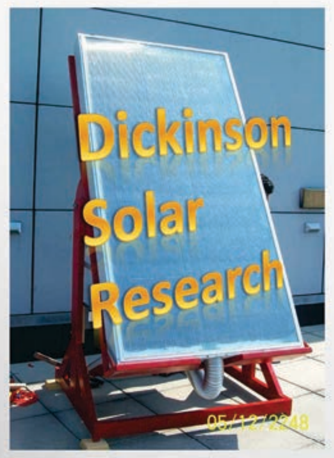


Dependence of the Efficiency of a Gridded Solar Air Heater on the Mass Flow Rate.

Dickinson

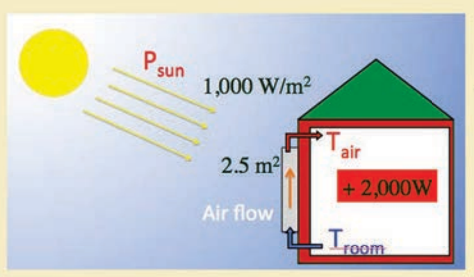
Tyler Ralston, John Root, Jonathan Barrick, and Hans Pfister

A new design of a cost-effective, gridded solar air heater with a high solar to thermal energy conversion efficiency is presented, featuring an increased air to absorber interaction, while still allowing high mass flow rates. We investigate the dependence of this solar air heater's conversion efficiency as a function of its mass flow rate and find that the efficiency significantly depends on it. Our investigation shows that the conversion efficiency of our solar air heater approaches 80% as the mass flow rate is increased to 0.06 kg/s. As the conversion efficiency depends linearly on the mass flow rate, a significant component of this investigation is the calibration of the anemometer. The findings of this research are based on data taken during both the winter and the summer seasons.

What is a Solar Air Heater (SAH)?

- A renewable energy device that converts solar energy directly into thermal energy
- Used in space heating, food drying, and other applications

How does a SAH work?



- Solar radiation is absorbed by dark absorber material
- Thermal energy is transferred to air as it flows around/through absorbing material
- Enclosure and glazing provide conductive and radiative insulation

SAH or PV Panel?

- Ave. Efficiency: 65%
- Cost: $200-$300
- ROI time: 2-4 years
- Produces hot air

- Ave. Efficiency: 18%
- Cost: $500-$3000+
- ROI time: 10-20 years
- Produces Electricity

Theory of Thermal Losses

- Thermal energy lost due to <u>conduction</u> through sides of SAH
- Governed by *Fourier Law of Conduction*

- Thermal energy lost due to <u>radiation</u> emitted from absorber
- Governed by *Stefan-Boltzmann Law*

$$\dot{Q}_{cond} = \frac{A}{R}\left(T_{ins} - T_{amb}\right) \qquad \dot{Q}_{rad} = \sigma A T^4$$

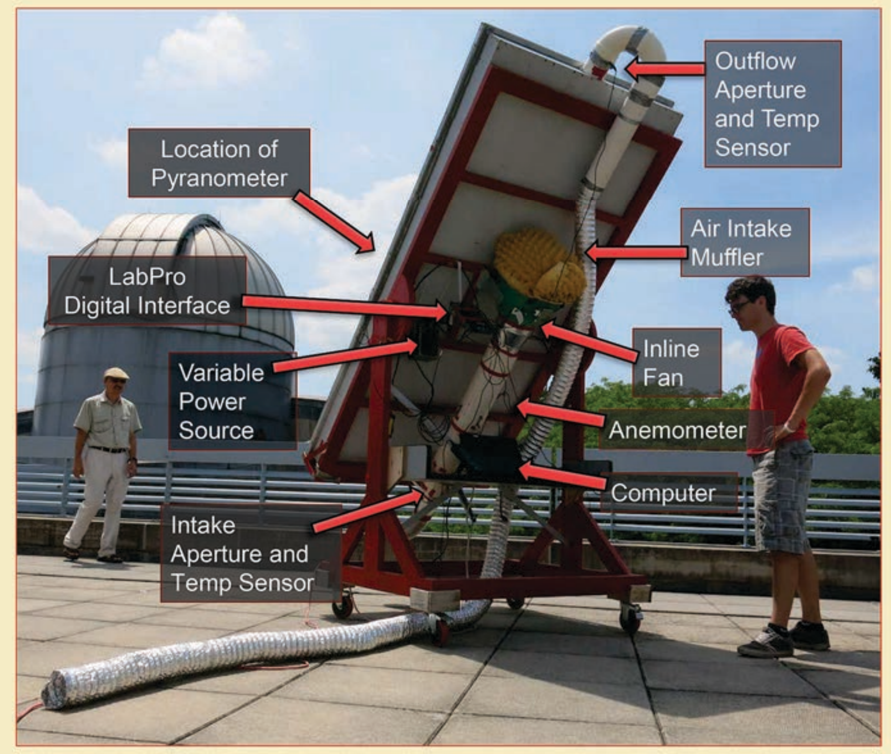
$$\dot{Q}_{cond} + \dot{Q}_{rad} = \left(\frac{A_s}{R_s} + \frac{A_e}{R_e} + \frac{A_b}{2R_b} + \frac{A_{gl}}{2R_{gl}}\right)\left(T_{out} - T_{amb}\right) + (\tau\alpha)\sigma A_{gl}\left(\varepsilon\langle T_{ins}\rangle^4 - \alpha T_{amb}^4\right)$$

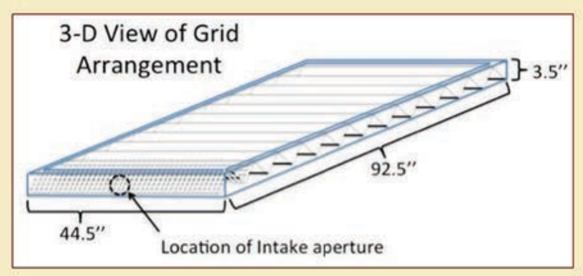
which simplifies to

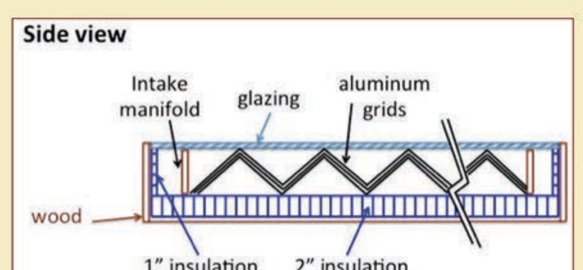
$$\dot{Q}_{loss} = h_{cond}\left(T_{ins} - T_{amb}\right) + h_{rad}\left(T_{ins}^4 - T_{amb}^4\right)$$

Total losses are directly dependent upon the temperature gain of the SAH

The Dickinson SAH

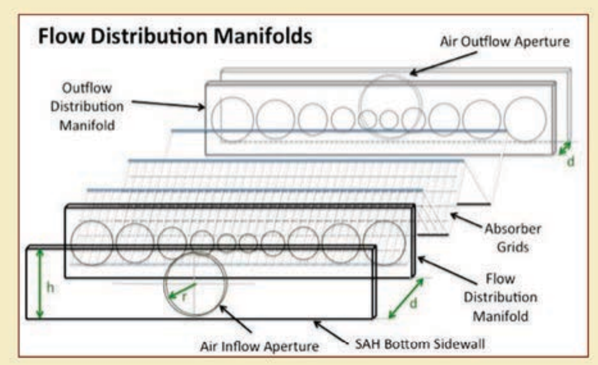






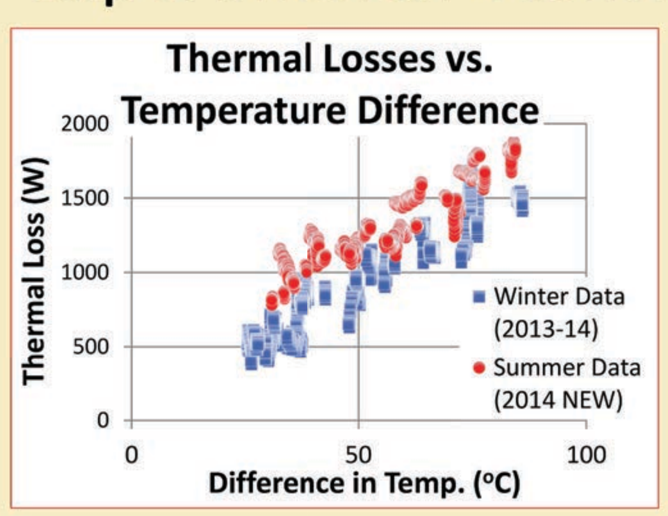
Principal Diagnostics

- Pyranometer – Measures Incoming Solar Radiation
- Anemometer – Measures Air Flow Speed
- Temp. Sensors – Measures Temperature Gain



The Dickinson SAH was designed and built by Sung Woo Kim '13, Rick Lindsey, and Hans Pfister.

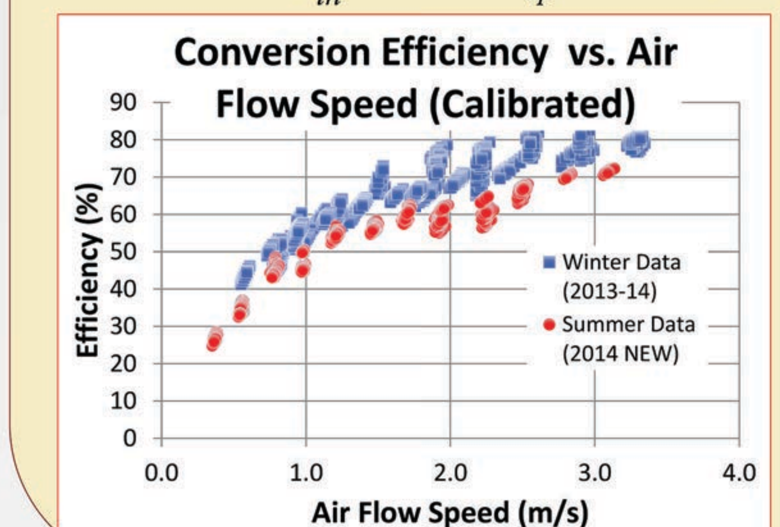
Experimental Verification of Thermal Losses



- The experiment shows an approx. linear relationship between the temperature gain and the total thermal losses.
- The non-zero y-intercept is representative of the reflected radiation that never enters the SAH
- We can achieve smaller thermal gains by increasing the air flow speed, leading to decreased losses and hence a higher efficiency

Solar to Thermal Conversion Efficiency

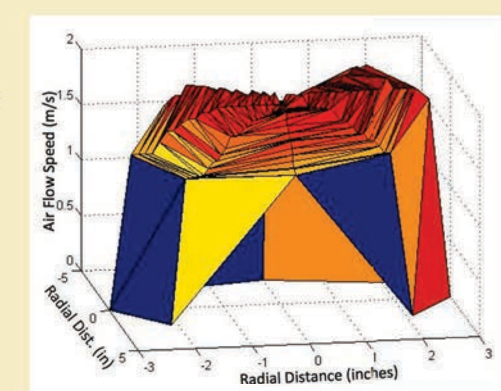
$$\eta = \frac{P_{out}}{P_{in}} = \frac{c_p \dot{m} \Delta T}{I \cdot A_{ap}} = \frac{c_p \cdot \rho A_T \mathrm{v} \cdot \Delta T}{I \cdot A_{ap}}$$



The conversion efficiency approaches **80%** as we increase the flow speed to 3.0 m/s

Calibration of the Anemometer

As the efficiency depends linearly on our air speed measurement, we must calibrate our anemometer.



<u>Problem</u>:

- Flow profile is non-uniform in the PVC tube.
- Measurement tool obstructs air flow, altering the measurement

Anemometer

<u>Solution</u>:

- Use a small hot filament anemometer to map the flow profile
- Integrate and average over cross-sectional area
- Use calculated reading to calibrate the anemometer

References

1. Dave. "A Half Project." *Solar Air Heater*. Bryantbay2 Blogspot, 3 Feb. 2011. Web. 10 Apr. 2015.
2. Mahmood, A.J., Aldabbagh, L.B.Y., 2013. Double Pass Solar Air Heater with Transverse Fins and without Absorber Plate. International Science Index 7, 1920-1925.
3. Photovoltaic Panels. SunSol, n.d. Web. 10 Apr. 2015.
4. Recommended Products for Renewable Energy with Vernier and LabQuest 2. Vernier Software & Technology. Web. 10 Apr. 2015. <http://www.vernier.com/products/packages/renewable-energy/labq2/>.
5. Romdhane, B.S., 2007. The air solar collectors: Comparative study, Introduction of baffles to favor the heat transfer. Sol. Energy 81 (1), pp. 139-149.
6. Solar Air Heater. Web. 10 Apr. 2015. <http://www.solarairsystems.com/shop/>.
7. Solar Air Heater Pt 1. YouTube, 22 Dec. 2008. Web. 10 Apr. 2015.
8. Solar Panels Cost Guide | Prices and Calculator. Solar Panels Cost Guide. 2013. Web. 10 Apr. 2015.
9. Weiland, J. DIY Solar Heating with the Heat Grabber. Mother Earth News. Sept.-Oct. 1977. Web. 10 Apr. 2015.

Construction of new Dickinson SAH