Energy Resources

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Lecture Contents

- Solar Air Heaters
- Energy Efficient Buildings
- Crop Driers
- Space Cooling
- Water Desalination
For similar energy input which fluid (air or water) can have a higher volumetric flow rate?
Solar Air Heaters

Thermal Conductivity of air is much less than water, therefore heat transfer from fluid to plate is low.

*How can the heat transfer be improved?*

\[
\eta_c = \frac{\rho c Q(T_2 - T_1)}{G_c A}
\]

\[
P_u = fA G_c \tau_{cov} \alpha_p - U_c A(T_p - T_a)
\]
Energy Efficient Buildings
Two types of solar heating systems:

1. **Passive Solar Systems**
2. **Active Solar Systems**
Elements of Passive Solar Design
Passive Solar Systems

- Three major factors to consider are:
  - Mass $m$
  - Resistance $R$
  - Area of collector $A$

- Increase insulation to reduce $R$

- Orientation, size and position of windows
  - Sufficient GA in winters
  - Shading in summers
  - Multi surface construction of windows
Passive Solar Systems

Main elements of a passive solar building:

- Properly oriented windows
- Thermal mass (concrete, brick, stone, and tile)
- Distribution mechanisms (conduction, convection, radiation)
- Control strategies (shades, sensor mechanism, low emissivity blinds)
- Insulation and air sealing
Passive Solar Systems

South windows accept direct sunlight to light and warm the building interior.

High Summer Sun

Overhang blocks direct sunlight.
Types of Passive Solar System

Direct Gain

A direct-gain passive system includes:
- south-facing windows (very often with movable insulation
- overhang shading,
- rooms behind the windows serving as cavity absorbers &
  energy storage devices.
Types of Passive Solar System

**Indirect Gain**

An indirect-gain passive solar home has its thermal storage between the south-facing windows and the living spaces. The most common indirect-gain approach is a Trombe wall (collector-storage).
Types of Passive Solar System

*Isolated Gain*

- Sun space
- Main function is heat distribution
- Energy store is building itself
- Air is the heat transfer fluid
Active Solar Systems
Active solar systems use separate collector with air or water
Easier to control
Can be retrofitted ~ though not very easy
Large storage systems
Heat Exchangers ~ water based systems
Ducting ~ air based systems

https://energy.gov/energysaver/active-solar-heating
Integrated energy-efficient buildings

Integrated energy systems in the building envelope or structure that utilizes the available on-site energy resources in a way that minimizes the need for purchased energy and maintains a satisfactory indoor environment.
Integrated energy-efficient buildings
Crop Driers

Wheat, rice coffee, copra (coconut flesh), certain fruits, and timber

Need drying before storage

Important factors for crop drying:
- Water vapour and air
- Water content of crop
- Energy balance and temperature for drying
Crop Driers

Main components of a solar crop drying system
Crop Driers

The Solarwall panel absorbs the sun’s energy
Crop Driers

The boundary layer air is heated and drawn through tiny perforations into the air space.
Crop Driers

The boundary layer air is heated and drawn through tiny perforations into the air space.
Crop Driers

The heated air travels up to the air intake and is drawn into the dryer.
Crop Driers

Additional heat is provided by the burner (if required) and the air passes through the material being dried.
Crop Driers

Heat loss through the roof is recovered when the fan is running.
Crop Driers

Water Vapour and Air

- **absolute humidity** (or ‘vapour concentration’) is the mass of water vapour present in 1 m³ of the air at specified temperature and pressure. It is maximum at saturation.
- saturation humidity /s depends strongly on temperature
- /s is called the relative humidity (0 -100%) (dry –saturated)
Crop Driers

**Water Content of Crop**

moisture content of a sample of grain (dry weight basis)

\[ w = \frac{(m - m_0)}{m_0} \]

moisture content of a sample of grain (wet weight basis)

\[ w' = \frac{(m - m_0)}{m} = \frac{w}{(w + 1)} \]
Energy balance and temperature for drying

If a volume $V$ of air is cooled from $T_1$ to $T_2$ in the process of evaporating a mass $m_w$ of water, then

$$m_w \Lambda = \rho c (T_1 - T_2)$$

$T_1$ and $V$ are critical parameters.

High temperatures and high humidity are not desirable.
Space Cooling

- Absorption refrigerator allows to use solar heat for cooling purpose
- Required pressure is achieved by difference in vapour pressure of the refrigerant
- Water as refrigerant and lithium bromide as absorbent

\[ \eta = \frac{\text{heat removed from cool space}}{\text{heat applied to generator}} \]

- Limited efficiency of commercial systems due to mechanical complexity & poor coefficient of performance ~0.7
- Variety of solar cycle refrigerators are available
- Passive solar systems are better at cooling spaces
Space Cooling

Diagram of a solar-driven cooling system with labeled components:
- Condenser
- Evaporator
- Absorber
- Expansion valve
- Dilute LiBr Solution
- Concentrated LiBr Solution
- H₂O Vapor
- H₂O Liquid
- Heat in
- Heat out
- Solar panel
- generator

The system operates by using solar energy to heat the concentrated LiBr solution, which then absorbs heat from the evaporator, allowing H₂O to vaporize and cool the space.
Water Desalination

**Basin solar still**
- internally blackened basin
- shallow depth of water
- transparent vapour tight cover
- cover is sloped towards the collection channel
Water Desalination

**Basin solar still**
- solar radiation warms the water, which then evaporates
- water vapour diffuses and moves convectively upwards and condenses on the cooler cover.
- condensed drops of water slide down the cover into the catchment trough.
Water Desalination

- Fraction of heat going to evaporation is independent of \((T_w - T_G)\)
- It is strongly dependent on \(T_w\)
- Max. production is only 50% of the ideal theoretical still
Water Desalination

Multiple effect still

- Heat given off by condensation is used to heat second mass of saline water
- Heat given off by condensation of second mass is used to heat third mass of saline water
- Limited practical performance due to imperfect heat transfer and complexity
- Other options ~ water storage for rainfall, reverse osmosis using PV
Solar Pond

Heat losses

Fresh

Salty

Very salty

Heat absorbing bottom
Solar Concentrators

Collectors are oriented to track the sun so that the beam radiation will be directed onto the absorbing surface.

**Collector:** Receiver and the concentrator

**Receiver:** Radiation is absorbed and converted to some other energy form (e.g. heat).

**Concentrator:** Collector that directs radiation onto the receiver. The aperture of the concentrator is the opening through which the solar radiation enters the concentrator.
Solar Concentrators

Concentration Ratio

The concentration ratio $X$ for a solar concentrator is defined as the ratio of the area of aperture to the area of the receiver.

$$X = \frac{A_a}{A_r}$$

where,

- $A_a$: projected area of the concentrator facing the beam
- $A_r$: area of the receiver
Solar Concentrators

Concentration Ratio

\[
\left( \frac{A_a}{A_r} \right)_{\text{circular, max}} = \frac{R^2}{r^2} = \frac{1}{\sin^2 \theta_s}
\]

\[
\left( \frac{A_a}{A_r} \right)_{\text{linear, max}} = \frac{1}{\sin \theta_s}
\]

Max concentrator ratio in this case is 45000

Max concentrator ratio in this case is 212
Solar Concentrators

Concentration Ratio

- The “lower limit” curve represents concentration ratios at which the thermal losses will equal the absorbed energy.
- Shaded range corresponds to collection efficiencies of 40 to 60%.
Solar Concentrators

Figure 7.1.1: Possible concentrating collector configurations: (a) tube and channel with diffuse...
Solar Concentrators

Planar and non-concentrating type which provides concentration ratios of up to four and are of the flat plate type.

Line focusing type produces a high density of radiation on a line at the focus. Cylindrical parabolic concentrators are of this type and they could produce concentration ratios of up to ten.

Point focusing type generally produce much higher density of radiation in the vicinity of a point. Paraboloids are examples of point focus concentrators.
Solar Concentrators

**Trough Collector**
- Concentration in only 1 D
- Mechanically Simple

\[ P_{\text{abs}} = \rho_c \alpha l D G_b \]
Solar Concentrators

\[ P_{\text{abs}} = \rho_c \alpha lDG_b \]

\[ P_{\text{rad}} = \epsilon \left( \sigma T_r^4 \right) (2\pi rl) \left( 1 - \zeta / \pi \right) \]

\[ r = D' \theta_s \]

\[ T_r = \left[ \frac{\alpha \rho_c \tau_a G_0 \cos \omega}{\epsilon \sigma} \right]^{\frac{1}{4}} \left[ \frac{D}{2\pi r (1 - \zeta / \pi)} \right]^{\frac{1}{4}} \]

\[ T_r^{(\text{max})} = \left[ \frac{\alpha \rho_c \tau_a G_0 \cos \omega}{\epsilon \sigma \theta_s} \right]^{\frac{1}{4}} = 1160 \text{ K} \]
Solar Concentrators

Theoretical $T_r = 1160K$
Practical temperatures are less than $T_r$ for two main reasons:
- Practical troughs are not perfectly parabolic, so that the solar image subtends angle $\theta s' > \theta s = R_s/L$.
- Useful heat $P_u$ is removed by passing a fluid through the absorber, so
  $$T_r^4 \propto P_{rad} = P_{abs} - P_u < P_{abs}$$
Solar Concentrators

Parabolic Bowl Concentrator

- Concentration in 2 D
- Complicated tracking arrangement
- The absorbed heat drives a Stirling motor, which converts the heat into motive energy and drives a generator to produce electricity.
Solar Concentrators

Parabolic Bowl Concentrator
Solar Concentrators

Parabolic Bowl Concentrator
Solar Concentrators

Distributed Concentrator
Solar Concentrators

Distributed Concentrator
Solar Concentrators

Power Tower
Solar Concentrators

Solar Power Tower

Electric power from sunlight by focusing concentrated solar radiation on a tower-mounted heat exchanger. Best suited for large scale applications: 30-400 MW
Solar Concentrators

Solar Power Tower

**Receiver:** Smaller and simpler receivers are needed to improve efficiency and reduce maintenance.

**Molten salt:** Molten nitrate salt, though an excellent thermal storage medium, it is not an ideal material due to its relatively high freezing point of 220°C.
Home Work

Chapter 06: Renewable-Energy-Resources-By-John-Twidell-Tony-Weir
Examples: 6.1, 6.2, 6.3
Questions?
Thank You