathered data and discover possible integration of the designed system into applications for commercial spaces around Chicago. The cost needs to be analyzed to determine the viability for the project of whether to actually create it or not.

The modification team worked on a wide variety of topics. The following are these topics: the solar technology options, pool covers, the mechanical system, methods of cooling Keating, Energy 10 and how to apply solar technology to Chicago.

The three main types of solar collectors are flat plate, evacuated tube and concentrating or trough collector. The flat plate is the most commonly used type of solar collector and is basically an insulated rectangular box that heats water to 120-150ºF. This type of collector is ideal for residential applications. Next the evacuated tubes are a setup of parallel glass tubes. These collectors are much more efficient and can heat the water to 180ºF. This type of collector is ideal for overcast areas and cold climates. Finally the concentrating collector is a setup of parabolic troughs with mirrored surfaces. This collector creates higher temperatures than the flat plate and is ideal for commercial and institutional applications. As a side note there is also a collector for producing electricity which is called a photovoltaic collector.

The type of collector chosen for this project was the evacuated tube. Through RETSCREEN calculations and research the evacuated tubes were predicted to be the most efficient. How this tube works is as follows: solar radiation is absorbed by the solar tubes and converted into heat. Heat pipes conduct the heat from within the solar tube up to the header pipe. Water is circulated through the header by a pump and each time the water circulates through the header the temperature is raised by 9-18ºF. The pool itself will be used as the storage tank for the water.

Next the group looked into methods of reducing the heat loss of Ekco pool. Even though the pool is located indoors, a pool cover can save energy costs. Up to 90% of the heat loss from the pool is through convection and radiation into the air. Adding a pool cover can increase the thermal resistance to an R value of approximately 5 and reduce the heat loss up to 80%. When investigating companies and options, a mechanized system seemed to be the best idea. The easier it is for someone to apply the pool cover, the more likely it will be utilized. The setback to this type of system is the cost, which is from $50,000-$80,000 after installation. The typical blue bubble wrap cover found on many residential pools would cost only $1000 but would also have a smaller R value and would not reduce heat loss as efficiently. This system would also have to be pulled across the pool by hand.

The best combination found to deliver the hot water from the collectors to Keating Hall was a ½" diameter pipe with the Yamada NDP-15 pump. This pipe and pump selection was easily able to overcome the minimum 4.15 GPM flowrate with 160 foot pressure head. With a smaller pipe size, the pump head would be much larger and would require a larger pump, while with a larger pipe size, the pump would be far too overpowered for the job, because the pressure head would be much lower. Also, the increased pipe size would yield far higher costs in materials, and would be harder to insulate. The Yamada NDP-15 pump is constructed of 316 stainless steel and Hytrel Diaprhragm material, which can easily accommodate temperatures of up to 120 degrees Celsius. To run this pump, 80 psi air pressure is required at 4 scfm air flowrate. The heat exchanged chosen for this system was the same model as is currently selected for Keating Hall's changeover to gas boilers.

(INFO FROM ENGINEERS HERE)
Heat exchanger chosen, Specs

In order to facilitate the heat transfer from the solar panels to the pool, it was necessary to insulate the pipes leading from the collectors to Keating's mechanical room correctly.

(INFO FROM ENGINEERS HERE)
Heat loss in pipes from Structure to Keating, calculations

Next the group wanted to investigate the options of using the system proposed to heat the pool, to also cool Keating. The basic principle behind solar-thermal driven cooling is the thermo-chemical process of sorption: a liquid or gaseous substance is either attached to a solid, porous material (adsorption) or is taken in by a liquid or solid material (absorption). The following are some options that can be used for this process: active solar cooling and refrigeration, absorption cooling and refrigeration, desiccant cooling, evaporative cooling/photovoltaic-powered, heat engine/vapor compression cooling (rankine-cycle), photovoltaic (PV)-powered heat pumps, air conditioners and refrigerators. Through the research the idea of absorption cooling seemed to fit this project the best. The temperature needed to run this system is between 180˚F and 250˚F. This process uses a chiller that uses the heat load of a building to provide cooling. An absorption chiller transfers thermal energy from the heat source (the solar collectors) to the heat sink through an absorbent fluid and a refrigerant. Advanced technologies for this method are still in development. The cost of installation of this project would be $4000-$10,000 per ton of cooling or approximately $1 Million for Keating with a 100-150 ton load.

The next step in the Keating Modification phase was to calculate the current rate of heat loss in the building. Due to the relatively low R-value of the current single-paned windows used in Keating hall, it was obvious that to reduce the heating load on the building that this value had to be increased. Because the cost of replacing the windows with more energy efficient models was much too high, the group decided to add curtains to the interior of the building surrounding the windows. These curtains, with an R-value of about 6, greatly reduced the heating load on the building. *(note: see attached graphs)* As is shown in the graphs, the yearly total heating load on the building was reduced from a staggering 164,900 Btu per square foot to just 60,000 Btu per square foot. *(note: the cost of this structure should be covered by Justin's report, but if it isn't, he has the information)* Such a large increase in the R-value of the façade does indeed yield quite a large decrease in the total heat loss, at less cost than replacing the entire window structure. At this stage in the analysis, no cooling system has been included in order to best simulate what would happen to the heat load on Keating Hall if just this addition were taken into consideration.

Finally the modification group looked at the bigger picture of solar technology in Chicago. It was discussed that this technology would be most useful for multi-family housing because the most hot water would be used there. The typical Chicago home energy use is between $300-600. Through the use of GIS on one neighborhood it was found, only for approximation, that there are 36 multifamily units in each neighborhood. Once installed the energy savings would pay for the installation of solar technology in 8-10 years. Since on average homes are in use for 20-50 years, this would be beneficial to society. This technology could also be extended in Chicago for the use of heating residential pools. Another point to keep in mind, the costs of installation can be cut through government sponsored incentives.

The enclosure group concentrated on designing a secondary structure which will act as a support structure for the solar thermal collectors. The group decided to avoid the attachment of the thermal collectors to the Keating Hall building due to the age and condition of the roof on Keating Hall. If the collectors were attached to the roof, the roof would need to be rebuilt and columns would need to be added to support the large amount of collectors needed for the project. Rebuilding and resurfacing the roof would add significant cost to the project. Also placing columns through the interior of Keating Hall will ruin the architectural design of the building and since there are many places where the columns cannot be placed on the interior. Basketball courts, bleachers, offices, a swimming pool and fitness center account for the majority of the building's space where the columns may not be placed. The new structure will be located on the south side of IIT's baseball field, and will have enough space for the large quantity of collectors and supporting structure. The design of secondary structure incorporated new baseball stands, shading for the fans, an area of storage for the maintenance equipment, as well as the announcer's booth. The structure was designed with the consideration of the placement and attachment of the solar thermal collectors and will sweep down the first base side of the field and wrap around the existing bleachers. Running entirely parallel to the road except at the far west side where it sweeps in towards the baseball field to emphasize the structure being part of the field.

The structure consists of 14 structural supports of a beam and column combination. Each end evacuated tubes will be fixed to the structural supports. The beam will be cantilevered, over the bleachers, to the extent of 20' at the top of the 20' column and be connected to the column with a moment connection, which will make the column and beam act as one. The structural supports will be a W Section steel, size W14. This will be strong enough to support the bending moment created by the cantilevered beam and the weight of the solar thermal collectors. Also the steel structure will be attached to a concrete foundation by embedding the column into the concrete. This way is the best way for attachment because of the substantial bending moment being created. Bolting the column to the foundation would not be as strong. The foundation will consist of 3,000 PSI (lbs/in^2) concrete with reinforcing steel and have a footing key to prevent the cantilever structure from being turned over. The group decided to use the steel structure over cast-in-place concrete, which was the second opinion, because using steel was dramatically less expensive than cast-in-place concrete. The steel structure would take less time to erect than the concrete structure. The 27 day waiting time for the concrete to set, the cost of many sets of concrete formwork, considerable labor, added concrete to the foundation to take the larger concrete weight, and the heavy amount of reinforcing steel, all added to large increase in price over the steel structure. The design of the concrete structure was over $100,000 more than the cost of the steel structure.

There is approximately 4,045 SF of evacuated tubes, each tube will be placed in the horizontal direction for aesthetic purposes, ease of connections manifolds together and the tubes will achieve the same results as placed in the vertical direction. Placing the evacuated tubes in the horizontal position allows for the manifold to run down the side of the column, generating a continuous look of the evacuated tubes on the side and top of the structure. The collectors will also create shading for the fans sitting in the new 8 row pre-engineered bleachers. The bleachers will seat approximately 320 individuals and be placed at the rear of the first base side dugout and connect, at west end, to the existing bleachers. The area under the bleachers will be available to have storage units placed to store maintenance supplies and equipment. To protect the evacuated tubes from vandals and also baseballs, they will be raised six feet off the ground and also have a protective fabric installed to the underside and top of the steel structure. This fabric will prevent damage occurring to the collectors in the case of a baseball being accidentally hit towards the structure.

The analysis group was mainly concerned with the learning of the RETScreen analysis software. This is a unique decision support tool which can be used to evaluate the energy production, life-cycle costs and greenhouse gas emission reduction for various energy modules. The software also includes product, cost and weather databases.

The team also reviewed past semesters' work and collected information about Keating and made a report on the present heating system at Keating hall and also compare and contrast the proposed addition/replacements to the existing one. The analysis group collected information from other groups and summed into a status/progress report and also produced a report on RETScreen simulation(s). The theory behind solar thermal energy was thoroughly researched and this was applied to RETScreen simulations.

Collecting information from other teams and writing the reports was primarily the work of the analysis team, other than simulating the RETScreen tables. The progress report, midterm report, abstract and the final report were done by the analysis team members.

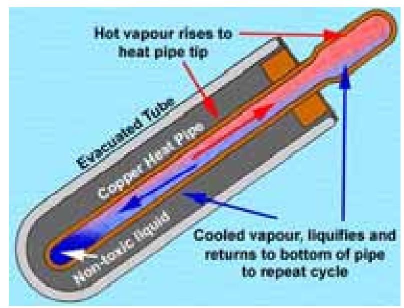
GENERAL SOLAR COLLECTOR INFORMATION

There are three main types of Solar Collectors on the market today; the flat plate solar collector, evacuated tube solar collector, and the concentrating (aka trough) solar collector. This technology offers the possibility of absorbing between 50-85% of a typical water heating bill. A solar water heating system is typically mounted on the roof of a building and connected to a heat exchanger which transfers the accumulated hot water to a holding tank inside for mixed use throughout the building. Efficiency of these products depends on the solar orientation and the climactic conditions in the area.

Integration of solar heating systems is growing in the US but it requires the initiative of clients building or renovating building projects. Money is often the deterring issue, however the government offers various incentives such as green building points or tax credits to those who incorporate this, as well as other solar technology into their building systems. Solar water heating products have a payback period of 4-10 years, and may last up to 30 years with relatively minimal maintenance required.

EVACUATED TUBE

These collectors are much more efficient, reaching temperatures of 170-350 degrees F, making them appropriate for industrial or commercial developments. They consist of rows of parallel glass tubes, each of about 2 inches in diameter. The units are made with a vacuum around the tubes, which makes the higher temperatures achievable by eliminating convective and conductive heat loss. The tubes are coated with a selective coating and contain an absorber mechanism, which heats the liquid passing through the tubes. This can be made of all inclusive glass, or metal. A glass-glass tube is less efficient, but more reliable and less expensive than glass-metal tubes. These systems work great in overcast areas (the tube shape lets in sun from all angles) as well as cold climates (the vacuum eliminates water freezing complications).



CRITICAL ISSUES:

Though the workers of the group seem to be completing their work in a timely manner the progress has not been as quick as originally predicted. This is due to a lack of cooperation form manufacturers of the needed equipment. Though several emails have been sent to multitude of companies the response has been slow and incomplete. The lack of getting hard factual information form several sources brings in to question the validity of our analysis. Though our facts do have a source it would be better to check them against several other companies for consistency.

CONCLUSIONS:

This IPRO has progressed remarkably compared to previous years'. Though currently unable to fully support the applications reviewed in this IPRO, we have designed an appropriate and practical prototype/blue print to provide heating to the pool facility and surrounding spaces of Keating Sport Facility through the use of solar thermal collectors placed in the immediate area. Solar thermal is clearly a worthwhile solution for reducing dependence on fossil fuels.

NEXT STEPS:

In order to further the evolution of both the Keating Hall case study and the Machinery Hall experiment, additional recommendations must be taken into account. An upkeep and monitoring plan must be contrived for the duration of the projects.

Further research and experimentation with the developing technologies of different solar panels should be incorporated in future solar energy IPRO's.

References and Resources:

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