HONOR CODE

I pledge to follow the Honor Code and to obey all rules for taking exams and performing homework assignments as specified by the course instructor.

I understand that when asked to follow the Honor Code on exams or homework assignments I must follow the rules below.

1. When following the Honor Code a student must work entirely alone on exams.

2. When following the Honor Code a student may not share information about any aspect of the exam with other members of the class, other faculty members, or other people who has not already taken the exam this year, or its equivalent in future years.

3. When following the Honor Code a student must direct all questions concerning the exam or homework assignment to the course instructor or teaching assistant.

4. When following the Honor Code it is the student's responsibility to obtain clarification from the instructor if there are questions concerning the requirements of the Honor Code.

5. When following the Honor Code a student can only access websites related to ODU (such as Blackboard, etc.) while taking the test.

6. When following the Honor Code a student cannot access, neither ask for help, from websites such as coursehero, chegg, and any other similar website, while taking the test.

I understand that failure to follow this Honor Code imply that the professor will immediately report my case for academic dishonesty to the ODU Office of Student Conduct & Academic Integrity.

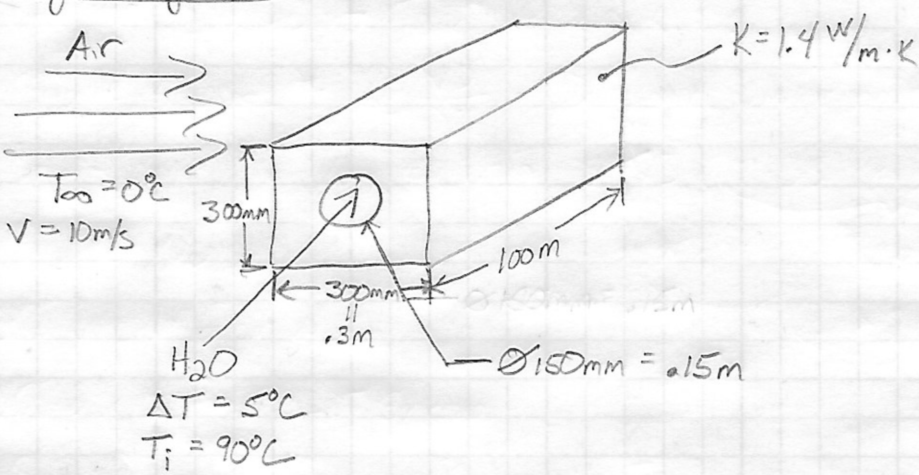
Student Name: Jason Nathanson

Student Signature: Jason A Nathanson

Date: 11/19/2018

① **Purpose:** Determine the heat loss and mass flow rate of hot water flowing through a pipe embedded in concrete using the given values.

Drawings + Diagrams:



Sources:

- Bayazitoglu, Y., Ozisik, N., "A Textbook for Heat Transfer Fundamentals." Begel House Inc (2012)
- Ayala, O., MET440 Heat Transfer. Old Dominion University. online. 2018. web. Nov 2018.

Design Considerations:

- Steady State
- No heat generation
- 1D heat Transfer
- Steel pipe resistance neglected

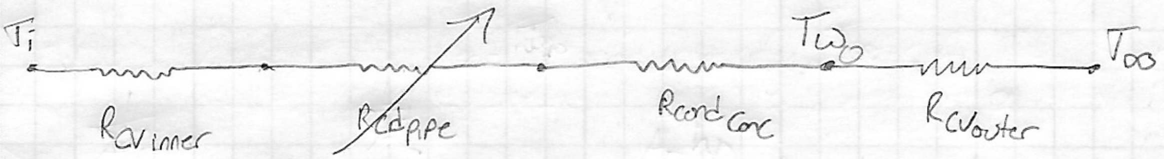
Data + Variables:

Variables for H_2O at 87.5°C T_b
$\rho = 969$
$C_p = 4.20$
$\nu = .338 \times 10^{-6}$
$K = .6725$
$\alpha = 1.65 \times 10^{-7}$
$Pr = 2.04$

Air properties to be determined by later guessed T_∞ values.

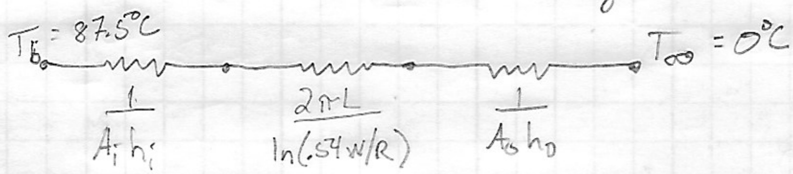
Procedure:

Determine Thermal resistance circuit
Find equations to solve for Nu to determine temperatures required
Calculate Re and Pr to determine flow characteristics and Nu
Once Nu is found, calculate for h – needs to be done for h_{inner} and h_∞.
Once h_i and h_o are calculated they can be plugged into the equation to find Q and $\dot{m}$.



R_{pipe} is neglected

Conductive Resistance for concrete slab in given scenario, use Shape factor 11 p 127.



$$Q = \frac{(T_{bi} - T_\infty) - (T_{bo} - T_\infty)}{\ln\left(\frac{T_{bi} - T_\infty}{T_{bo} - T_\infty}\right)} \times \frac{1}{\frac{1}{A_i h_i} + \frac{2\pi L}{\ln(.54w/R)} + \frac{1}{A_o h_o}}$$

we know all variables on right side except h_i and h_o. once we know those two values we can solve for Q.

Then use calculated Q in $Q = \dot{m} c_p (T_{bi} - T_{bo})$ to solve for $\dot{m}$.

I will start by looking for h_o. we need to calculate Re and to use in Nu equation for flow across a singular non circular Cylinder

$$Nu = C(Re)^n$$

$Re = \frac{uD}{\nu}$ we need to evaluate properties at T_{film}. However, we do not know T_w.

I will guess <u>30°C</u> for T_w.

$$T_{film} = \frac{30°C + 0°C}{2} = 15°C = 288K$$

properties at 15°C:

$\rho = 1.233896$
$C_p = 1.005604$
$\nu = 1.52 \times 10^{-5}$
$K = .025287$
$\alpha = 2 \times 10^{-5}$
$P_r = .71136$

$$Re = \frac{uD}{\nu} = \frac{(10\,m/s)(.3m)}{1.52\times10^{-5}\,m^2/s} = 197368$$

Per Table 7.1:

$C = .092$
$n = .675$

$Nu = c(Re)^n = .092(197368)^{.675}$

$Nu = 345.2$

$h_o = \frac{Nu\,k}{D} = \frac{(345.2)(.025287)}{.3}$

$h_o = 29.1$

Now we need to solve for h_i. To calculate Nu, we need Re and Pr
we will need properties of water at T_b which $= 87.5°C$.

$Re = \frac{uD}{\nu}$ we do not know u nor do we have $\dot{m}$ to calculate it.

I will start by guessing a value for $\dot{m} = .1\ kg/s$

$u = \frac{\dot{m}}{\rho A} = \frac{.1}{(969)(\frac{\pi}{4} \cdot .15^2)} = .0584\ m/s$

$Re = \frac{uD}{\nu} = \frac{(.0584)(.15)}{.338 \times 10^{-6}} = 25917.16$

For Nu we will use Petukhov Equation:

$Nu = \frac{Re\,Pr}{X}\left(\frac{f}{8}\right)\left(\frac{\mu_b}{\mu_w}\right)^n$

$f = 0.184 Re^{-0.2} = 0.184(25917.16)^{-0.2} = 0.024$

$X = 1.07 + 12.7(Pr^{2/3} - 1)\left(\frac{f}{8}\right)^{1/2}$

$X = 1.07 + 12.7(2.04^{2/3} - 1)\left(\frac{0.024}{8}\right)^{1/2}$

$X = 1.49$

$Nu = \frac{Re\,Pr}{X}\left(\frac{f}{8}\right)\left(\frac{\mu_b}{\mu_w}\right)^n$

$Nu = \frac{(25917.16)(2.04)}{1.49}\left(\frac{.024}{8}\right)\left(\frac{3.27 \times 10^{-4}}{8.3 \times 10^{-4}}\right)^{0.25}$

$Nu = 84.34$

$h_i = \frac{Nu\,k}{D} = \frac{(84.34)(.6725)}{.15}$

$h_i = 378.12$

Shape factor $= \frac{2\pi(100)}{\ln(.54 \cdot 3/.075)}$

$S = 815.88$

$$Q = \frac{(T_{bi} - T_\infty) - (T_{bo} - T_\infty)}{\ln \frac{T_{bi} - T_\infty}{T_{bo} - T_\infty}} \times \frac{1}{\frac{1}{A_i h_i} + \frac{1}{KS} + \frac{1}{A_o h_o}}$$

$$Q = \frac{(87.5 - 0) - (30 - 0)}{\ln\left(\frac{87.5 - 0}{30 - 0}\right)} \times \frac{1}{\frac{1}{(378.12)(.15\pi\ 100)} + \frac{1}{(1.4)(815.88)} + \frac{1}{(.3)(100)(4)(29.1}}$$

$$Q = \frac{57.5}{1.07} \times \frac{1}{5.612\times10^{-5} + 8.755\times10^{-4} + 2.864\times10^{-4}}$$

$$Q = 44119.4\ W = 44.119\ KW$$

Use Q to solve for $\dot{m}$ and compare

$$\dot{m} = \frac{Q}{C_p(T_{bi} - T_{bo})} = \frac{44.119}{(4.20)(5)}$$

$$\dot{m} = 2.1\ kg/s$$

$$\frac{2.1\ kg/s - 1\ kg/s}{2.1\ kg/s} = 52.4\%$$

Need to recalculate using 2.1 kg/s as $\dot{m}$

$$u = \frac{2.1}{(969)(\frac{\pi}{4}.15^2)} = .1226\ m/s$$

$$R_e = \frac{(.1226)(.15)}{.338\times10^{-6}} = 54408.28$$

$$f = 0.184(54408.28)^{-.2} = .0208$$

$$X = 1.07 + 12.7(2.04^{2/3} - 1)\left(\frac{.0208}{8}\right)^{1/2}$$

$$X = 1.46$$

$$N_u = \frac{(54408.28)(2.04)}{1.46}\left(\frac{0.0208}{8}\right)\left(\frac{3.27\times10^{-4}}{8.3\times10^{-4}}\right)^{0.25}$$

$$N_u = 156.6$$

$$h_i = \frac{(156.6)(.6725)}{.15}$$

$$h_i = 702.1$$

$$Q = \frac{57.5}{1.07} \times \frac{1}{\frac{1}{(.15\pi)(100)(702.1)} + \frac{1}{(1.4)(815.88)} + \frac{1}{(.3)(100)(4)(29.1)}}$$

$$Q = 53.738 \times \frac{1}{3.022\times10^{-5} + 8.755\times10^{-4} + 2.864\times10^{-4}}$$

$$Q = 45077.77\ W = 45.078\ KW$$

$$\dot{m} = \frac{45.078}{(4.20)(5)}$$

$$\dot{m} = 2.15\ ^{kg}/_{s}$$

Summary: Under the given circumstances the heat loss is 45.078 KW and the mass flow rate is 2.15 kg/s.

Materials:

Steel Pipe
water
Concrete
Air

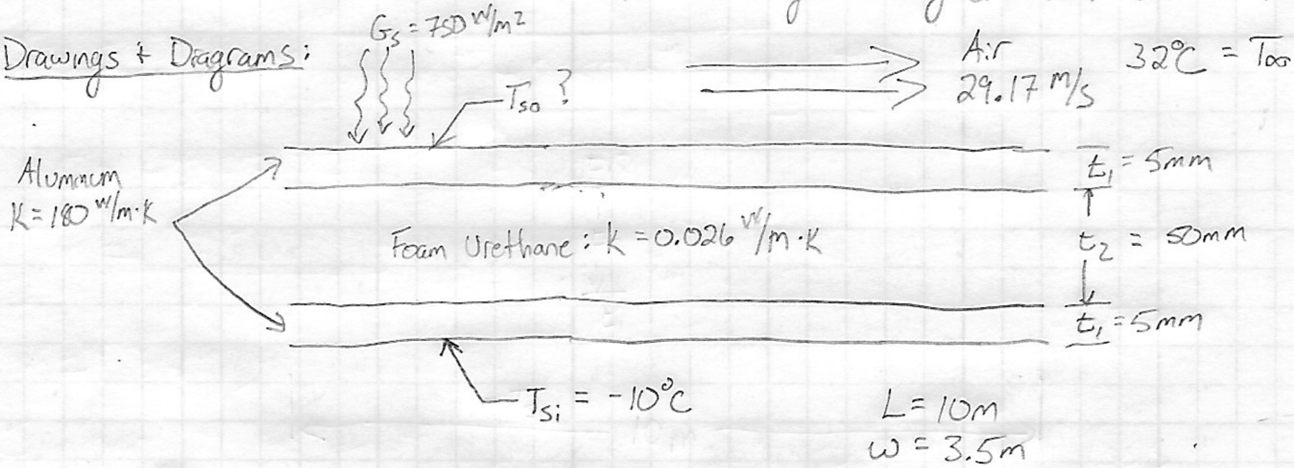
Analysis:

- It can be seen how much the properties at different temperatures can affect the heat loss. The difference between the temperatures has a big impact.

2

Purpose: Determine the average temperature of the outer surface of a truck's roof for the given scenario.
Determine the heat load on the refrigeration system of the truck.

Drawings + Diagrams:



Sources:

- Bayazitoglu, Y., Ozisik, N., "A Textbook for Heat Transfer Fundamentals." Begel House Inc (2012).
- Ayala, O., MET440 Heat Transfer. Old Dominion University. online. 2018. web. Nov 2018.

Design Considerations:

Constant Properties
1D heat transfer
Turbulent Air flow across entire roof.
Radiation released from surface to surroundings is negligible

Data + Variables:

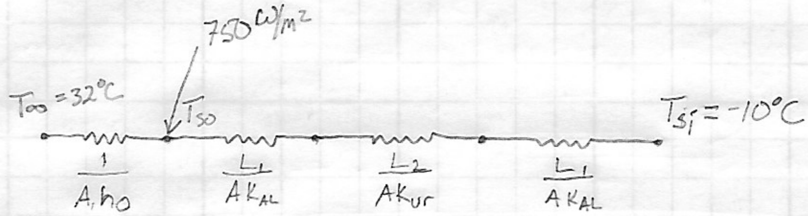
Air at 28.5°C (301.5K)
ρ : 1.172
c_p : 1.006
ν = 1.7×10^{-5}
K = 0.026354
Pr = 0.708

Solar Absorption $\alpha = 0.5$

Procedure:

- Since we have multiple layers of material and a ΔT which is not varying with time, we will use $Q = \frac{\Delta T}{\Sigma R}$ and $Q = hA\Delta T$ to solve for heat.
- We will need to dermine the thermal resistances for each layer.
- The thermal resistances will require h_o which we don't have.
- To solve for h_o and for Q we will need to guess T_{so}, Calculate Re and the correct Nu equation for the given scenario.
- Once we have Nu, we can solve for h and determine Q.
- We will then plug Q into the other equation to determine T_{so} and compare to guess
- If they are not within 10%, we will recalculate using a different T_{so}.

Calculations:



- We need to solve for the Q due to convection but we don't have h_o. To solve for h_o we need to guess a value for T_{so}. I will use 25°C which will give me a T_{film} = 28.5°C or 301.5K. The properties at this temperature are listed in the data & Variables section.
- Next we solve for R_e:

$$R_e = \frac{uL}{\nu} = \frac{(29.17\ m/s)(10\ m)}{1.70\times10^{-5}\ m^2/s} = 1.72\times10^{7}$$

- Now solve for N_u:

$$N_u = 0.0296\, R_e^{.8}\, P_r^{1/3}$$

$$N_u = 0.0296\,(1.72\times10^{7})^{.8}\,(0.7069)^{1/3}$$

$$N_u = 16199$$

- Now solve for ho:

$$h_o = \frac{N_u K}{L} = \frac{(16199)(.026619)}{10} = 43.12\ W/m^2\,°C$$

- Solve for Q due to Convection

$$Q = h\Delta T$$

$$Q = (43.12\ W/m^2\cdot°C)(7\,°C) = 301.84\ W/m^2$$

- Q due to Solar:

$$(.5)(750\ W/m^2) = 375\ W/m^2$$

- Total Q on roof surface

$$301.84\ W/m^2 + 375\ W/m^2 = 676.84\ W/m^2$$

- Thermal resistive circuit

$$T_{so} = 25°C \quad \frac{L_1}{A_1 K_{Al}} \quad \frac{L_2}{A_2 K_{ur}} \quad \frac{L_3}{A_3 K_{Al}} \quad T_{s_i} = -10°C$$

$$R_1 = \frac{L_1}{A_1 K_{Al}} = \frac{.005m}{(35m^2)(180\,W/mK)} = 7.936 \times 10^{-7}$$

$$R_2 = \frac{L_2}{A_2 K_{ur}} = \frac{.05m}{(35m^2)(.026\,W/mK)} = .054945$$

$$R_3 = \frac{L_3}{A_3 K_{Al}} = \frac{.005m}{(35m^2)(180\,W/m\cdot K)} = 7.936 \times 10^{-7}$$

$$.0549467$$

$$Q = \frac{T_{so} - T_{s_i}}{\Sigma R}$$

$$T_{so} = Q \Sigma R + T_{s_i}$$

$$T_{so} = (676.84)(.0549467) - 10°C$$

$$\boxed{T_{so} = 27.2°C}$$

Compare to guess of 25°C

$$\frac{27°C - 25°C}{27°C} = 7.4\% < 10\%$$

Summary: The temperature on the top of the roof would be 27.2°C under the given circumstances.

Materials:

Aluminum
urethane foam
Air
Sun

Analysis: It appears that the foam insulation does a good job insulating. If you wanted the system to be more efficient you could make any of the layers thicker. You could also use a material for the roof that would have less absorptivity than the aluminum.