SOLAR THERMAL
ABSORPTION CHILLER SYSTEMS
BASIC COMPRESSOR CYCLE

HEAT OUT:
1. SUPERHEATED VAPOR (HIGH PRESSURE)
2. SUBCOOLED OR SATURATED LIQUID
3. LIQUID/VAPOR MIX

TO AMBIENT (AIR COOLED)
TO COOLING TOWERS (WATER COOLED)

ELECTRICITY IN

HIGH PRESSURE SIDE
LOW PRESSURE SIDE

EXPANSION DEVICE

1. SUPERHEATED VAPOR (HIGH PRESSURE)
2. SUBCOOLED OR SATURATED LIQUID
3. LIQUID/VAPOR MIX

CHILLER CONDENSER SECTION

CHILLER EVAPORATOR SECTION

HEAT IN:
- WATER
BASIC ABSORPTION CYCLE

**HEAT SOURCE IN**

- SOLAR THERMAL
- NATURAL GAS
- STEAM
- WASTE HEAT

**LITHIUM BROMIDE (LiBr)**

\[ rH_2O = r718 \]

**HIGH PRESSURE SIDE**

**VACUUM SIDE**

**EXPANSION ORIFICE**

**DILUTED SOLUTION PUMP**

**CHILLER CONDENSER SECTION**

**CHILLER ABSORPTION SECTION**

**CHILLER EVAPORATOR SECTION**

rH20 VAPOR

\[ rH_2O = 41^\circ F \]

UNDER VACUUM, REFRIGERANT WATER REMOVES HEAT FROM BUILDING LOAD BY RE-EVAPORATING AT AROUND 55-57°F
**BASIC ABSORPTION CYCLE**

<table>
<thead>
<tr>
<th>[Microns]</th>
<th>Absolute pressure</th>
<th>Vacuum (below standard atmospheric pressure)</th>
<th>Water boiling point</th>
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<tr>
<td>[μm]</td>
<td>[in Hg]</td>
<td>[mbar]</td>
<td>[mm Hg]</td>
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<td>12.7</td>
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<tr>
<td>2.54</td>
<td>0.0001</td>
<td>0.00005</td>
<td>0.003</td>
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</tbody>
</table>

\[ r_{\text{H2O}} = r_{718} \]

- 14.7 PSIG (ATM) = 212°F
- 0.147 PSIG (VAC) = 45°F
BASIC ABSORPTION CYCLE

rH2O = r718

VACUUM

ABSORBING CHILLER LOOP HEAT FROM BUILDING
BASIC ABSORPTION CYCLE

**Generator**
- **Heat Source in:**
  - Solar Thermal
  - Natural Gas
  - Steam
  - Waste Heat

**Chiller Condenser Section**
- **rH₂O Vapor Condenses by Rejcting Heat to Cooling Towers**
- **Expansion Orifice**
- **rH₂O = 41°F**

**Chiller Evaporator Section**
- **rH₂O = 41°F**

**Chiller Absorption Section**
- **LiBr = 284°F**
  - Concentrated LiBr to Absorber
- **Diluted Solution Pump**

**Under Vacuum, Refrigerant Water Removes Heat from Building Load by Re-Evaporating at Around 55-57°F**

**The Re-Evaporated rH₂O Condenses to Create a “Diluted Solution” with the LiBr, While Sending the Building Load to the Cooling Towers**
BASIC ABSORPTION CYCLE

TO COOLING TOWER

FROM SOLAR THERMAL ARRAY

WATER VAPOR

CONDENSER

GENERATOR

200°

WATER

EXPANSION DEVICE

EVAPORATOR

40°

TO BUILDING LOAD

PUMP

ABSORBER

100°

TO COOLING TOWER

HEAT EXCHANGER

PUMP

WEAK SOLUTION

STRONG SOLUTION
LiBr CYCLE

Freezing Point Temperature (°C)

LiBr Solubility (Weight Fraction)

LITHIUM BROMIDE (LiBr)
BASIC ABSORPTION CYCLE COMPONENTS

CONDENSER LOOP

COOLING TOWERS

LOAD LOOP PUMPS

CONDENSER LOOP PUMPS

LOAD LOOP PUMPS

HEAT SOURCE

ABSORPTION CHILLER
SOLAR COOLING DESIGN CURVE
SOLAR THERMAL ARRAYS

Average Daily Solar Radiation Per Month

ANNUAL

Collector Orientation

One-axis tracking flat-plate collector

North-South Axis Tracking Flat Plate

This map shows the general trends in the amount of solar radiation received in
the United States and its territories. It is a spatial interpolation of solar radiation values
derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The data
on the map represents the 2019 values of the NSRDB.

Maps of average values are produced by averaging 39 years of data for each site.
Maps of maximum and minimum values are composites of specific months and years
for which each site achieved its maximum or minimum amounts of solar radiation.

Though useful for identifying general trends, this map should be used with caution
for site-specific resource evaluations because variations in solar radiation are reflected
in the maps can exist, including uncertainty into resource estimates.

Maps are not drawn to scale.

NREL
National Renewable Energy Laboratory
Resource Assessment Program
SOLAR THERMAL ARRAYS

- Tube within a tube; vacuum between prevents heat loss.
- Heat pipes move heat to header and delivered to the use point as free BTUs.
SOLAR THERMAL ARRAYS

Roberts Hall, University of Indianapolis

• 10 panel array

• New construction – 165 bed dorm.

• Looking for a way to offset 50% of their expected gas usage for domestic hot water.

• August, 2012 (start of Fall Semester) – 100% of student usage was provided by solar thermal.

• The system is generating enough FREE ENERGY from the sun to provide 95% of the student hot water needs.
SOLAR THERMAL ARRAY PAYBACK

- RETscreen is a software resource developed by the Canadian government and NASA, [www.retscreen.net](http://www.retscreen.net). It is a recognized world-wide standard that produces a financial analysis and break even graph showing ROI.
Example Application: For 30 RT System we will need 25 solar thermal collectors. On an annual average this will produce 550,000 BTU’s per hour or 5,500,000 BTU’s per day. On a sunny day (regardless of the outside temperature) we will produce over 7,500,000.

Approximately 1000 SF of space required, including spacing and perimeter maintenance access.

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>25</td>
<td>SunQuest 250 Solar Thermal Collectors &amp; Racks</td>
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<tr>
<td>25</td>
<td>Heat Dissipaters</td>
</tr>
<tr>
<td>5</td>
<td>Auto Air Vents w/Shut-off Valves</td>
</tr>
<tr>
<td>5</td>
<td>Thermostatic 3-way Valves</td>
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<tr>
<td>1</td>
<td>Expansion Tank &amp; Pump</td>
</tr>
<tr>
<td>1</td>
<td>Controller &amp; DL2 for internet connectivity</td>
</tr>
<tr>
<td>1</td>
<td>Heat Exchanger</td>
</tr>
<tr>
<td>LOT</td>
<td>Lull, Labor, Materials and Shipping</td>
</tr>
</tbody>
</table>
SOLAR COOLING EXAMPLES

Desert Mountain High School
Largest Solar Cooling system in the world
SOLAR COOLING EXAMPLES

ASU SOLAR COOLING ARRAY
SOLAR COOLING EXAMPLES

UNITED WORLD COLLEGE OF SOUTHEAST ASIA (UWCSE)
PAYBACK
BASIC ABSORPTION MAINTENANCE

- CHILLER OPERATION
- LiBr TESTING/INHIBITORS
  - AVOID CORROSION
  - VACUUM MANAGEMENT (RUBBER GASKETS/SEALS)
    - AVOID LEAKAGE

NO CORROSION, HIGH RELIABILITY, SAFETY, EFFICIENCY, LONG LIFE
BASIC ABSORPTION MAINTENANCE

SOLUTION AND REFRIGERANT PUMPS
BASIC ABSORPTION MAINTENANCE

LiBr SOLUTION SIGHT GLASS:
• COVER ABSORBERS BOTTOM
• SOLUTION PUMPS SHOULD NOT BE EMPTY

rH2O SOLUTION SIGHT GLASS:
• MIDDLE LEVEL OF SIGHT GLASS
• NOT ABOVE COPER BUNDLE
BASIC ABSORPTION MAINTENANCE

LiBr SOLUTION ANNUAL TESTING

Corrosive (Fe, Cu)  Corrosive (Cu2O or CuO)  Solution high temp. over 329°F (165 °C),
BASIC ABSORPTION MAINTENANCE

AUTO PURGE SYSTEM
BASIC ABSORPTION MAINTENANCE

### Flow Switch

<table>
<thead>
<tr>
<th></th>
<th>Flow rate</th>
<th>Open</th>
<th>Flash</th>
<th>Close</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chilled water flow</strong></td>
<td>High flow rate</td>
<td>&lt;45%</td>
<td>45%~55%</td>
<td>&gt;55%</td>
</tr>
<tr>
<td><strong>Condenser water flow</strong></td>
<td>Low flow rate</td>
<td>&lt;60%</td>
<td>60%~70%</td>
<td>&gt;70%</td>
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<tr>
<td></td>
<td>High flow rate</td>
<td>&lt;40%</td>
<td>45%~55%</td>
<td>&gt;50%</td>
</tr>
<tr>
<td></td>
<td>Low flow rate</td>
<td>&lt;50%</td>
<td>50%~60%</td>
<td>&gt;60%</td>
</tr>
</tbody>
</table>
BASIC ABSORPTION MAINTENANCE

- Chilled water outlet temp. sensor
  - Detects chilled water outlet temperature
  - Controls the cooling load accordingly
  - Prevents tube freezing in the evaporator

- Chilled water calibration temp. sensor
  - Checks the chilled water outlet temperature
  - Avoids copper tube freezing in the evaporator caused by chilled water outlet temperature error

- Chilled water inlet temp. sensor
  - Detects chilled water inlet temperature
BASIC ABSORPTION MAINTENANCE

Precision pressure gauge

Check pressure drop:
- Open one valve at the time, note pressure then close it
- Compare the inlet and outlet pressure to get your pressure drop
- Compare these results to chiller’s designed pressure drop
BASIC ABSORPTION MAINTENANCE
BASIC ABSORPTION MAINTENANCE
BASIC ABSORPTION MAINTENANCE

VACUUM GASKET REPLACEMENTS
BASIC ABSORPTION MAINTENANCE

EDDY CURRENT TESTING
BASIC ABSORPTION MAINTENANCE

**Automatic Ball Tube cleaning system**
The creation of a closed loop within the greater circulating water system. Within this closed loop, sponge rubber balls are circulated, which by random selection flow through all tubes on a frequent basis, thereby maintaining optimum tube side cleanliness.
BASIC ABSORPTION MAINTENANCE

24/7 FACTORY MONITORING
HOT WATER POWER?
AERCO - ORIGEN
AERCO - ORIGEN

Key:
- : Ref 245FA
- : Cold Water
- : Hot Water

Heat Source

Evaporator

Condenser

Expander

Generator

Cooling Source

Electricity to building or grid

170° F – 600° F

Electricity to building or grid
AERCO - ORIGEN

Screw expander-based technology allows for efficient, reliable energy solutions at lower operating temperatures from low-grade heat sources.

Screw expanders are insensitive to liquid droplets and allows operation at near maximum cycle efficiencies while the system utilizes a non-toxic, chlorine-free, zero ODP working fluid – R245.