Performance Review of the SH 1500G Solar Air Heater

Manufactured by Your Solar Home

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1.0 Introduction

This report explains the informal testing method of the SH 1500G, performed by a student at Ryerson Universit y as part of an undergraduate thesis. The tests were performed throughout the month of March, to determine the energy output and efficiency of the solar collector, in outdoor winter conditions.

1.1 Introduction to the SH1500G

The Solarsheat 1500G is manufactured by Your Solar Home in Vaughan, Ontario. The unit is a glazed recirculation solar air collector designed for space heating applications. Colder inside air near the floor is drawn into the collector, reheated and forced back into the room, by the use of a fan, near the ceiling. The SH 1500G consists of two parts. The 1.9m² collector plate consists of a tempered glass outer surface, and a black painted corrugated aluminum absorber. The second part consists of a 0.5m² (14.5 watt) PV cell, making the total area of the unit 2.4m². The internal fan inside the unit is powered by the 14.5 watt PV cell, allowing the collector to operate with no electrical hookup. The fan is variable speed, and provides variable flow rates based on the intensity of solar radiation. Air is supplied to and from the collector by 127mm (5”) ducts. The unit is integrated with the home’s main heating system by virtue of satisfying the main thermostat before the furnace or existing heating system is called upon to do so. The unit is also controlled by a secondary thermostat so the space won’t over heat on warm days with intense sunlight. The manufacture claims that the unit can produce enough heat for about 92m² of living space. The life expectancy of the product is 25-30 years and retails for $1799 Canadian.

Figure 1-Schematic diagram of how the SH1500 G works.

2.0 Methodology

The testing of the SH 1500G is based on the prescribed methods of the ASHRAE 93-2003 standard “Methods of Testing to Determine the Thermal Performance of Solar Collectors”. This standard is used in Canada and the US to test solar collectors which heat air, water or any other single phase fluid. The testing will be used to determine the efficiency of the SH 1500G collector, the amount of the sun’s energy which can be converted into heat energy. By testing the collector other important relationships will also be observed such as the minimum intensity of solar radiation required to operate the fan unit, or to provide sufficient temperature rise, and maximum temperature rise based on the intensity of solar radiation, and ambient temperatures.

2.1 Determining the efficiency of the solar collector

As prescribed in ASHRAE Standard 93-2003, the efficiency of the solar collector can be calculated by the following equation:

$$\eta = \frac{m \bullet cp \bullet (t_{fe} - t_{fg})}{Ag \bullet It} \quad (2.1)$$

Where: η = The percentage of solar radiation converted into heat
m = mass flow rate of air (kg/s)
c_p = Specific Heat, constant = 1.005
t_{fe} = temperature of air leaving the collector (ºC)
t_{fg} = temperature of air entering the collector (ºC)
A_g = area of solar collector (m²)
I_t = global solar irradiance incident upon the aperture plane of collector (W/m²)

2.2 Test setup

The collector was set up for testing on a mount made of 38x89 lumber, 60° to the horizon, and facing 0° south. The testing location was in Pickering, Ontario approximately 35km from Downtown Toronto, with approximate GPS coordinates of 43°N, 79°W. Required readings for testing were taken every 20 minutes, and eleven in total were taken throughout the day. Five were taken prior to solar noon, one at approximately solar noon, and five after solar noon. This is so that solar angles around the collector will be symmetrical throughout the testing period. The testing period did not extend beyond 120 minutes plus or minus of solar noon because low winter sun angles, and natural obstacles, such as trees and other buildings in the testing area did not permit unobstructed solar access on the collector beyond this time frame. Solar noon was determined by the following equation:

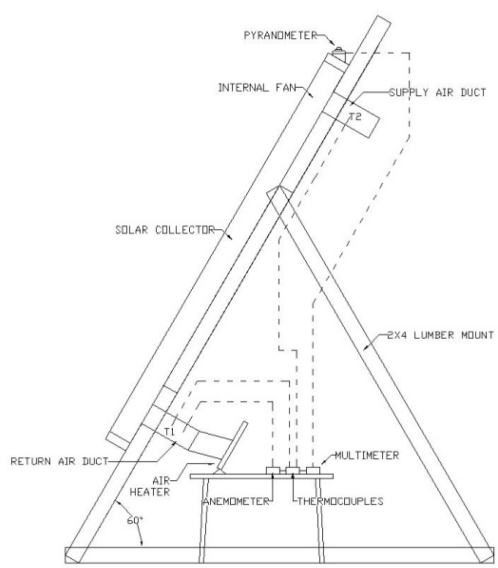

Figure 2.2: Planned design of test

$$\textbf{AST} = Rt + 4(L_{st} - L_{loc}) + E \qquad (2.2)$$

Where: AST = absolute solar time (00:00 hrs:mins)

Rt = real time (00:00 hrs:mins)

L_{loc} = Longitude of Location (ºW)

L_{st} = Standard meridian for local time zone (Eastern Time Zone = 75ºW)

E = [9.87 sin(2B) - 7.53 cos(B) - 1.5 sin(B)]

B = 360 (n - 81)/364

n = day of the year, January 1 being day 1

2.3 Required Instrumentation for Testing

The Instrumentation used in the testing is as follows:

1) **Pyranometer** – Used to measure the intensity of solar radiation incident on the collector. The brand used was Kipp & Zonen: SP Lite. The specifications have tested the unit to be accurate to ±5%.
2) **Multimeter** – Used to measure the voltage output of the pyranometer, used to determine the intensity of solar radiation in W/m². Brand used was Fluke: 79III
3) **K-Type Thermocouples** – Used to measure the temperature of flowing air at the supply and return air duct of the solar collector. The brand used was Digi-Sense. The instrument has an accuracy of ±.5°C
4) **Rotating Vane Anemometer** – Used to measure air speed in m/s through the collector. The brand used was Airflow. Accuracy ±3%

Figure 2.3: Test set up of the solar collector

To ensure that the equipment would provide accurate results an error analysis was performed to ensure that after equating the data from the instrumentation the percentage of error was less than 5%. The error analysis showed an accuracy of 4.24%.

Other equipment required for testing:

1) Air heater, used to preheat outside air to near room temperature before entering the solar collector. This is to make the testing as close as possible to a real life use. The air heater used for the testing was a halogen type heater. This heater contained no additional fan unit, to avoid introducing errors in air flow through the collector
2) 5" diameter rigid and flex duct.
3) Aluminum tape, for taping joints in the duct work.

2.4 Use of Pyranometer and the Calculation of Solar Irradiance

As noted above the pyranometer is used to determine the intensity of solar radiation. To ensure accurate readings the device must be placed level using the attached leveling fixture which comes with the unit. The instrument must also be set up, where it will not be shaded from the sun by another object. The pyranometer outputs the reading in voltage (μV) so the use of a high sensitivity multi-meter must be used to display the readings. Once the multi-meter is wired correctly with the pyranometer, the multi-meter will display the reading. To calculate solar irradiance the following equation must be used:

$$E_{solar} = \frac{U_{emf}}{S} \qquad (2.3)$$

Where: Esolar = Irradiance (W/m²)
U_{emf} = Output Voltage (μV)
S = Sensitivity ($\frac{\mu V}{W/m^2}$)

Sensitivity ranges from 60 to 100 μV/W/m² depending on how the instrument was calibrated. The calibration certificate for the pyranometer used in this experiment stated the sensitivity to be 74 μV/W/m². It is also important to note that since the pyranometer sits on a level horizontal base, and the collect sits 60° to the horizontal, the value for E-solar must be multiplied by Sin60 to determine the true value of solar irradiance on the collector.

2.5 Use of the Anemometer and Calculation of Mass Flow Rate

The use of the Anemometer is to determine the speed of air in m/s flowing through the collector. A 100mm diameter vane type anemometer was used instead of a probe type to ensure greater accuracy of air speeds, since air speeds vary inside of an air duct. (air traveling down the center of the duct travel faster then air near the sides) The vane of approximately the same diameter as the air duct was placed inside the center of the return air duct. To convert the reading of m/s to kg/s the following equation was used:

$$m = \rho \bullet V \bullet A \qquad (2.4)$$

Where: m = Mass flow rate (kg/s)
P = Density (kg/m³)
V= Velocity (m/s)
A= Cross-sectional area of air duct (m²)

3.0 Observations

A summary of the observations from testing of the SH 1500-G is presented below. The R-squared value on the graphs shows the predictability of the relationships between the variables in the solar collector efficiency equation. The closer this value is to 1 the greater predictability of the relationship.

3.1 Air Flow Rate of the SH 1500G

Since the internal fan for the solar collector is powered by a PV cell, it runs at variable speeds depending on the intensity of solar radiation absorbed by the collector. Figure 3.1 represents air speed levels in m/s at the return air duct measured by the anemometer versus the intensity of solar radiation. The air speed increases as the intensity of solar radiation increases. From observations it was concluded that the fan will not operate when solar radiation levels drop below 300W/m². Based on the information from the chart the maximum air velocity recorded was approximately 2.5m/s which means the volume of air travelling through the 127mm (5") air duct is equal to 0.03m³/s or 65cfm

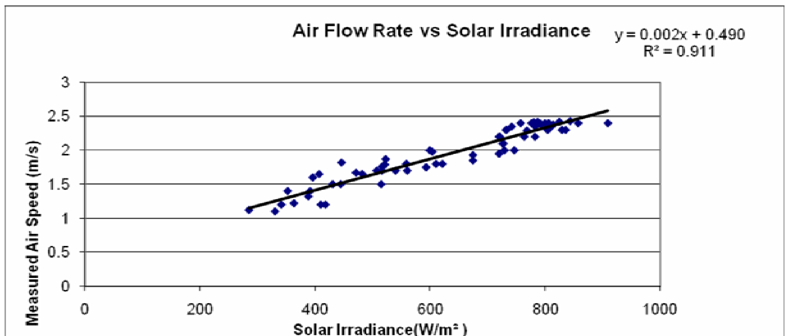

Figure 3.1 Air speed in return air duct based on solar radiation

3.2 Temperature Rise of the SH 1500G

Figure 3.2 displays the difference in air temperature between the temperature of air measured at the supply air duct (t_{fe}) leaving the collector and the ambient air temperature. Temperature rose between 30 and 40°C when the intensity of solar

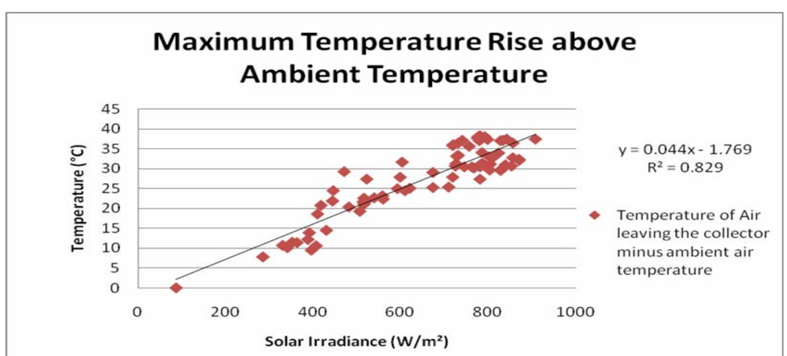

Figure 3.2 Maximum temperature rise above ambient air temperature

radiation on the collector reached 800W/m².

Using the halogen heater, different air temperatures entering the collector were tested on March 9 and March 11, to determine how the temperature of air leaving the collector and overall temperature rise would be effected. The results from these two experiments showed that under similar values of solar radiation, and ambient air temperature, that even when the initial temperature (temperature of air entering the collector, t_{gf}) was varied by about 10°C, the final temperature (temperature of air leaving the collector, t_{fe}) only differed by 2°C. Figure 3.2.1 shows these results. Figure 3.2.2 shows how the efficiency of the collector is increased since the temperature difference between the initial temperature and final temperature is increased on March 11th than on March 9th.

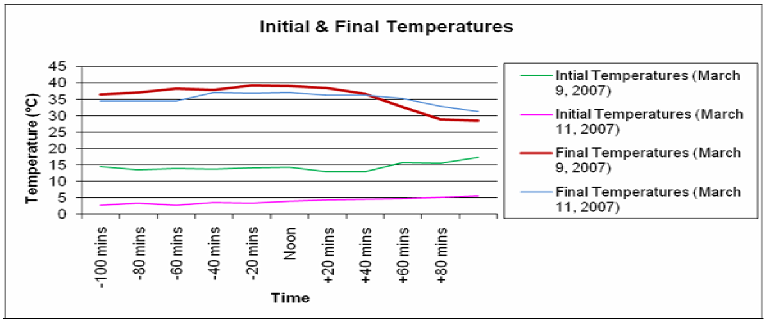

Figure 3.2.1: Temperature comparisons on March 9 and March 11.

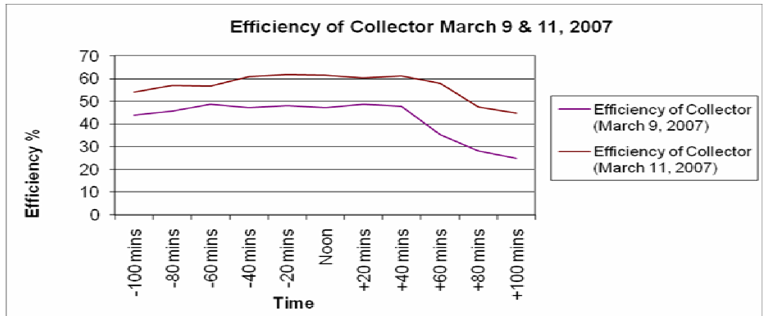

Figure 3.2.2 Difference in efficiency of the collector on March 9 and March 11

3.3 Efficiency of the SH 1500G

Figure 3.3 shows that as the intensity of solar radiation increases so does the efficiency of the collector. The graph also shows that the SH 1500G operates when the intensity of solar radiation is above 400W/m². The data points taken for this graph were taken when the ambient air temperature was observed at around 0°C, and the temperature of air entering the collector was heated to around 14°C. From this data the highest efficiency was recorded to be 49.42% and average efficiency was calculated at 33.7%. Higher efficiency values were calculated under different testing conditions. As noted above in section 3.2, when the temperature of air entering the collector was not pre-heated efficiency values increased. During the testing period on March 11, the efficiency of the collector reached its highest at 61.66%.

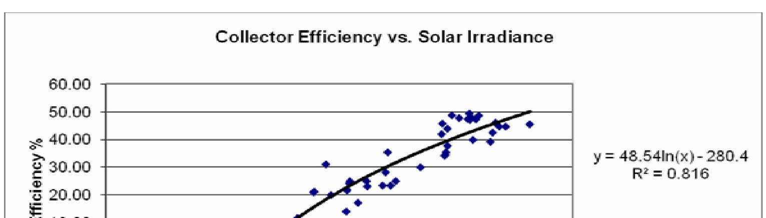

Figure 3.3 Collector Efficiency vs. Solar Radiation

4.0 Conclusion

Based on the observations above, the SH 1500G can operate quite well on a clear sunny day when the intensity of solar radiation climbs above 700W/m^2. When these conditions are present, the SH 1500G can output a volume of air of 0.024m^3/s (50cfm), increase the temperature of that air by over 30°C, and have a level of efficiency around 45%. Using the air flow rate of 0.024m^3/s a or 50cfm the collector could provide a full air change of a 92m^2 (1000 sqft) dwelling with a volume of 220m^3 (8000cubic feet) every 2 hours and 40 minutes. With these performance characteristics, the SH 1500G can provide enough heat to be equivalent to a 1kW heater.

Appendix A:
Photos of Test Setup

Appendix B:
Raw Test Data