Thermal Power Plants

Lecture #5

Solar power plants

- **Solar energy:** perennial, silent, free and no pollutant source of energy.
- **Solar energy:** responsible for all life forms in the planet.
- **Solar energy:** the largest renewable source of energy.

Solar power plants

- **Solar energy: can be direct or indirect:**
  - Indirect solar energy: wind, hydro, photo;
  - Direct solar energy: heating, cooling, drying, distillation and photovoltaic;

Two technologies exist for conversion of solar energy into electricity:

- **Solar light into electricity:**
  - efficiency of something between 3% and 25%
- **Solar radiation into heat and, then, into electricity:**
  - large-scale applications using: parabolic plate, parabolic trough and tower of energy.

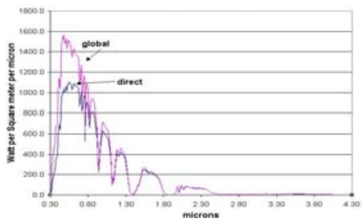
Characteristics of the solar energy:

- **1,000 Watts per square meter (= 1 sun)**
- **10% to 12% of efficiency (crystalline silicon)**
- **From hydrogenated amorphous silicon is obtained from 10% to 12% of efficiency in laboratory and commercially, from 7 to 8%;**

Direct and global radiation 37 deg tilt

(ASTM E892 and E891)

- The photovoltaic (PV) industry, in conjunction with the American Society for Testing and Materials (ASTM) (http://www.astm.org) and the USA government research and development laboratories developed and defined two standard terrestrial solar spectral irradiance distributions.
- These two spectra define: (1) a standard direct normal spectral irradiance (ASTM E-891) and (2) a standard total (global, hemispherical, within steradian field of view of the tilted plane) spectral irradiance (ASTM E-892). The direct normal spectrum is the direct component contributing to the total global (hemispherical) spectrum [2,3].



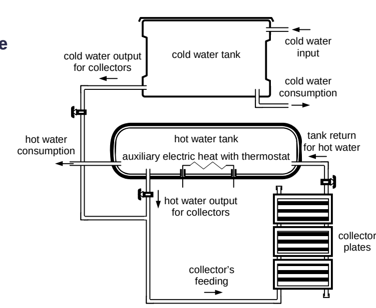
HEATING BY SOLAR ENERGY

Heating by solar energy

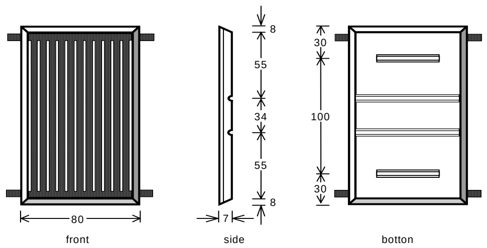
- **Stages:**
  - Reception
  - Transfer
  - Accumulation

Heating of water with solar collectors

- The cold water from the cold reservoir reaches the base of the solar collector pipes, which absorb heat.
- Through thermal expansion and natural, or forced convection it returns to the reservoir.
- The water flow continues in this cycle, and the temperature increases gradually after each passage through the collector pipes.



Typical solar collector



Sizing of solar plates:

$$Q = F \bullet A[I(a \bullet b) - U(T_i - T_a)]$$

Q = energy extracted by the plate (W)
F = efficiency factor of the heat removal from the plate
A = plate area (m^2)
I = rate of the incident to the absorbed solar radiation per unit of area of the plate surface (W/m^2)
a = coefficient of solar transmittance of the transparent coverings
b = coefficient of solar absorption of the plate sheet
U = coefficient of energy loss of the plate ($W/^\circ C - m^2$)
T_i = temperature of the fluid ($^\circ C$)
T_a = ambient temperature ($^\circ C$)

Useful energy

$$Q_u = A \cdot G \cdot c_p \cdot (T_i - T_o)$$

- **where:**
  - G = fluid volume per unit of the collector area
  - c_p = specific heat of the collector fluid
    (in the case of water it is $4190J/kg-^\circ C$)
  - T_o = output temperature of the fluid

Heating of domestic water

$$L = N \bullet P \bullet 100 \bullet (T_w - T_m) \bullet \rho_w \bullet C_p$$

L = energy for water heating per month
N = number of days per month
P = number of people
T_w = acceptable minimum temperature for the hot water ($60^\circ C$)
T_m = desired temperature for the water
ρ_w = water density ($1.0kg/\ell$)

To estimate the average monthly energy use in water heating in Joules (W/s) for a 4-person family, using water at an ambient temperature of 11º yields

Example:

$L = 30days \bullet 4people \bullet 100\ell/day \bullet (60^\circ - 11^\circ) \bullet 1.0kg/\ell \bullet 4190J/kg-^\circ C$

$L = 2.464 \bullet 10^9 Joules$

Home

Heat Transfer Calculation of Thermally Isolated Reservoirs

- The heat goes from the high temperature region, to the low temperature region, according to:

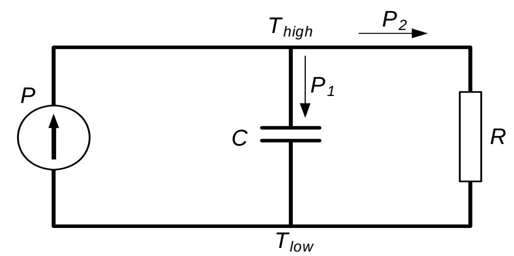
$$P = \frac{T_{high} - T_{low}}{R_{th}}$$

P is the steady state power dissipated in the reservoir in watts (or joules/second)

T is the temperature in degree centigrade

$R_{th} = R$ is the thermal resistance in $^{\circ}C/W$

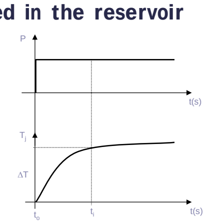
Assessing Thermal Time Constant



Thermal Calculation in Transient State

- The amount of heat Q stored in the reservoir with mass m is

$$\Delta Q = c_p m \Delta T = C \Delta T = \int P_1 dt$$



- From the heat balance

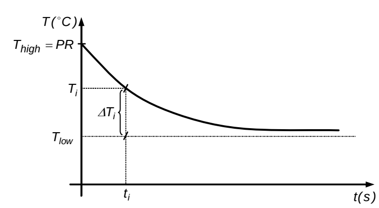
$$\Delta T = T_{high} - T_{low} = RP_2 = \frac{1}{C}\int P_1 dt$$

- Differentiating with time and finding the solution

$$P_2 = P(1 - e^{-t/RC})$$

$$\frac{\Delta T}{P} = R(1 - e^{-t/RC}) = Z_{th}$$

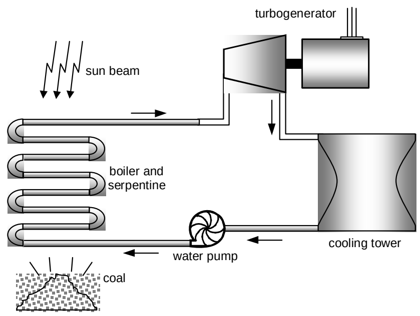
Temperature Decaying for measurement of thermal capacity



$$C_i = -\frac{t_i}{R\ell n(\frac{\Delta T_i}{PR})}$$

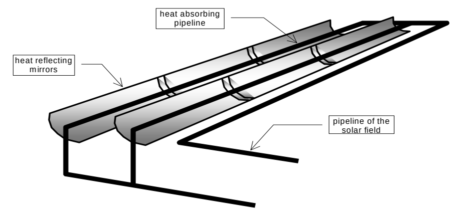
There will be as many values of C_i as the instants of measurement of T_i and a good average value could be obtained from there.

Solar electrical energy



Conversion of solar heat and fossil fuel into electricity

Parabolic troughs



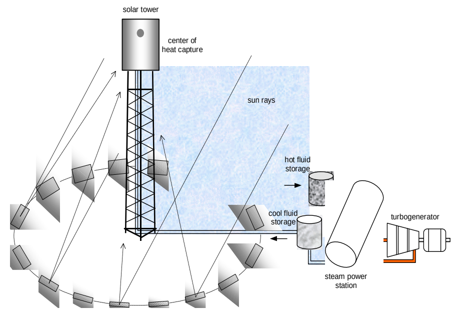
Experimental use of solar array

(UFRGS-PROMEC-RS, Brazil)

The parabolic dish

Solar dish system in Australia

Tower of Energy



Production of Hydrogen

- In the production of hydrogen, steam reforming for natural gases, and synthesized hydrogen from either gasoline or methanol are being considered for fuel distribution supply in fuel cell powered vehicles. However, in the so-called "solar belt" regions, the use of an environmentally friendly option for a solar-thermal distributed hydrogen process for these vehicles will probably need to be based on the already existing infrastructure to generate the required hydrogen.

Production of Hydrogen – Cont.

$$C_xH_y + concentraded\ sunlight \Rightarrow C + 2H_2 + unreacted\ C_xH_y$$