Solar Air Collector Project

ACE High School Presentation
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Desert Research Institute
Air Collector Project

- May 12th: Solar Seminar
- May 13th: Visit to DRI to see air collectors
- May 14th – May 23rd: Team building of Air Collectors
- May 27th & 28th: Air Collector Performance Testing
Today’s Seminar

• Introduction to Heat Transfer
• Review of Solar Technologies
• Construction of Air Collectors
• Project Guidelines
Heat Transfer

Exchange of thermal energy between physical systems

Conduction, Convection, Radiation
Radiation

- Electromagnetic waves
- Frequency affects how the waves pass through a medium; emissivity
- Sunlight: Infrared, Visible, and Ultraviolet Spectrum
Conduction

• Heat transfer through diffusion and collision of particles within a body that has a temperature gradient
• Can only take place within a body, or between two bodies in contact
## Conduction: Insulation

- Watts per meter degree
- Higher value means more energy flows through the material

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Aluminum</td>
<td>250</td>
</tr>
<tr>
<td>Antimony</td>
<td>18.5</td>
</tr>
<tr>
<td>Asphalt</td>
<td>1.26</td>
</tr>
<tr>
<td>Brass</td>
<td>109</td>
</tr>
<tr>
<td>Brick dense</td>
<td>1.6</td>
</tr>
<tr>
<td>Cadmium</td>
<td>92</td>
</tr>
<tr>
<td>Carbon</td>
<td>1.7</td>
</tr>
<tr>
<td>Copper</td>
<td>401</td>
</tr>
<tr>
<td>Carbon Steel</td>
<td>54</td>
</tr>
<tr>
<td>Cotton Wool insulation</td>
<td>0.029</td>
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<tr>
<td>Epoxy</td>
<td>0.35</td>
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<tr>
<td>Felt insulation</td>
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<tr>
<td>Glass</td>
<td>1.05</td>
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<tr>
<td>Ice</td>
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<tr>
<td>Iron</td>
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<td>Magnesium</td>
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<tr>
<td>Mica</td>
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<tr>
<td>Nylon 6</td>
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<tr>
<td>Polyethylene HD</td>
<td>0.5</td>
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<tr>
<td>Polystyrene expanded</td>
<td>0.03</td>
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<tr>
<td>Steel</td>
<td>46</td>
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<tr>
<td>Stainless Steel</td>
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<tr>
<td>Water</td>
<td>0.58</td>
</tr>
<tr>
<td>Wood</td>
<td>0.13</td>
</tr>
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</table>
Convection

• The motion of individual particles in fluid
  – Weather, thunderstorms, etc.

• Takes place in gases and liquids, and solids
  – Natural Convection: Fluid motion by density differences in the fluid due to temperature gradients
  – Forced Convection: Induced by an external force. Energy exchange based on type of fluid flow; laminar or turbulent
Convection Examples
Earth Heat Transfer

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**INCOMING SOLAR RADIATION**
- Reflected by clouds
- Back-scattered by air
- Absorbed by water vapor and gases
- Absorbed by earth

**NET LONGWAVE RADIATION**
- Emitted by clouds
- Emitted by water vapor and gases

**OUTGOING LONGWAVE RADIATION**
- Emitted by clouds
- Absorbed by water vapor and gases

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**SPACE**

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**ATMOSPHERE**
Complex Heat Transfer Example

- Direct Sunlight
- Scattered Sunlight
- Infrared Radiation from the atmosphere
- Infrared Radiation from the animal
- Infrared Radiation from the ground
- Wind Convection
- Evaporation
- Conduction
- Reflected Sunlight
Solar Energy Uses

• Electrical Output: Photovoltaics
  – Convert solar radiation into direct current
  – 15% to 20% efficient

• Thermal Output: HEAT!
  – 50% to 60% efficient

• Passive Solar
  – South facing absorbing
Solar Heat Transfer
Types of Solar Thermal Collectors

- Liquid Collectors
- Air Collectors
Solar Air Collectors

Also known as air heaters

- Modular, off the shelf design
  - Rreal
  - Show SRCC

- Fresh air
  - Used to preheat incoming air for fresh air exchange

- Site-Built Solar Air Collectors
Advantages and Disadvantages of Solar Air Collectors

• Air is a Lower Technical Risk!!!
  – Leaking
  – Freezing
  – Boiling
• Easier to build
• Build into architectural design
• Not as efficient heat transfer
  – Lower Temperatures
  – More collector area needed
Air Collector Components

- **Glazing/Cover**: A transparent material to create a separation between ambient air and the air being heated.
- **Absorber**: The material inside the collector that absorbs solar radiation.
  - Air passing over the absorber then removes its energy through forced convection.
- **Backplane**: Backside of the collector providing insulation so energy is not lost to surrounding.
- **Framing**: Material used to hold the components together.
Air Collector Components

- Thermoply or Thermax Insulation Board
- Aluminum Flashing
- Sunlite® HP Glazing (0.060” x 4’ x 8’)
- 2” x 4” Frame
- Black Painted Aluminum Sheet
- 1-1/2” Frame
- Batten Trim
- Support Brace
An air collector is a simple flat-plate collector used mainly for space heating. Air flows through the collector by natural convection or when forced by a fan.
Air Collector Performance

• ASHRAE Standard to measure energy output of collector
  – Solar Energy
  – Temperatures: In and Out
  – Flow Rate

• Determines the energy into the collector and out of the collector: Efficiency

• Solar Rating and Certification Corporation:
Location, Location, Location

- Orientation: South Facing!
- Tilt: Higher angle for winter sun!
- Geographical Location
Figure 3-4: This map, which indicates the potential for solar energy use in six zones, considers both the need for heat and the amount of sunshine available at different locales and is helpful in evaluating the usefulness of solar space heating at your site.

Zone 1: great sun, moderate heating need
Zone 2: great sun, high heating need; in zones 1 and 2, you can't go wrong with a properly sized space-heating system
Zone 3: good sun, moderate heating need
Zone 4: good sun, high heating need; in zones 3 and 4, it's hard to go wrong with a space-heating system
Zone 5: poor sun, moderate heating need
Zone 6: poor sun, high heating need; in zones 5 and 6, you need to take a hard look at the economics involved

Material Considerations for Heat Transfer

• Glazing
  – Emissivity: How much radiation will pass through

• Absorber
  – Absorptance: How much radiation will be absorbed
  – http://www.solarmirror.com/fom/fom-serve/cache/43.html

• Backing
  – Conduction: How much energy will be lost through conduction out of the back and sides of the collector.
Importance of Glazing

• Reduce Losses from:
  – Cold temperature
  – Wind

*Figure A-19:* Efficiency curves for different numbers of glazings for a collector.
Controls

• Thermostat
  – Control the blower
  – Based on Temperature in the collector and in the room
  – Set a maximum room temperature

• Damper
  – Ensure space heating does not occur in the summer
Examples: Rooftop
Architectural Component

Design for aesthetics!!
Air Collector Project

• Design, build, and test an “active” solar air collector
  – Design: Create CAD drawing for design into a tiny house
  – Build: Use provided, and local materials to build the structure, not including the blower/ducting
  – Test: DRI will bring testing apparatus for performance testing
Project Guidelines

• No Larger than 64 ft$^2$
  – Consider evaluation parameters
  – Roughly 8’ x 4’ a good practical size; a larger collector is not necessary for the tiny house

• SunLite HP glazing is available for everyone
  – Single or double glazing is up to you

• Absorber, framing, backing up to you and based on available local materials
Evaluation Criteria

• Performance:
  – Efficiency: Energy Out versus Energy In
    • Based on per square foot, so size is not a consideration

• Economics
  – Capital Investment
  – Simple Payback Period

• Architectural Design
  – Conformity to the tiny house
  – Aesthetics
Energy Efficiency

- **Energy In**: watts per square meter provided by the sun during the testing period
- **Energy Out**: watts per square meter of energy gain in the air passing through the collectors
  - Affected by wind, temperature, air flow rate (will use the same for all collectors)
Economics

• Capital Investment: Initial cost is always a consideration for such an investment

• Simple Payback Period
  – How long it takes until the consumer is saving money on their utility bills
  – Cost of energy output from the collector versus energy from natural gas required for heating
  – Will not consider labor costs for this project, but is a consideration in the real-world
  – **HAVE TO KEEP TRACK OF MATERIAL COSTS!!!!**
Architectural Design

• Will it fit on the tiny house?
• What is the weight load?
• How will it look?
Bored Yet? Or Ready to Build?

... let's see if I can warm up the house!