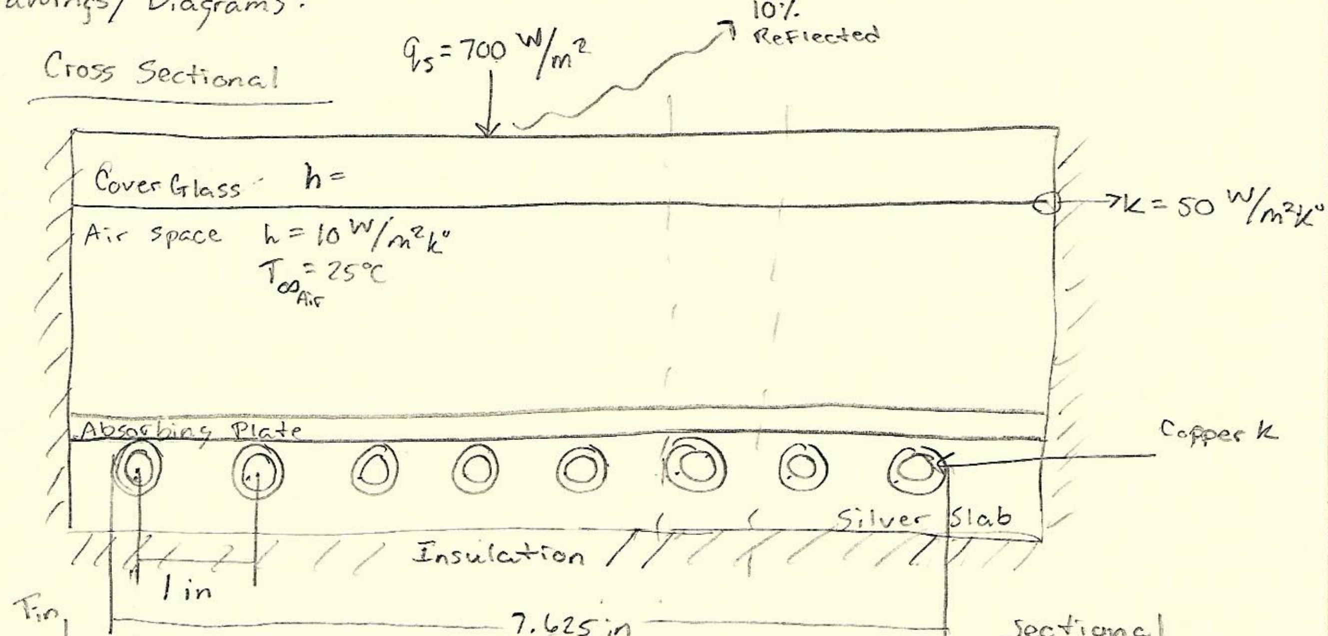
MET 440 | Test 1 | 18-09-2019

1. Purpose: A Flat-plate solar collector is used to heat water to a designated Temperature, Using the specified parameters of the collector, The rate of heat transfer must be found in order to calculate the amount of heat absorbed by the water, air space temperature, flow rate of the water, and collector efficiency.

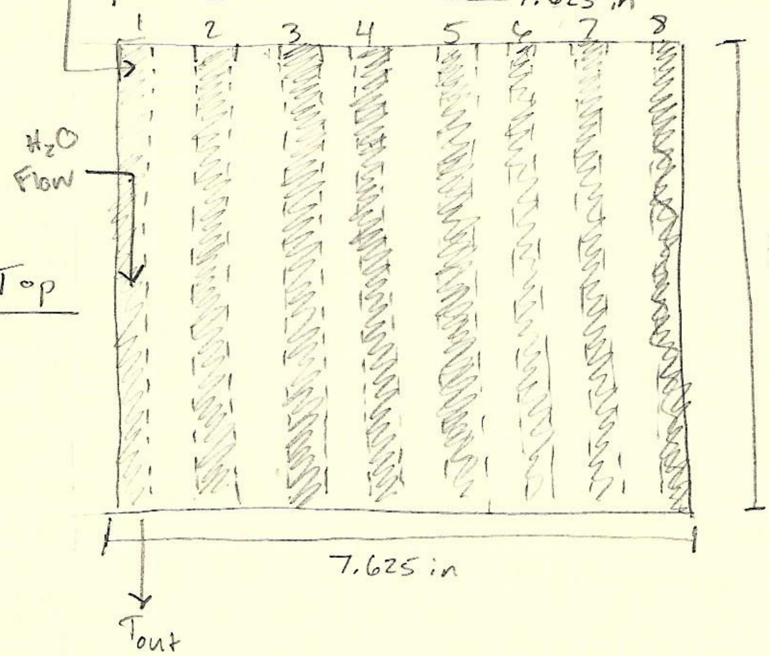
Sources: 1.) Heat Transfer Fundamentals, 1st Ed., Yildiz Bayazitoglu & Necati Ozisik, Begell House Inc.

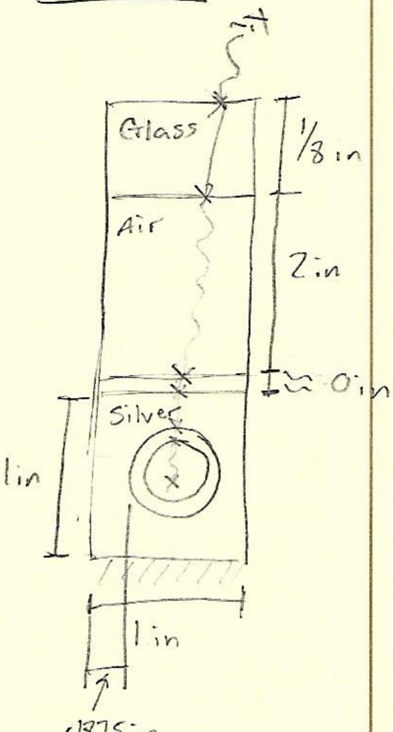
Drawings/Diagrams:

Cross Sectional



Sectional





Design Considerations:

1.) Incompressible fluids
2.) $A_{surf} = .0254\ m^2$
3.) Flow of Q is 1D
4.) Conservation of mass and energy
5.) Materials have certain convective / conductive properties
6.) Thermal Resistance concepts apply to solutions.
7. Steady state
8. No radiation
9. Const Properties
10. $L_{Pipe} = 1m$

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Data/ Variables:

q_s = flux = 700 $W/m^2 k$ ⟶ 90% absorbed

$T_{H_2O_i}$ = Temp @ water inlet = 20°C

h_{H_2O} = 1000 $W/m^2 \cdot k$ = Convect. of water

h_G = convect. Glass and Air = 50 $W/m^2 \cdot k$

T_{air} = 25°C

h_{air} = 10 $W/m^2 \cdot k$

$Ø_o$ = Diameter outer = .625 in = 0.0159 m

$Ø_i$ = inner Diameter = 0.528 in = 0.0134 m

L_p = Length pipe = 1 m

A_{surf} = Surface area receiving heat = .0254 m^2

$T_{H_2O_o}$ = Temp @ water outlet

C_p = Specific heat of water = 4179 $J/kg \cdot k$

L_{air} = 2 in = .0508 m

L_g = .125 in = .003175 m

L_{silver} = 1 in = 0.0254 m

$L_{Absorber}$ ≈ .01 in = .000254 m

k_{silver} = 419 $W/m \cdot °C$

k_{Air} = 0.025 $W/m \cdot °C$

k_{glass} = 1.177 $W/m \cdot °C$

k_{copper} = 386 $W/m \cdot °C$

k_{water} = 0.6 $W/m \cdot °K$

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Procedure:

1.) Calculate $q_{absorbed}$
$q_{abs} = q_s(.9)$

2.) Draw Resistance path of heat through the collector

3.) Find the Q through the whole system.

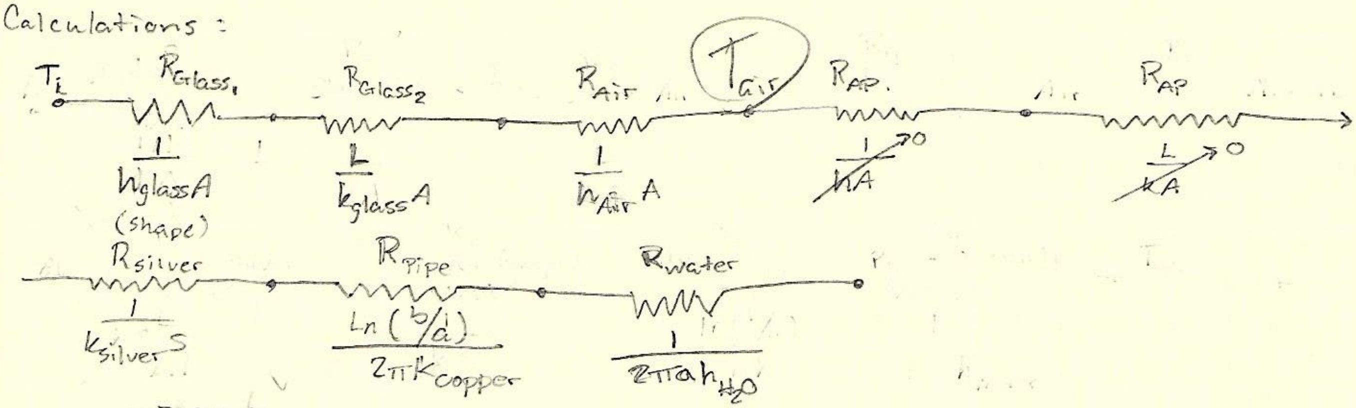
4.) Calculate the heat absorbed by the water

5.) Use the temp of air to find air in space temp with boundary temp.

6.) Find the water fowrate with Cp value
$Q = mC_p(T_o - T_i)$

7.) Efficiency can be found by dividing heat absorbed by the water with absorbed heat, q_s.
$\eta = \frac{q_{abs\ by\ water}}{q_s}$

Calculations:



$R_{glass_2} = \frac{.003175\ m}{(1.177\ W/m°C)(.0254 m^2)} = .1062\ °C/W$

$R_{glass_1} = \frac{1}{(50\ W/m^2°C)(.0254\ m^2)} = .7874\ °C/W$

$R_{Air} = \frac{1}{(10\ W/m^2C)(.0254 m^2)} = 3.937\ °C/W$

$R_{silver} = \frac{0.0254\ m}{(419\ W/m.C°)(0.0254\ m^2)} = .0024\ °C/W$

$R_{silver} = \frac{1}{(419\ W/m.C)\left(\frac{2\pi(1\ m)}{Ln(1.08(\frac{.0254m}{.0159m}))}\right)} = 5.26\ E-6\ \frac{°C}{W}$

$R_{cyl} = \frac{Ln\left(\frac{0.0159m}{0.0134m}\right)}{2\pi(386\ W/m\cdot C)(1m)} = 7.053\ E-5\ °C/W$

$R_{water} = \frac{1}{2\pi(.0134m)(1000\ W/m^2.k)(1m)} = .01188\ \frac{°C}{W}$

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$\Sigma R = R_{eq} = 4.845\ ^{\circ}C/W$

a.) $Q = \frac{\Delta T}{R_{eq}} = \frac{T_{air} - T_{H_2O i}}{R_{eq}} = \frac{25^{\circ} - 20^{\circ}C}{4.845\ ^{\circ}C/W} = 1.032\ W$

b.) $\Sigma R = R_{glass_1} + R_{glass_2} + R_{Air} = 4.8306\ ^{\circ}C/W$

$Q = \frac{T_{outside} - T_{air\ space}}{R_{eq}} \longrightarrow T_{outside} - Q R_{eq} = T_{air\ space}$

$25^{\circ}C - (1.032\ W)(4.8306\ ^{\circ}C/W) = 20.015^{\circ}C$

c.) $Q = \dot{m} C_p (T_o - T_i) \longrightarrow \dot{m} = \frac{Q}{C_p (T_o - T_i)}$

$\dot{m} = \frac{1.032\ W}{(4179\ J/kg \cdot {}^{\circ}C)(45^{\circ}C - 25^{\circ}C)} = \frac{1.032\ J/s}{83580\ J/kg} = 1.2347 \times 10^{-5}\ kg/s$

d.) $Q(A) = \frac{1.032\ W}{.0254\ m^2} = 40.63\ W/m^2$

$\eta = \frac{40.63\ W/m^2}{630\ W/m^2} = .0645 \longrightarrow 6.45\%$

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Summary:

Heat absorbed by water = Q = 1.032 W
Temp of air space = T_{air} = 20.015°C
$\dot{m} = 1.23 \times 10^{-5}$ kg/s
$\eta = 6.45\%$

Materials:

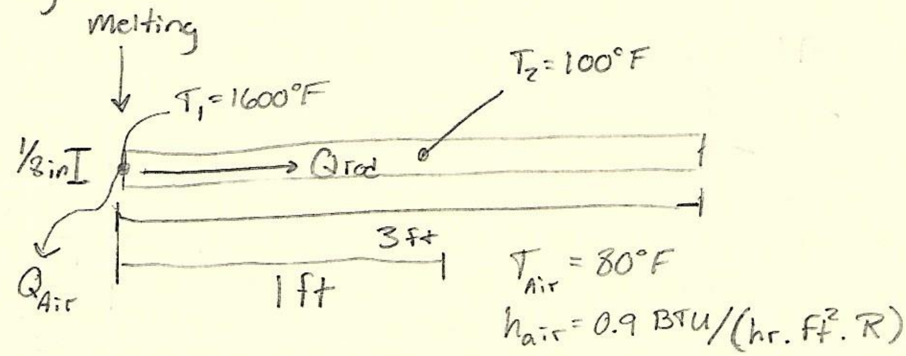
1.) Glass (1/8 in)
2.) Highly conductive absorbing plate
3.) 1 in silver slab
4.) K-Type Copper 1/2 in pipe
5.) insulation
6.) cooling water @ 20°C inlet temp
7.) 2in Air gap

Analysis: The system itself is very inefficient when transferring heat to the water in the pipes. After calculations, it was found that the highest thermal resistance was the air space between the glass an absorbing plate. The system could be improved upon if that Air space was reduced or removed completely. By doing so, the heat flux that is incident will be more effective because the convection from glass to air space will be less.

2. Purpose: Brazing materials often have a high thermal conductivity, k, which assist it in reaching it's melting point. Using a brazing tool, with fixed properties, to find the thermal conductivity of a material when exposed to the tool at a known distance and temperatures.

Sources: Heat Transfer Fundamentals, 1st Ed., Yildiz Bayazitoglu & Necati Ozisik, Begell House Inc.

Drawings:



Design Considerations:

1.) Heat transfer occurs to ambient air
2.) Const Properties
3.) No Radiation
4.) Steady state
5.) Flow is 1D
6.) Thermal Resistance concepts of convection and conduction apply

Data and Variables:

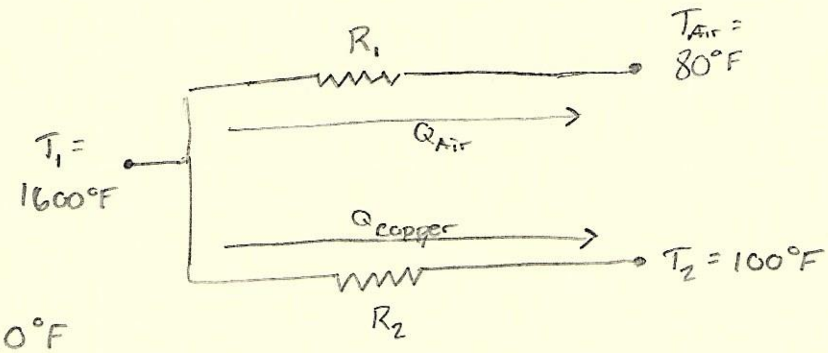
$\varnothing_{rod}$ = diameter rod = 1/8 in
L = Length of rod = 3 ft
L' = Length from T_1 to T_2 = 1 ft = x
T_1 = Temp at Tip = 1600 °F
T_2 = Temp in rod

$\theta = T - T_\infty$
$\theta_b = T_b - T_\infty$
$m = \sqrt{\frac{hP}{kA}}$

Procedure:

1.) Find Thermal resistance path
2.) Treat Rod as a fin
3.) Assume Case A because of convection to the outside air
4.) Iterate To Find The value of k

Calculations:



$\theta = 100 - 80 = 20°F$

$\theta_b = 1600 - 80 = 1520°F$

Equation used:

$$\frac{\theta}{\theta_b} = \frac{\cos(hm(L-x)) + \left(\frac{h}{mk}\right)\sin(hm(L-x))}{\cos(hmL) + \left(\frac{h}{mk}\right)\sin(hmL)}$$

$L - x = 1\ ft$

Summary:

- see spreadsheet for calculations/iterative process

$k = 0.811\ BTU/hr \cdot ft \cdot °R$

Materials:

1. Copper alloy
2. Air @ 80°F

Analysis: The copper alloy must have a very low conductivity because of the large temperature difference. With the tip at 1600°F, the rod must still be able to be phyically held for soldering. The dimensions of the rod and convection coefficient of the air were fixed, leaving the Thermal Conductivity, k, the only variable to be found or manipulated. A high k value would make the entire rod heat up more and faster & when a low k value makes the brazing material easier to handle.