Solar Choice Blinds

Sky Solutions Team

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Mechanical/Industrial Engineering

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Problem Statement

Solar Choice Blinds is a growing company who needs their current solar blind system scientifically evaluated and potentially improved.

Mission Statement

Sky Solutions will evaluate the current Solar Choice Blind product. Controlled experiments will be conducted to analyze the efficiency and thermal output of the blind. A procedure for measurement parameters of these experiments will be developed. Preliminary numerical analyses of the blinds using Computational Fluid Dynamic modeling will be created. Time permitting, the model (if within specifications) will allow studies to be performed to advance system design. Sky Solutions, a student design team within the University of Minnesota Duluth Mechanical/Industrial Engineering Department was assigned a design project for a local company, Solar Choice Blinds. Solar Choice Blinds is a newly developed company that specializes in solar alternative energy products. Over the past 14 weeks Sky Solutions have focused on Solar Choice's current blind product.

Solar Choice Blinds has designed a vertical blind system to efficiently transfer heat from the sun's energy into a home. The design consists of a vertical aluminum sheet which is enveloped in a plastic sheath. Solar energy (light) travels through the window and sheath. The blinds capture the solar energy in this aluminum core through radiation and warm the room by natural thermal convection of room air up between the sheath and aluminum sheet to be discharged back into the room at an elevated temperature.

Intake and Outlet Temperatures

Sky Solutions chose single channel USB loggers capable of collecting 16,000 samples at variable rates. This number of samples enabled the team to collect two consecutive weeks of data at a rate of 1 sample per minute. The data loggers offered the ability to plug in different thermocouple temperature sensors. To access the data the team inserted the logger into a computer's USB port. The included software allowed the team to view the data through graphs, spreadsheets, etc. The data logging system was a simple, affordable, and portable method for collecting the experimentally measured data. There are relationships between when the maximum solar flux occurs in the day and the maximum ambient and outlet temperatures achieved. Table 5 shows that the maximum solar flux occurs around 1:00 PM. After this time the amount of energy that can be transferred into heat decreases. The outlet reaches its maximum temperature at 3:00 PM. **This indicates that although the solar flux is decreasing, the energy stored in the aluminum is able to increase the transfer of heat for another two hours (bold for emphasis)**. The maximum ambient temperature does not occur until 4:00 PM. The distribution of heat through the room increases for an hour.

Table 5: Time of Day Maximum Solar Flux, Ambient, and Outlet Temperatures Occur

Passive System	Max Solar Flux (time)	Max Ambient (time)	Max Outlet (time)
Day 1 (March 14)	1:30 PM	3:30 PM	3:00 PM
Day 2 (March 15)	1:00 PM	4:00 PM	3:00 PM
Day 3 (March 16)	1:00 PM	4:00 PM	3:00 PM
Day 4 (March 18)	1:00 PM	4:00 PM	3:30 PM
Day 5 (March 19)	1:00 PM	4:00 PM	3:30 PM

Table 6 shows that there is correlation between the maximum available solar flux during the day and the maximum core surface temperatures reached by the blinds. As the solar flux decreases from Day 1 to 3, the maximum core surface temperatures decrease as well. A decrease of 50 Watt/m_2 resulted in a six degree loss of the core surface temperature. Atmospheric conditions, such as temperature, cloud cover, and precipitation will interfere with the blind's ability to reach higher surface temperature. Although the highest solar flux occurred on Days 4 and 5, the maximum core surface temperatures reached were similar to Day 3. The maximum core surface temperature reached by the blinds will vary depending on the outside environmental conditions.

Table 6: Maximum Solar Flux and Core Surface Temperatures

Passive	Max kW/m^2	Max Core Surface Temp. (Deg. F)
Day 1 (March 14)	0.966	114
Day 2 (March 15)	0.956	110
Day 3 (March 16)	0.916	108
Day 4 (March 18)	1.02	109
Day 5 (March 19)	1.01	106

The results of the fluid temperature distribution suggest the fluid volume attains the core surface temperature (319 Kelvin/116 F) within the lower third section of the blind. The thermal heat transfer from the core surface to the fluid has a direct correlation to the velocity flow through the blind. The average inlet temperature (295 Kelvin/71 F) of the fluid is slightly above the ambient air temperature. **As expected, the average outlet temperature is equivalent to the aluminum core surface temperature (bold for emphasis).**

The energy output for the current blind product has been calculated based on three experimentally recorded values: Air Velocity, Inlet and Outlet Air Temperature. Through heat transfer analysis, an energy value of 60 watts per blind segment has been calculated. This means a one window blind system containing 24 slats yields approximately 11.5 kWh per day. **This one window system value represents approximately 7% of the energy consumed in heating an average home in northern Minnesota during the winter months (bold for emphasis).**

Energy Output Analysis

Energy required to heat an average home in northern Minnesota during the winter months was based on a program provided by Minnesota Power's website. With this information it can be determined with a high degree of confidence how much heat the blinds produce in relation to the average home heating requirements. It will help the team to determine how much money consumers can expect to save on their heating bills by using the Solar Choice Blinds. For the efficiency of the blinds it must be determined how much solar flux is received from the sun as measured by the pyranometer on top of the stadium. Then, using the amount of heat produced by the blinds, the efficiency will be determined.

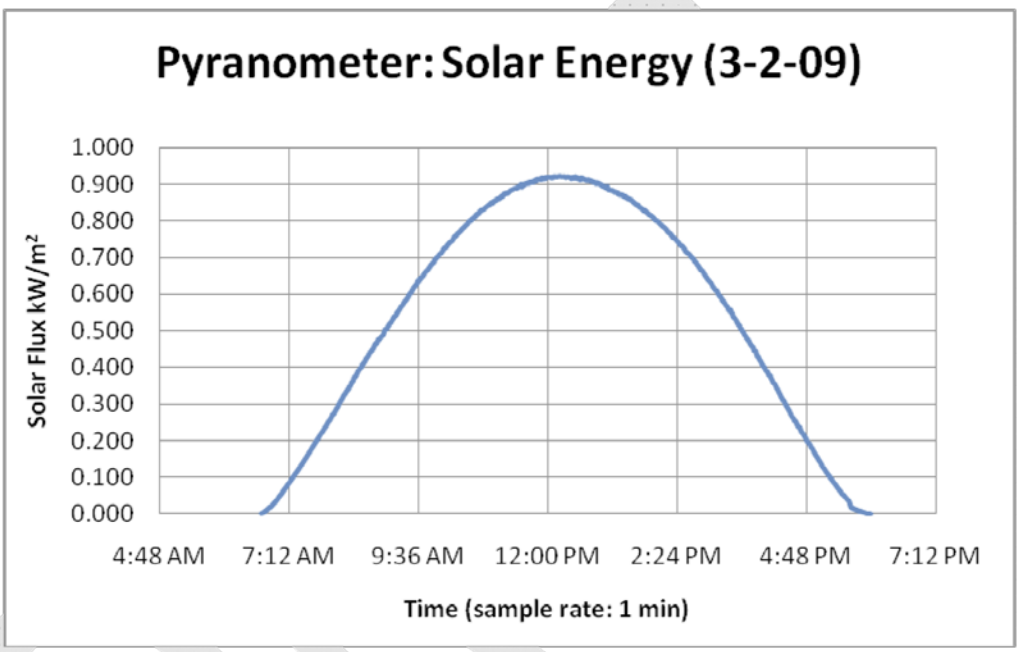

Figure 9: Solar Energy (Malosky Stadium)

Calculations

Solar energy transferred from the blinds can be determined on three experimentally measured quantities: Air Velocity, and Inlet and Outlet Air Temperature. The following assumptions were made:

1. Steady-state Operating Conditions Exist
2. The room air can be treated as an ideal gas with constant properties at room temperature

Energy generated per day based on 8 hours of sun at highest intensity:

$$Q_{total} = 11.52 kWh$$

$$Q_{total} = 3.933 \times 10^{4} tBTU$$

$$Q_{total} = 4.147 \times 10^{7} J$$

Efficiency based on an average thermal BTU used to heat

a 1600 square foot home per day in Northern Minnesota.

$$\eta := \frac{Q_{total}}{571000\ tBTU}$$

$$\eta = 6.889\%$$

Natural Convection Calculations

The efficiency analysis that is currently underway makes a number of assumptions in order to simplify the problem. The assumptions are listed below:

1. Assume natural convection over a vertical plate
2. Assume 8 hrs. of "workable" sunlight a day
3. Surface temperature is 100°F and ambient temperature is 60°F
4. Average heat required in winter is about 571,000 BTUs/day

These assumptions should help us provide accurate data to Solar Choice regarding the efficiency of their blinds.

$$Q_{total} = 2.091 \times 10^4\ BTU \qquad Q_{total} = 6.129 kWh$$

$$\eta := \frac{Q_{total}}{600000 \cdot BTU}$$

$$\eta = 3.486\ \%$$

From these calculations, if ideal gas behavior is assumed with incoming air at 60°F exiting air at 100°F by natural convection through the blind, the blind system efficiency is about 3.5% of required energy needed to heat the average home.

Experiment Location Alternatives

To perform the experiment on the blinds the team will need an experimental facility. The three location possibilities are: Malosky Stadium, Darland Administration building (Regents Room), and the Solar Choice Testing Facility. The location that would give the most realistic data will be chosen as the best alternative.

Malosky Stadium

The first location the team has studied is Malosky Stadium located on the UMD campus. A benefit of this location is the close proximity to the M.I. Engineering Department. Malosky Stadium has three rooms that could be used to set up different blind sets. This would be valuable because the team could perform analyses comparing various blinds under similar conditions at the same time. The rooms are identical in their dimensions and characteristics assuring consistent data collection. The Engineering department is conducting their own experiment involving solar energy, and would allow our team to use their resources to aid in the solar blind effectiveness experiment. Using their pyranometer would give the team an accurate reading of the sun's intensity on the windows. Another resource is the department's computer and data logger used to store the data that is being retrieved from the sensors. There are currently 12 open channels in the data logger that are available for additional sensors to monitor room conditions. At Malosky Stadium Sky Solutions could perform data analysis whenever it is convenient. .

Sky Solutions has been given permission by UMD Facilities Management to have exclusive access to the three identical rooms. Low traffic through the experimental rooms provides consistent data. There is possibility of keeping the rooms thermostats at the same temperature, but room air flow is difficult to control due to air duct flow. By sealing the vents none of the heat transferred by the blinds (into the air) can escape, enabling the team to analyze its true heat output (BTUs). To accommodate the blinds at Malosky Stadium the team has built a structure that holds the blinds 2.75" away from the windows. The blinds hang on hooks drilled into 2" x 4" boards and which allow the team to control the angle of the blinds.

Malosky Stadium has south facing windows that are large enough to hold multiple blind sets. The stadium windows are composed of double pane low-emissivity (low-e) glass that obstructs a portion of the solar energy. Low-e glass limits solar flux through the glass providing low efficiency data.

Darland Administration Building (Regents Room)

The second location for this experiment is also located on the UMD campus. Like Malosky Stadium, a the benefits are proximity and access. This location has a room large enough to house the multiple blind sets, required for the experiment. the room is significantly larger than the rooms located in Malosky Stadium, analysis would be limited. While Sky Solutions would not have the pyranometer at this location, the team could use the measurement at Malosky Stadium as a baseline estimation of solar flux. Since both location's windows are south facing they should have the same flux hitting them and be a legitimate comparison for our experiment. Darland Administration could still give an accurate calculation of the efficiencies of the various blind sets. Opposed to the windows at Malosky Stadium, Darland features windows that filter less of the incident solar energy, which is crucial for the blinds to perform as designed. The ECE computer resources will be unavailable, but our own laptop computers could be used to collect data on the blinds. The team could capture the data to Excel spreadsheets and gather it on a weekly basis. This would require the use of a data logger which may add more expense to the project.

Unlike Malosky Stadium, the room in Darland is highly trafficked. Data consistentcy is a concern. The doors opening and closing would allow the heat salvaged by the blinds to escapethis location has multiple vents allowing external air in the room. Although the vents could be temporally sealed, frequent door opening would significantly reduce the accuracy of the experiment. This location, with only a single room for testing, would not allow the team to run different types of blind sets at the same time.

Solar Choice Testing Facility

The final location that the team considered for performing the experiment is at Solar Choice's own Testing facility. The facility is located on a lake about 20 minutes away from UMD campus. This location has many benefits that would allow the team to observe accurate measurements. The major advantage to using this facility is that the windows allow a much greater portion of solar energy than windows found on campus. The facility has large south facing windows which allows the blinds to transfer heat more easily. This will enable Sky Solutions to measure values that would be more a more reasonable approximation of the type of windows found in most homes. The location itself is one room that is large enough to hold multiple sets of blinds, enabling the team to gather more data for the experimental analysis. Another advantage to using the Solar Choice Testing Facility is that the team would be able to control the ambient air temperature. This will allow Sky Solutions to gather more useful data for a more accurate analysis of blind efficiency. There will be few people entering or exiting the Solar Choice Testing Facility, again adding to experimental accuracy.

The facility forces the team to overcome some difficulties to obtain acceptable experimental results. At this location no pyranometer is installed to measure the sun's flux hitting the south facing windows. To estimate equivalent flux at the facility the team will use the pyranometer results at Malosky Stadium. The flux of these locations should be similar and is likely reasonable to use in the experimental analysis. Another inconvenience would be the distance between UMD and the testing facility. It may not be possible to retrieve data on a regular basis. To address this issue, the team proposes the initialization of a data collection device (data logger) that could store data for for an extended period.

Before the team could decide what the best alternative location was to perform the experiment it was necessary to gather initial data. The most vital measurements in the experiment are the inlet/outlet temperatures and the air flow velocity of the blind. These measurements will enable Sky Solutions to calculate the amount of energy coming out of the blind. The following are the initial findings at Malosky Stadium and the Solar Choice Testing Facility:

Table 7: Location Blind Measurement

Location	Inlet Temp. (Deg. F)	Outlet Temp. (Deg. F)	Air Velocity (m/s^2)
Malosky Stadium	76	83	0.1
Solar Choice Testing Facility	70	94	0.9

Note: *Data was not gathered at Darland due to lack of accessibility. Darland Administration Building was rejected because of its uncontrollable environment. Also, temperature measurements at the Solar Choice Testing Facility location have been found to be as high as 106 deg. F at the upper portion and as low as 65 deg. F at the lower portion of the blind.*

Based on the research Sky Solutions conducted, the following weighted matrix has been devised to explicitly choose between the alternative locations:

Table 8: Location Decision Weighted Matrix

Variables	Weight	Malosky	Darland	Solar Choice Testing Facility
Windows	10	1	2	5
Vents	4	4	3	2
Traffic	9	5	3	4
Distance	2	5	5	3
Resources	6	5	3	4
Total Score		**111**	**87**	**133**

Usage Display
Date: Jun 01/09
Time: 03:57 PM

Standard Usage Display

User: jturnqu

5190

Customer: 317231 Name: KEITH MCKINZIE

	Posting Code	Description	Location	Units 1	Amount 1	Units 2	Amount 2
1	30	LPG-PROPANE R	Tank 1	841.80	1,909.19	1,627.00	3,805.07
2	Subtotal (1): 30			841.80	1,909.19	1,627.00	3,805.07
3	336	SERVICE CHARG		0.00	11.30	0.00	0.00
4	Subtotal (1): 336			0.00	11.30	0.00	0.00
5	351	FUEL SURCHARG		0.00	8.94	0.00	24.88
6	Subtotal (1): 351			0.00	8.94	0.00	24.88
7	352	HAZMAT FEE		0.00	11.49	0.00	11.49
8	Subtotal (1): 352			0.00	11.49	0.00	11.49
9	400	PAYMENT		0.00	2,353.83	0.00	3,428.53
10	Subtotal (1): 400			0.00	2,353.83	0.00	3,428.53
11	Grand total (5)			841.80	4,294.75	1,627.00	7,269.97

JUNE 1st 08
MAY 31st 09

JUNE 1st 07
MAY 31st 08

Superior Fuel 877-388-1744

NOTE FROM DAVID STRANDBERG OF SOLARCHOICE: The below figures for 6/08-5/09 do not include a propane delivery from another supplier. Superior Fuel Company delivered 375 gallons on 3/27/09 and 48 gallons on 4/30/09 for a total of 423 gallons. Adding 423 to the 841.80 total above equals 1264.80 gallons. This equates to a period v. period reduction in propane gallons used of approximately 23%.

COMPARATIVE YEARS SUGGESTS A 23% REDUCTION IN PROPANE USAGE (Gallons).

E-MIAL COMMUNICATION BETWEEN UNIVERSITY OF MINNESOTA/DULUTH SKY TEAM LEADER, THOMAS RUSTAD, AND JOHN F. STAPLETON OF SOLARCHOICE REGARDING VANE PERFORMANCE.

From: John F Stapleton
Sent: Tuesday, April 14, 2009 12:27 PM

To: 'Thomas Rustad'
Subject: RE: Value Proposition

Previous information was that the panels tested

- yielded in excess of 40,000 BTU's per 8 hour period
- from 6,912 square inches of aluminum exposed to the sun
- equating to 5.51 BTU's per 8 hour day
- calculated on a 30 day per month basis
- equals 262,766,592 BTU's