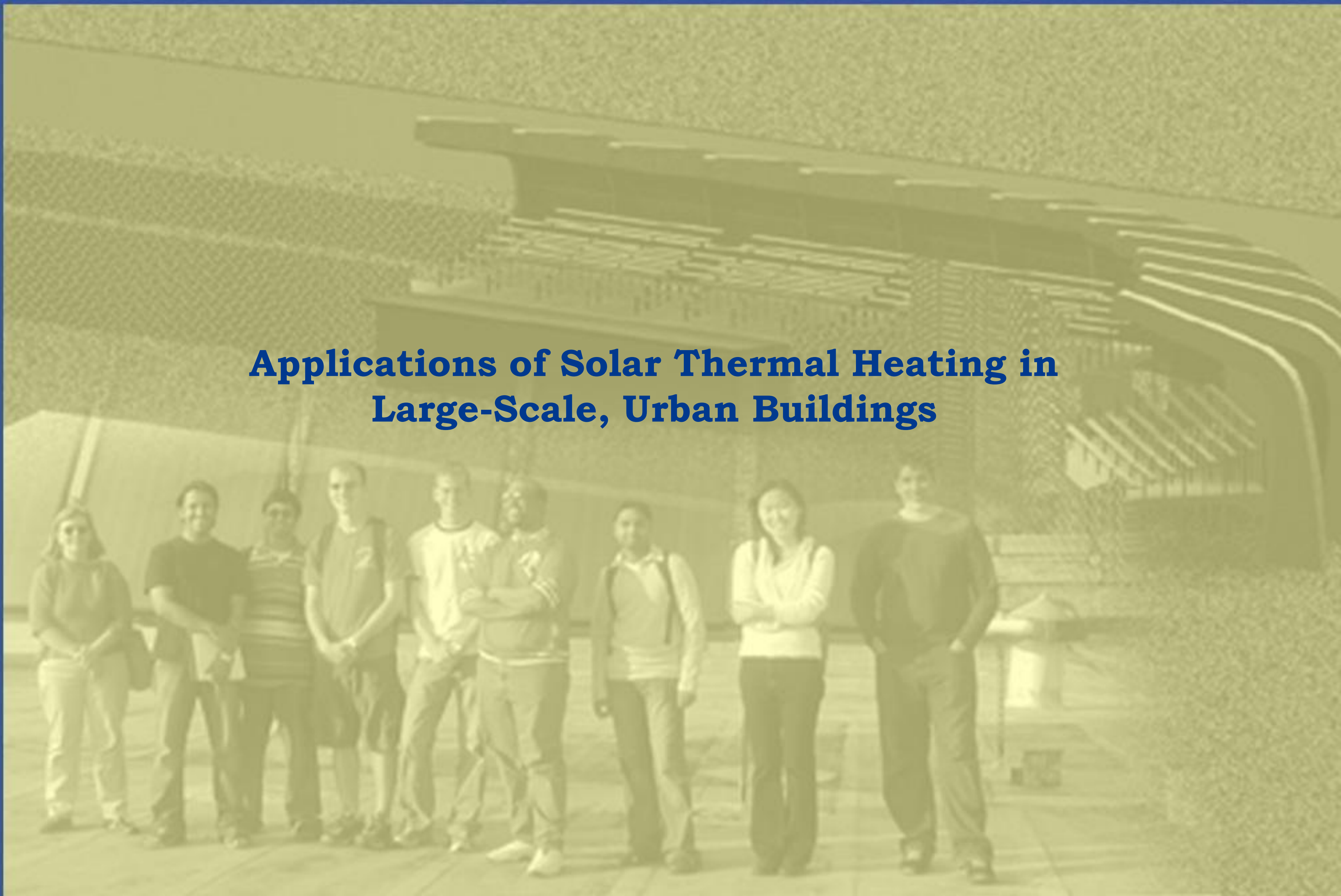
IPRO 328

Applications of Solar Thermal Heating in Large-Scale, Urban Buildings



Team Members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Chris Tokarz	•	Architecture, 4th Year
Harsha Pannala	•	Architecture, 5th year
Joe Sutulo	•	Mechanical Engineering, 4th year
Kristen Kelley	•	Mechanical Engineering, 3rd year
Jaesun Jaeong	•	Chemistry, 4th year
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Rajiv Shah	•	Electrical Engineering, 4th year
Sriram Mahadevan	•	Electrical Engineering, 4th year









Objectives

Primary

• 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

• 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.

Creating a Renewable Recreational Facility

- Application of wide variety of renewable energy technologies.
- Contains a large pool facility, is located adjacent to a large open field and is currently not air conditioned.
- The opportunity to transcend generational building technology through the application of real world renewable technology.

The Project

- To propose the use of solar thermal technology as a viable renewable energy source to heat Keating's pool.
- Measure heating requirements for heating the pool and the surrounding areas.
- Calculate the amount of evacuated tubes to be used for the heat required.
- Calculate the total cost of the technology to be used and compare it to Keating Hall's annual current cost for payback purposes.

Calculations for Pool Heating

POOL DIMENSIONS

- Volume: 14210 Gallons
- Area 3000 ft^2
- Makeup Water is 1%
- Pool Temperature Maintenance: (24-32C or 78°-80°F)

AVERAGE ANNUAL INSOLATION LEVEL IN CHICAGO

3.75kWh/m^2/day

POOL HEATING

(INITIAL)

Makeup Water (1%) Heating: 4.96*10^8J

HEAT LOSS THROUGH EVAPORATION

$$Q = mc\Delta t = 4.96 \times 10^{10}\, J$$

$$Q_e = p_a (V_w + 43 (Tp - Ta)^{\frac{1}{3}})(w_p - wa)$$ =9.0138*10^8J

-pa: ambient air pressure (Kpa)

-Vw: Wind Speed (m/s)

-Wp: Saturation Humidity ratio at the temperature of the pool

-Wa: Humidity ration of the ambient air above the pool

-Tp: temperature of the pool

-Ta: ambient pool

Heat Loss through Convection

$$Q_c = Q_e \times 0.0006 \left(\frac{T_p - T_a}{w_p - w_a} \right) \times A$$ =2.2529*10^9J

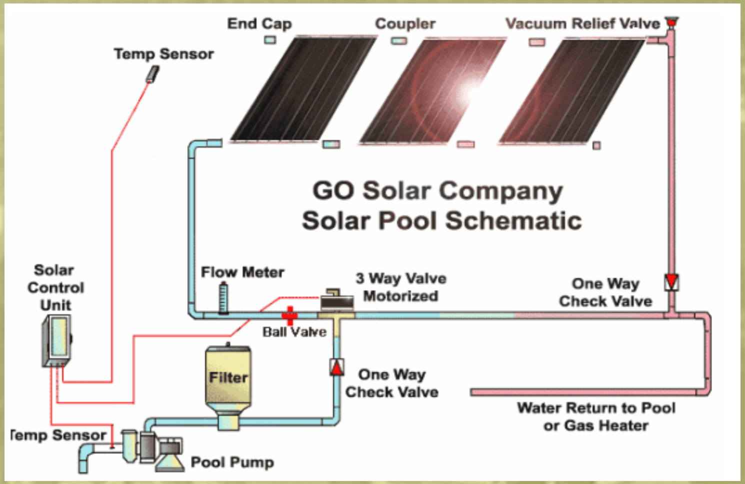
Solar Collectors

Types

- Flat plate solar collector

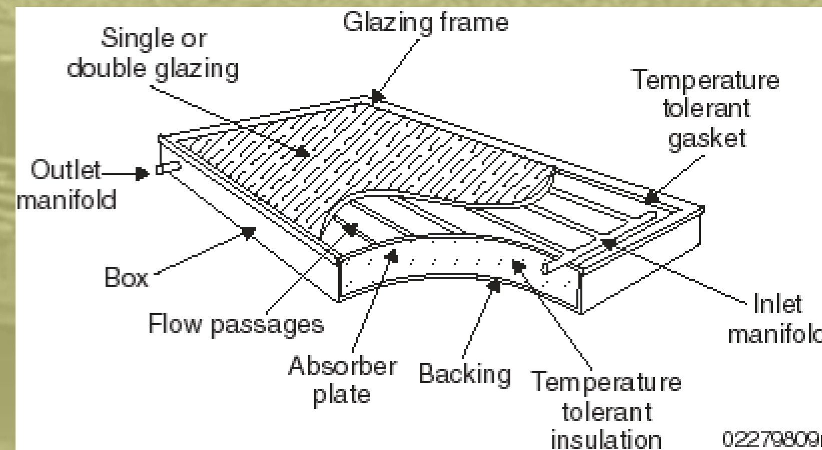
- Concentrating (aka trough) solar collector

- Evacuated tube solar collector



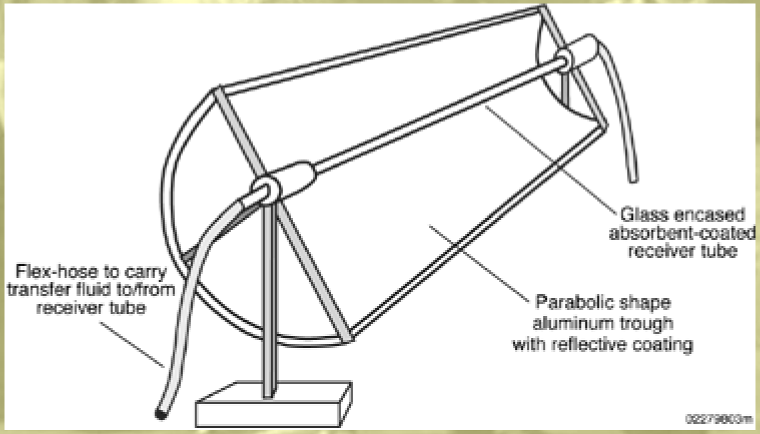
Flat Plate

- The flat plate system is the most commonly used type of solar heat collector on the market today.
- Insulated rectangular box
- Heat water to 120-150 degrees F.
- Ideal for residential applications.



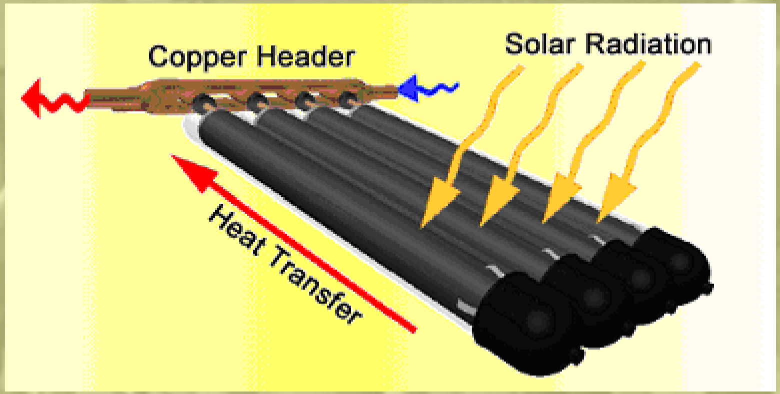
Trough Collector

- Parabolic troughs with mirrored surfaces
- Used in commercial and institutional applications
- Higher temperatures than the flat plate systems.



Evacuated Tube

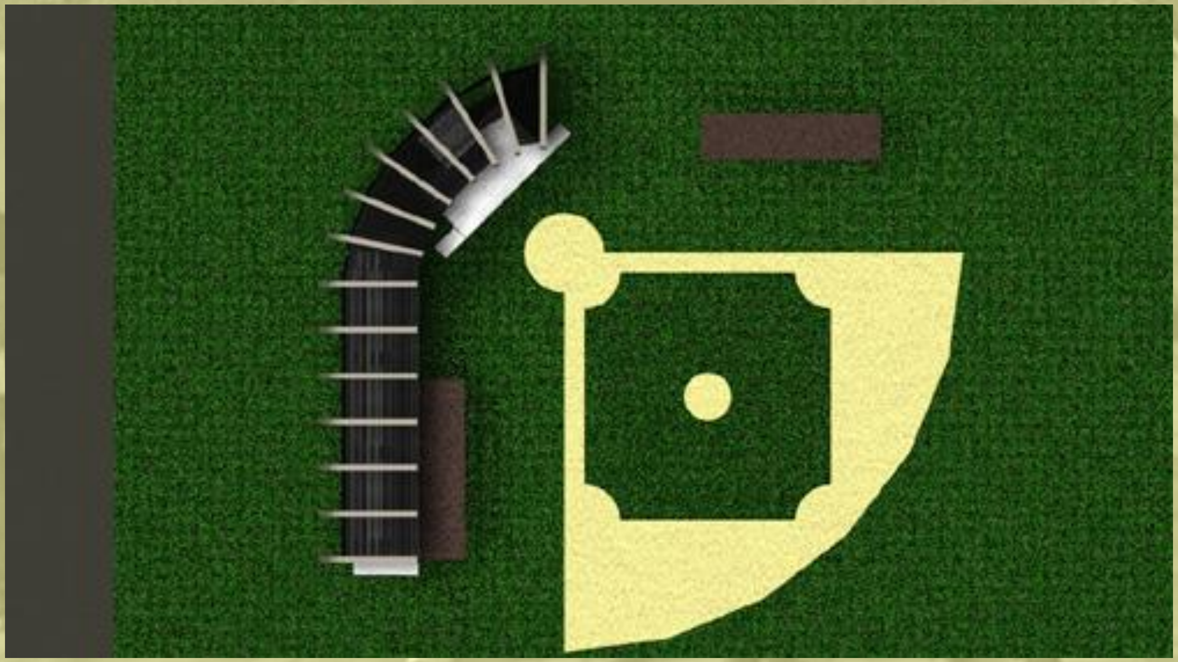
- These collectors are much more efficient
- They consist of rows of parallel glass tubes
- Achieve temperatures of 180 degrees F
- Work well in overcast areas and cold climates



Proposed Enclosure

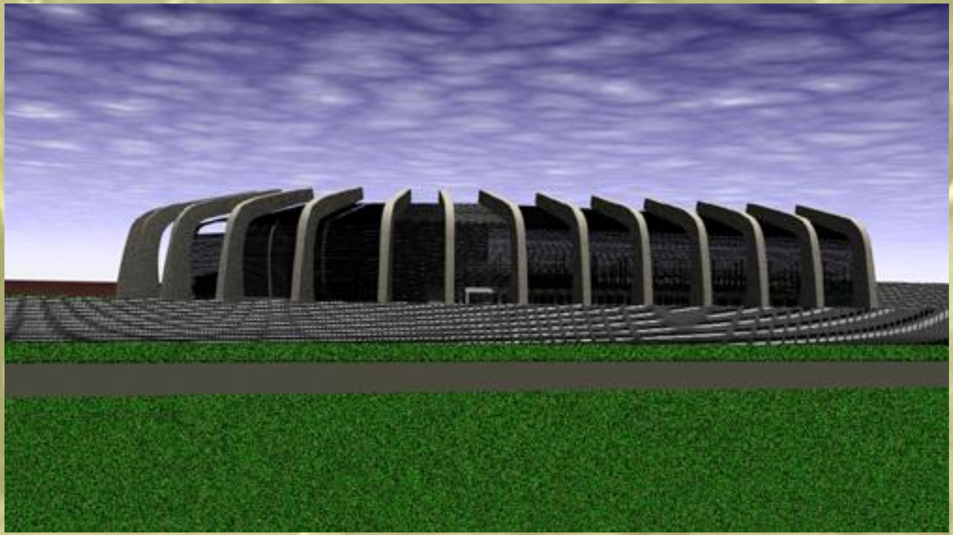
Proposed Enclosure

- Steel Columns
- Wrap around shading enclosure
- 4150 ft^2 of evacuated tubes.
- 150%

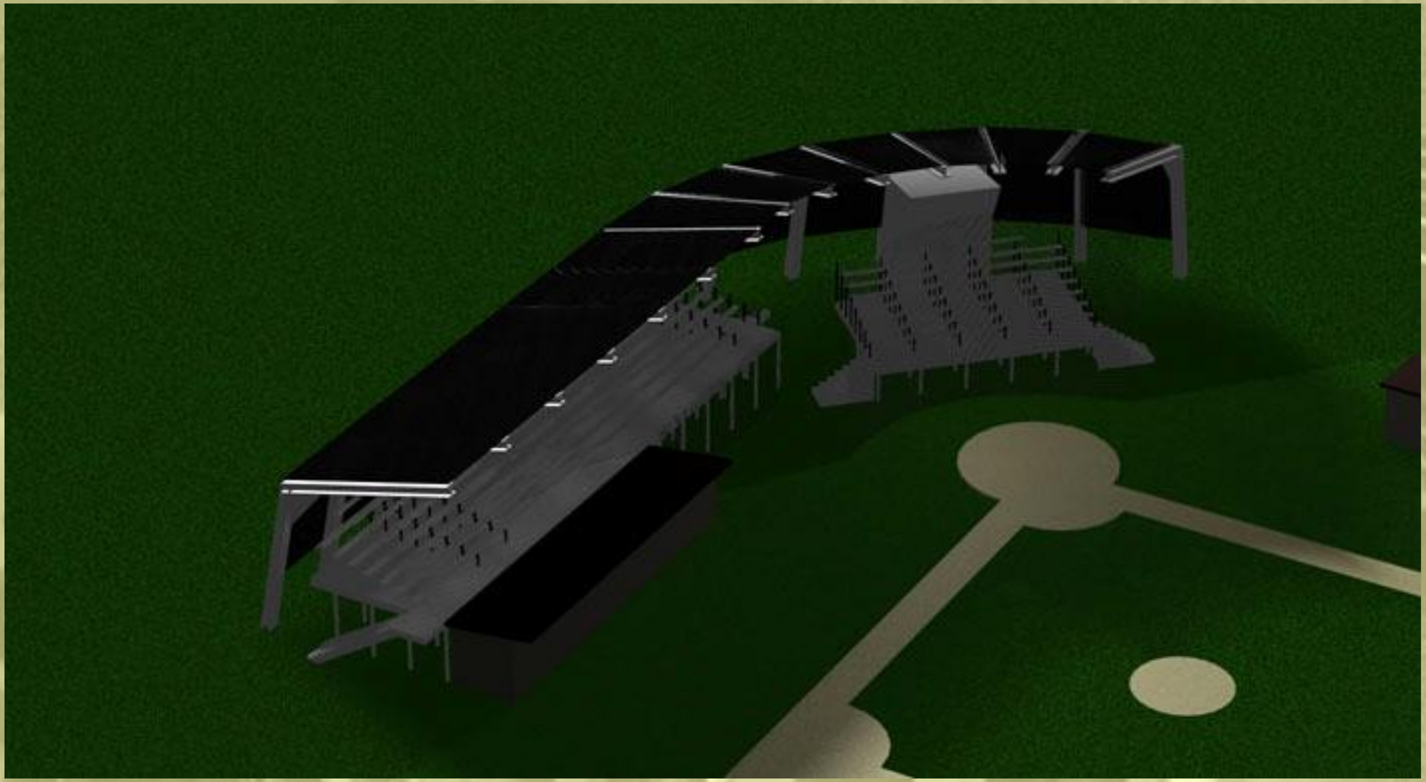


Additional Benefits

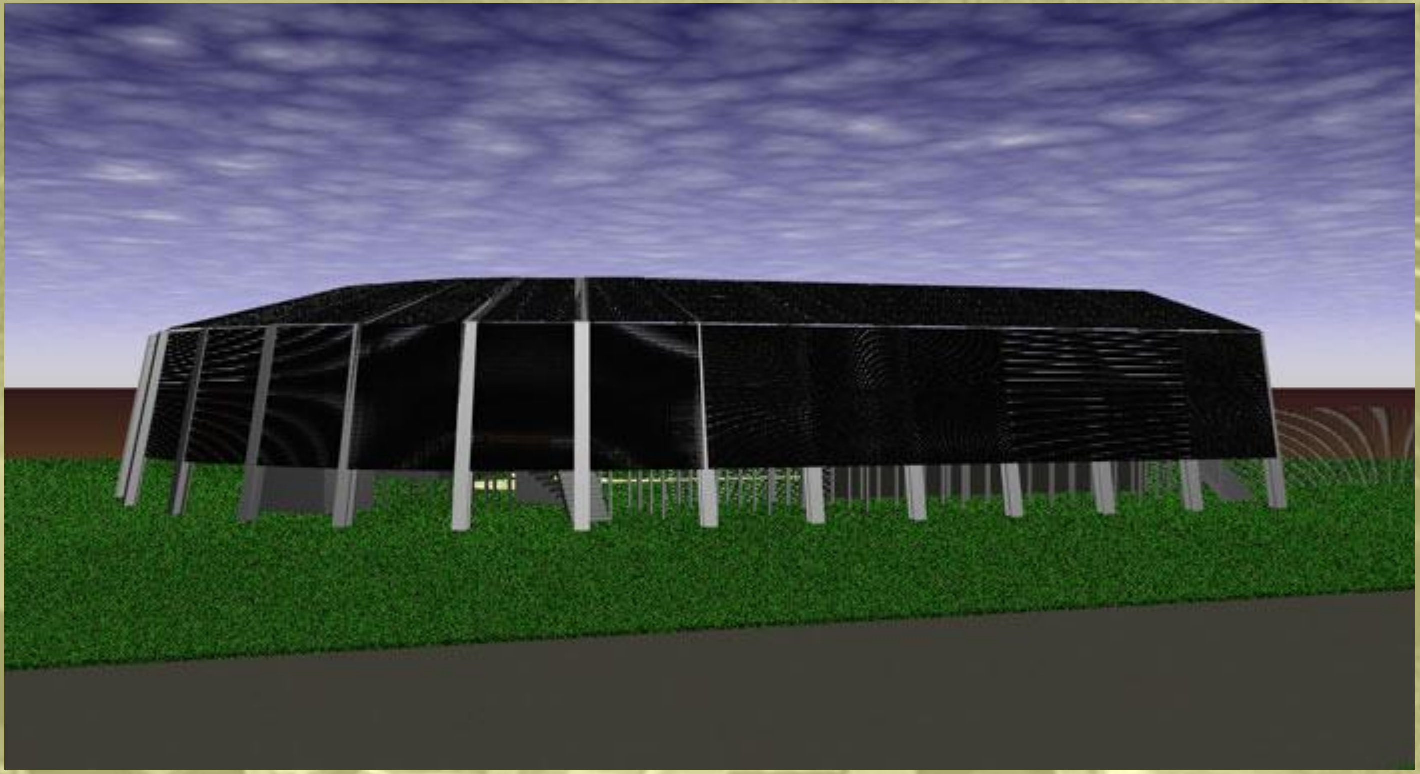
- Provides covered shading for seating area of the baseball field
- Provides a storage area for the maintenance equipment of the facilities crew
- Has possible applications in cooling system associated with the high heat for evacuated tubes
- Provide structure for new announcer's booth and score sign



Structure Pictures



Structure Pictures



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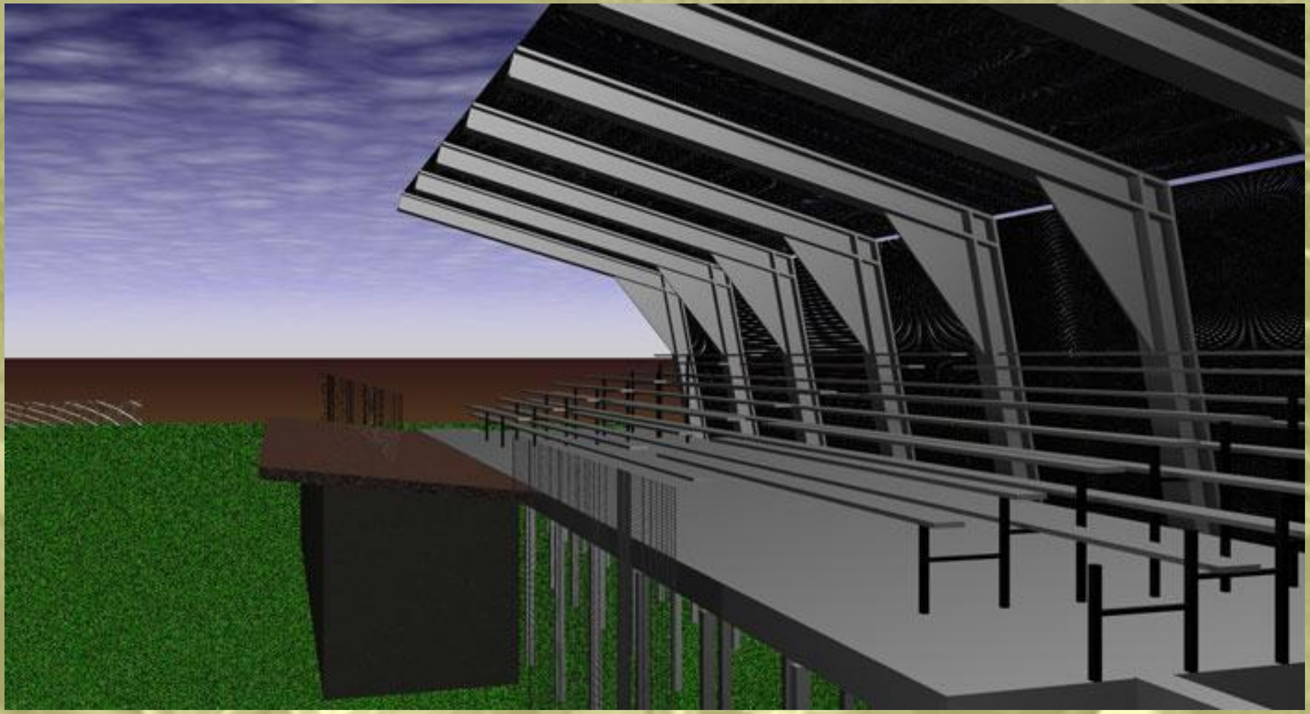

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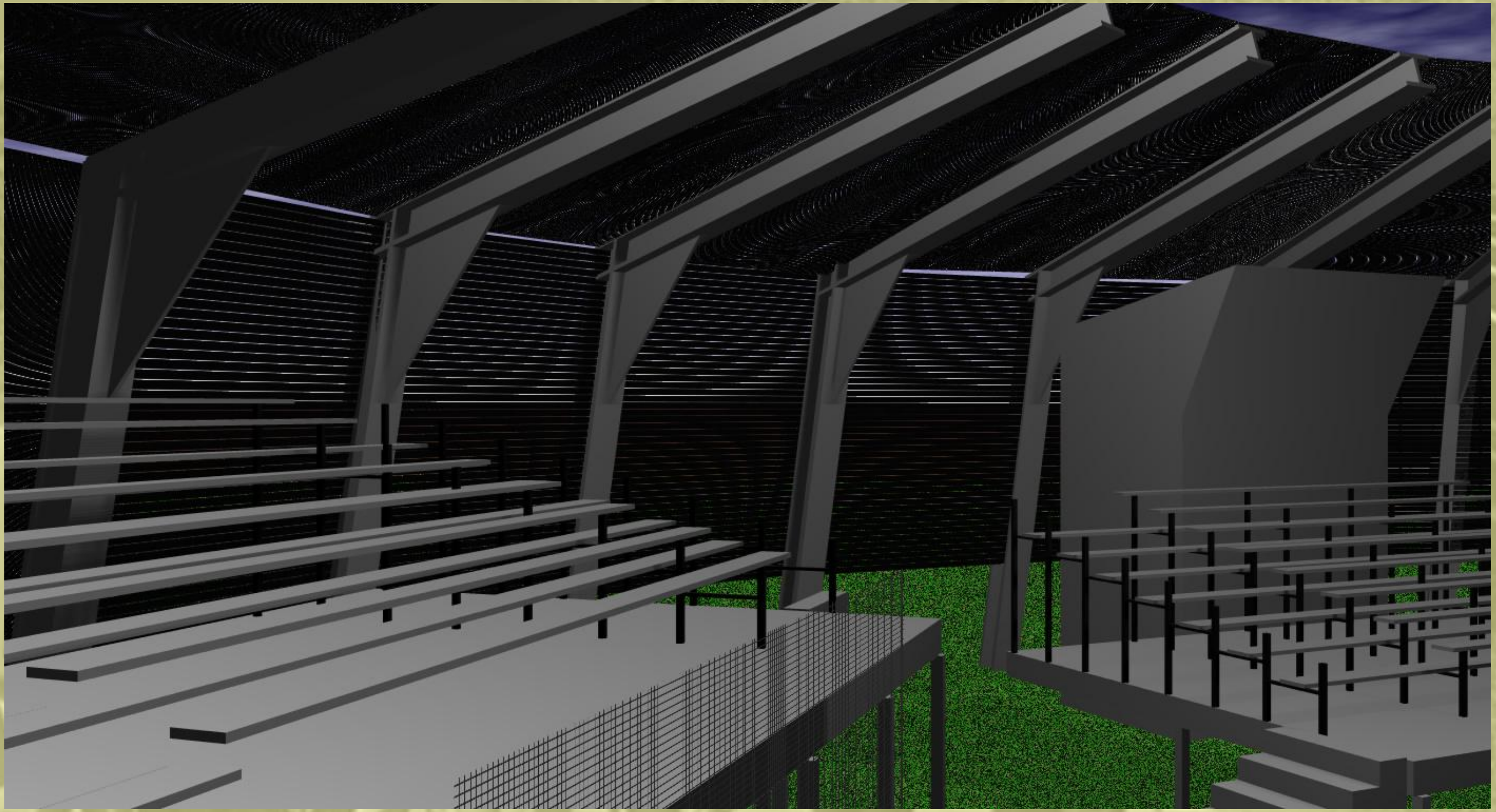

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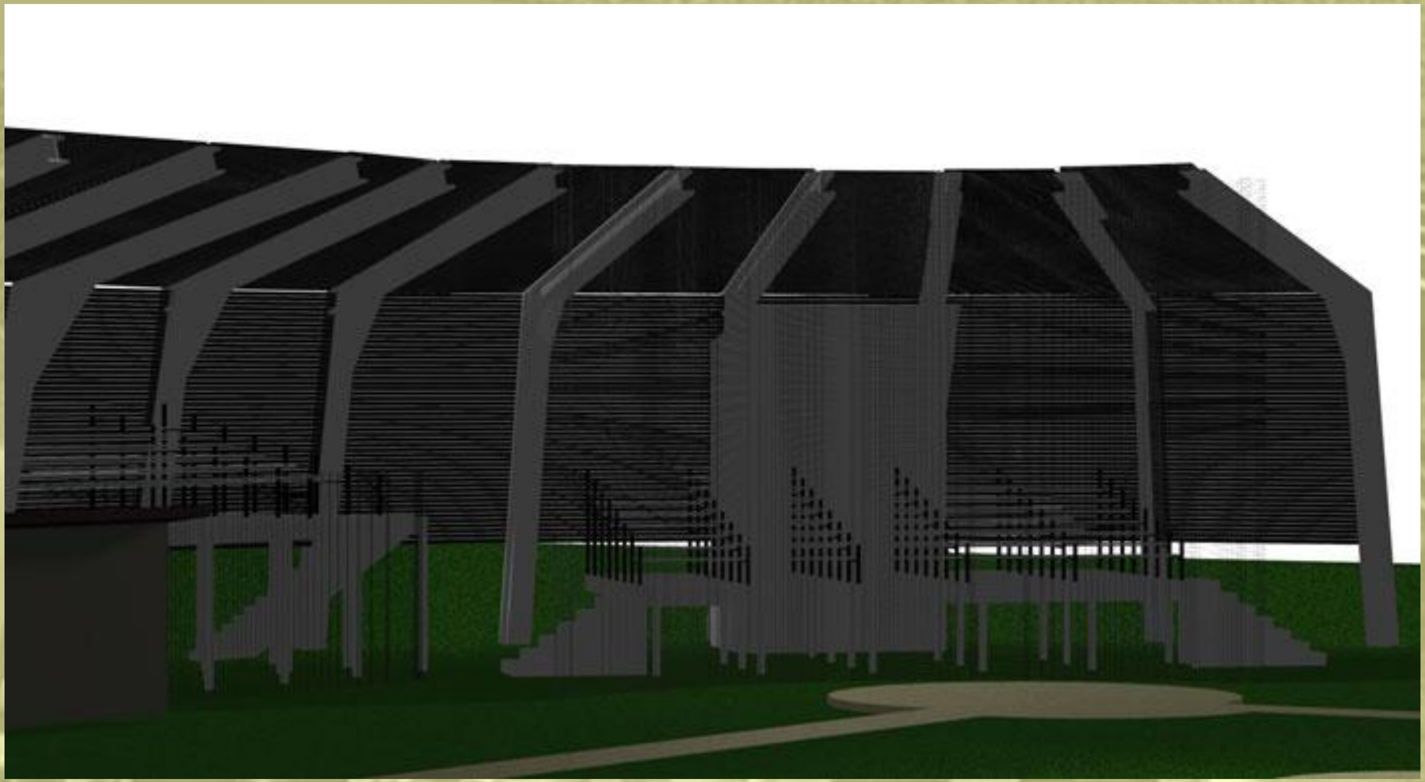
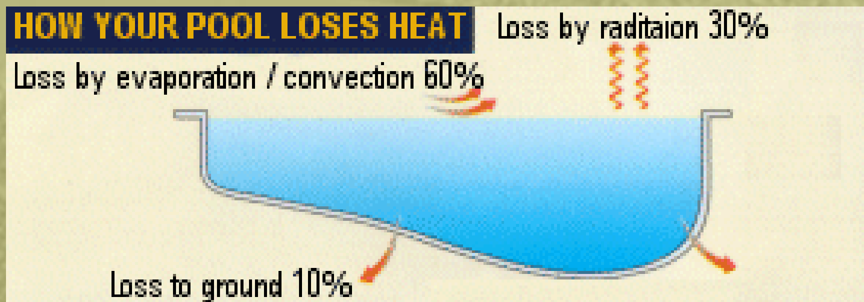


Modifications

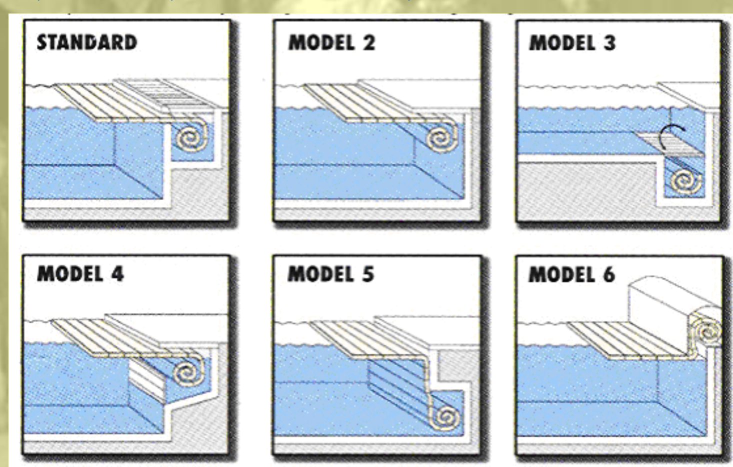
To make the system as work as well as efficient as possible mechanical and additional equipment must be added to Keating hall. These include:

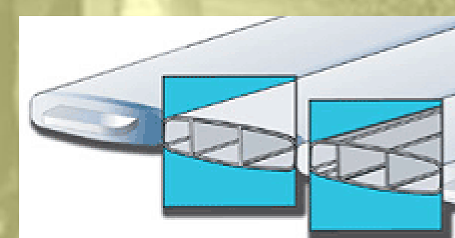
- The mechanical equipment to transfer the heat
- A pool cover
- Additional building envelope

Modifications: Pool Cover



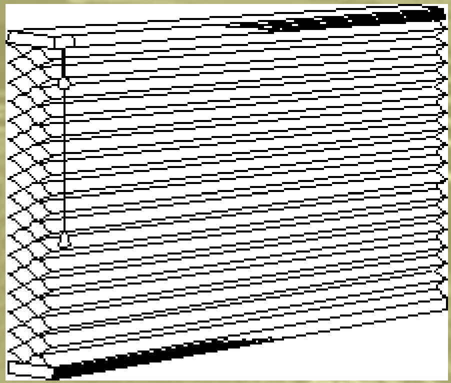
- Up to 90% of the heat loss from pools is via convection and radiation to the air.
- Reduce the pool heat loss by 70 to 80 percent.
- Total Cost, \$50,000-\$80,000



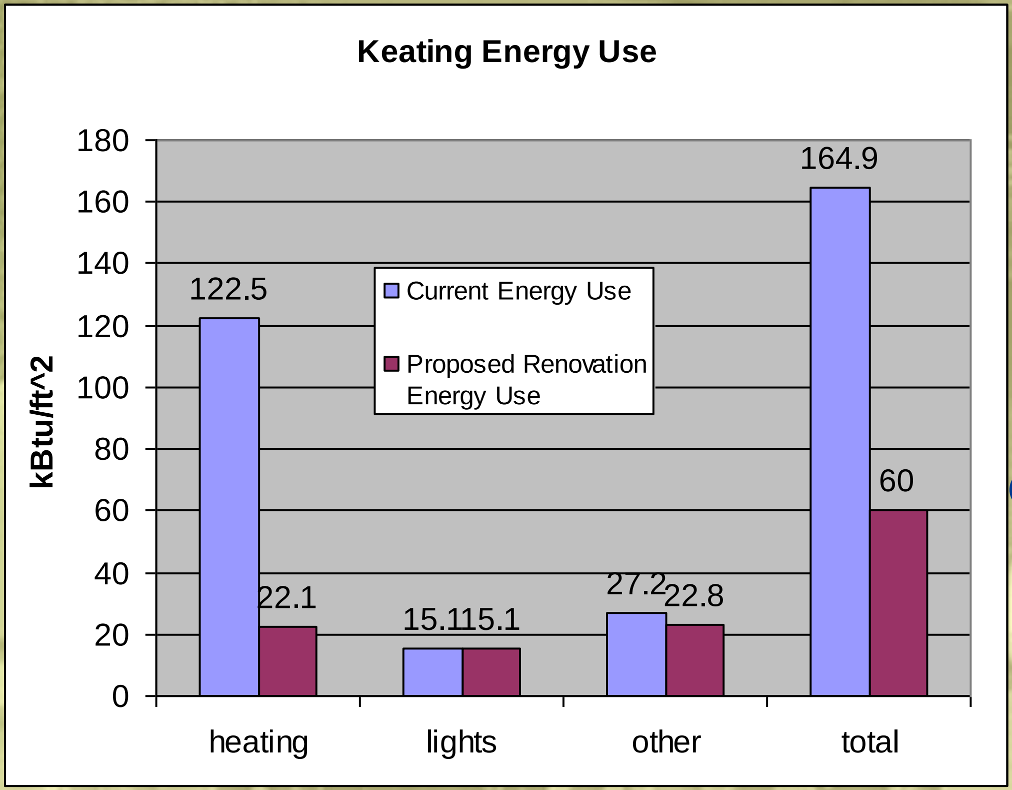


Modifications: Curtain Wall

- Maintain visual appearance
- R value of 5.7
- Reduce the current heat loss and gain by 70 to 80 percent.



Energy 10 Report



The purpose of the Energy 10 software was to calculate the current rate of heat loss in the building and compare with the changes made. The results are shown in the graph to the left.

Changes included:

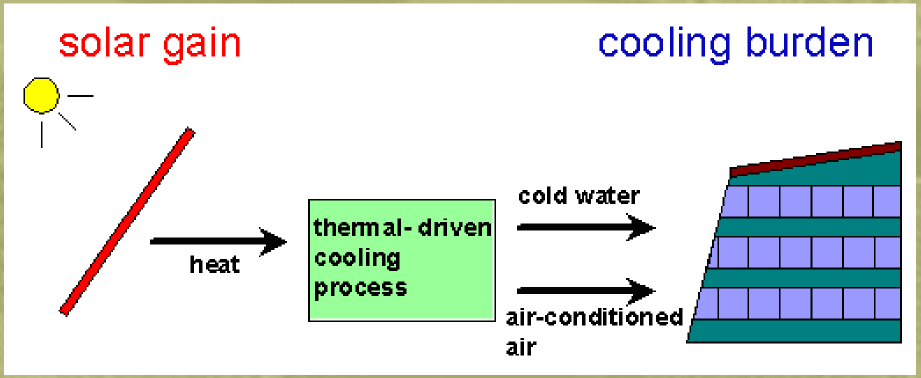
- Solar Thermal Technology
- Pool Cover
- Curtains

Not Included:

- Cooling System

Cooling

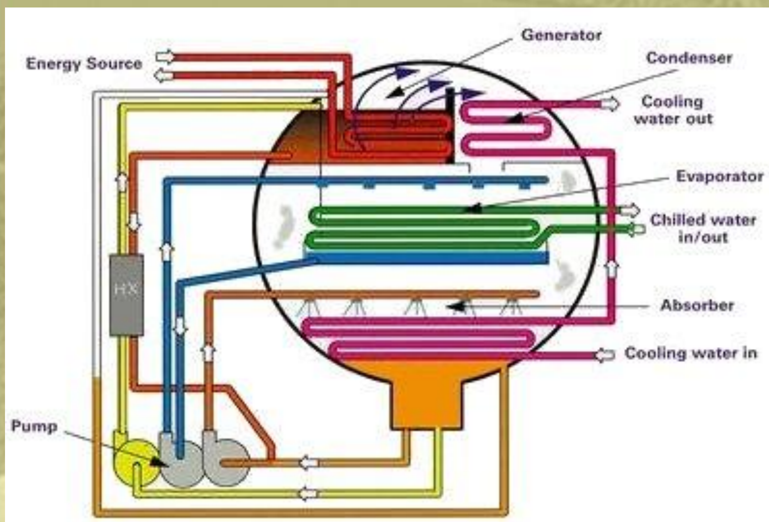
How does Solar Air conditioning Work?



Possible Solar Methods:

- 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

Cooling



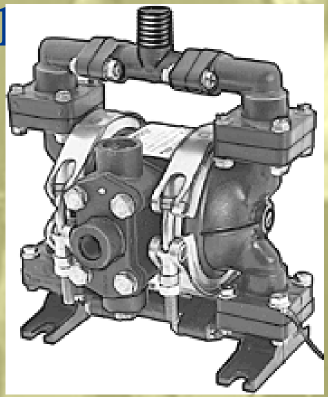
- The chosen method, Absorption cooling system
- The temperature needed to run this system is between 180˚F and 250˚F
- This process uses a chiller that uses the heat load of a building to provide cooling.
- An absorption chiller transfers thermal energy from the heat source (the solar collectors) to the heat sink through an absorbent fluid and a refrigerant.
- Technologies still in development
- Cost = $4000-$10,000 per ton of cooling or approximately $1 Million for Keating.

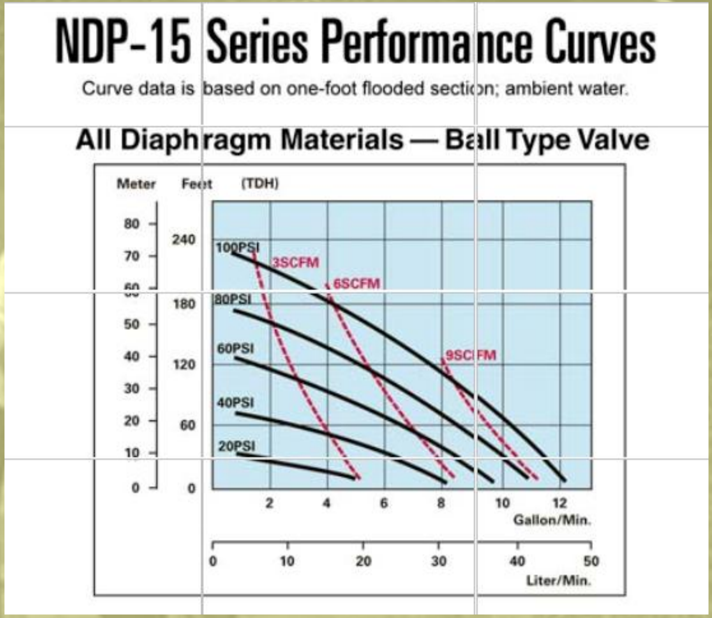
Mechanical System

- ½” diameter pipe
- Minimum 4.15 GPM flow rate with 160 foot pressure head.
- The Yamada NDP-15 pump is constructed of 316 stainless steel and Hytrel Diaphragm material
- Can accommodate temperatures of up to 120
- To run this pump, 80 psi air pressure is required at 4 scfm air flowrate.

PIPING PRESSURE DROP FORM

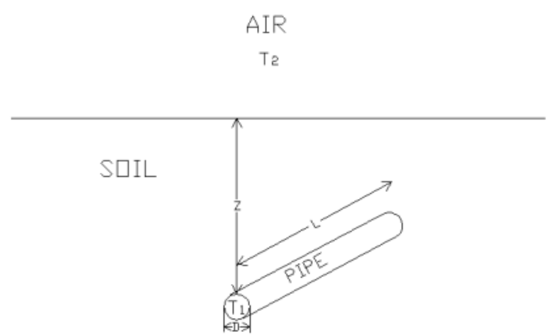
ITEM	GPM	PIPE SIZE (IN)	NO. OF FIT.	FITTING EQ. LEN. (FT)	TOTAL EQ. FIT. LENGTH (FT)	PIPE LENGTH (FT)	TOTAL LENGTH (FT)	PRESSURE DROP FT/100FT	TOTAL PRESS. DROP (FT)
	4.144	0.5	35	0.5	17.5	300	317.5	45.16	143.39
					0		0	0.00	0.00
					0		0	0.00	0.00
					0		0	0.00	0.00
				TOTAL PRESSURE DROP					143.39
				SAFETY FACTOR					10%
				SPECIFIED PRESSURE DROP					157.73





Piping and Heat Loss

Heat Loss of Pipes Underground:



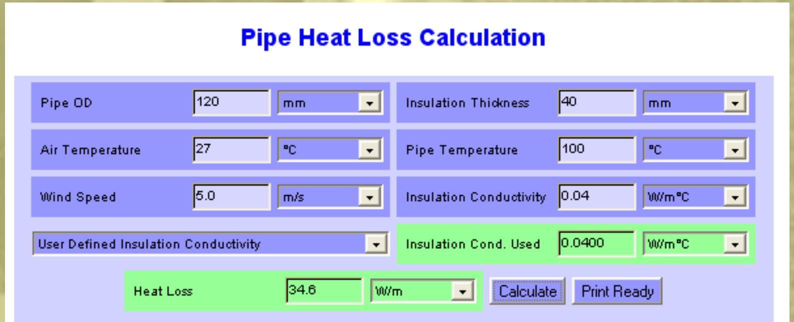
heat lost is $\dot{Q} = k\Delta T S$

where $S = \dfrac{2\pi L}{\ln\left(\dfrac{4z}{D}\right)}$ and $\Delta T = T_1 - T_2$

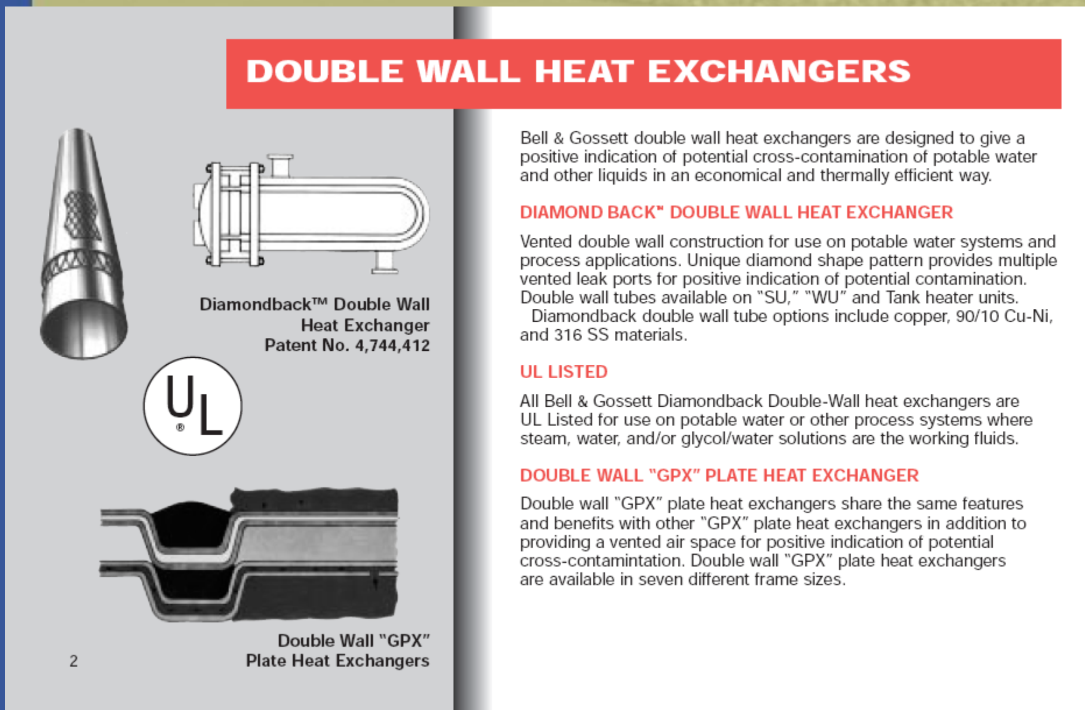
so $\dfrac{\dot{Q}}{L} = k\Delta T S$ $\quad \dot{Q} = k\Delta T \dfrac{2\pi}{\ln\left(\dfrac{4z}{D}\right)} = (Watts/meter)$

The deeper you bury the pipe the smaller the heat transfer.

- ½” diameter piping
- 1” thick fiberglass insulation
- When assuming the ground temperature is on average 50 degrees F and the water will be around 100 degrees C, the total heat loss is found to be 3.5 kBTU/hr in the path underground from the solar collectors to Keating.
- 34.6 W/m loss



Heat Exchanger



DOUBLE WALL HEAT EXCHANGERS

Bell & Gossett double wall heat exchangers are designed to give a positive indication of potential cross-contamination of potable water and other liquids in an economical and thermally efficient way.

DIAMOND BACK™ DOUBLE WALL HEAT EXCHANGER

Vented double wall construction for use on potable water systems and process applications. Unique diamond shape pattern provides multiple vented leak ports for positive indication of potential contamination. Double wall tubes available on "SU," "WU" and Tank heater units.
Diamondback double wall tube options include copper, 90/10 Cu-Ni, and 316 SS materials.

UL LISTED

All Bell & Gossett Diamondback Double-Wall heat exchangers are UL Listed for use on potable water or other process systems where steam, water, and/or glycol/water solutions are the working fluids.

DOUBLE WALL "GPX" PLATE HEAT EXCHANGER

Double wall "GPX" plate heat exchangers share the same features and benefits with other "GPX" plate heat exchangers in addition to providing a vented air space for positive indication of potential cross-contamintation. Double wall "GPX" plate heat exchangers are available in seven different frame sizes.

Diamondback™ Double Wall Heat Exchanger
Patent No. 4,744,412

Double Wall "GPX" Plate Heat Exchangers

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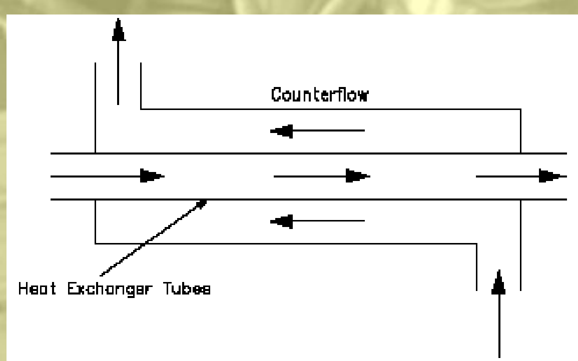
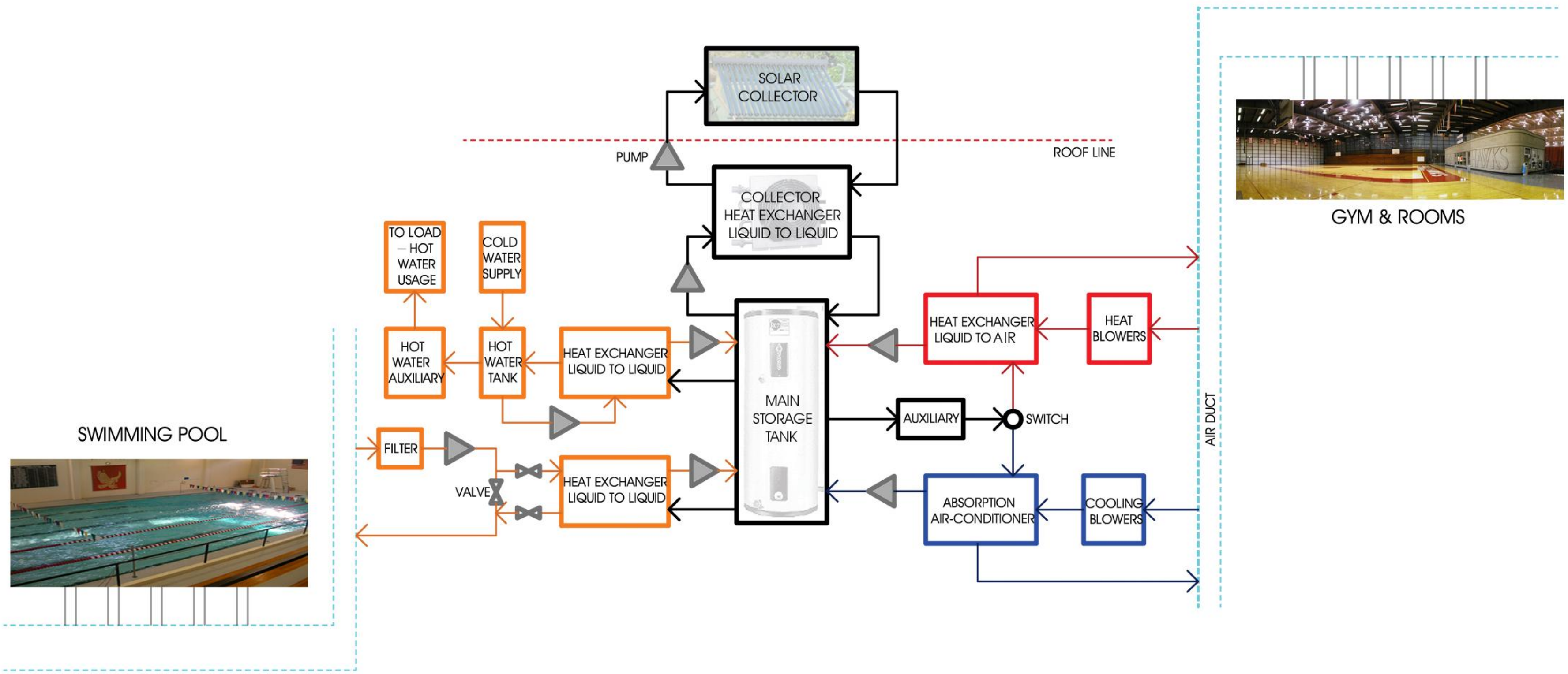


- Double Wall "GPX" Plate Heat Exchanger by Bell and Gossett.
- The design is double wall because Chicago requires a double wall so there is no cross contamination into the domestic water supply.
- Counter-flow setup.
- Cost is approximately $4000.

Heating/Cooling Diagram



Cost Analysis

Structure cost	$ 94,000.00
Collector cost	$ 151,700.00
Mechanical cost	$ 80,000.00
Total cost	$ 325,700.00
Incentive offset	$ 75,850.00
Total Cost with incentive	$249,850.00

IPRO 328

Keating Hall

Cost Analysis

Keating annual energy cost	$ 44,111.00
Structure energy produce	$ 20,464.00
Pay back time	16 years
With incentive	12.2 years

Possible Applications

- Chicago home energy use is typical between $300 to $600
- In a typical Chicago neighborhood is 36 multi-family units
- Once installed the energy saving would counteract expense in 8 -10 years
- Houses are in use from 20 to 50 years.
- Possible use for pool applications

Applications of Solar Thermal Heating in Large-Scale, Urban Buildings

Thank You.