Final Gate Review (12/13/13)

- Look at Risks - now compared to 1st week

- lead times
- Robust Design

→ Re-Do calculations for heat transfer

h_3 $U_\infty = 0.04863$ m/s (from Phung's calculations)

1 iron

$$Re_D = \frac{U_\infty D}{\nu} = \frac{(0.04863 \frac{m}{s})(.0254m)}{(112.2 \times 10^{-6} m^2/s)}$$

Pg 995 heat treat text air @ 950 K

$Re = 11.01$

$Pr = 0.723$

$C = 0.911$ (table 7.2 heat treat text) Pg 458

$m = 0.385$

$K = 64.3 \times 10^{-3}$ w/mk

$$Nu = C(Re)^m (Pr)^{1/3}$$

$$= (0.911)(11.01)^{.385}(0.723)^{1/3}$$

$Nu = 2.059$

$$Nu = \frac{h_3 D}{K} \rightarrow h_3 = \frac{(Nu)K}{D} = \frac{(2.059)(64.3 \times 10^{-3} w/mk)}{(.0254m)}$$

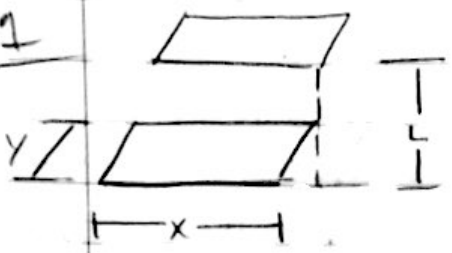
$$\boxed{h_3 = 5.212 \quad w/m^2K}$$

h_3 = conduction from fire to pipe

$h_4 = h_r$

determine view factor

CATE 1



$\frac{X}{L} = \frac{.722m}{.1524m} = 5.06$

$\frac{Y}{L} = \frac{.722}{.1524} = 5.06$

6"

$F_{ij} = .7$

-use Figure 13.4 Pg 868
13.2 Pg 867

$$F_{ij} = 1 - \left[1 - \left(\frac{D}{S}\right)^2\right]^{1/2} + \left(\frac{D}{S}\right)\tan^{-1}\left[\left(\frac{S^2 - D^2}{D^2}\right)^{1/2}\right]$$

D = .0254m (1")
S = .0508m (2")

$$= 1 - \left[1 - \left(\frac{1}{2}\right)^{1/2}\right] + \left(\frac{1}{2}\right)\tan^{-1}\left[\left(\frac{.0508^2 - .0254^2}{.0254^2}\right)^{1/2}\right]$$

(3)

$$= 1 - \left[1 - .125\right] + .5\tan^{-1}\left(\sqrt{3}\right)$$

$$= 1 - .875 + .5(1.04719) = .648$$

$$F_{ij} = \frac{\left[(W_i + W_j)^2 + 4\right]^{1/2} - \left[(W_j - W_i)^2 + 4\right]^{1/2}}{2W_i}$$

(3 coils) x 4

$$W_i = \frac{w_i}{L} = \frac{.3098}{.1524} = 2$$

$$W_j = \frac{w_j}{L} = \frac{.722}{.1524} = 5.06 \approx 5$$

$$F_{ij} = \frac{\left[(2+5)^2 + 4\right]^{1/2} - \left[(5-2)^2 + 4\right]^{1/2}}{2(2)}$$

$$= \frac{\sqrt{53} + \sqrt{13}}{4} = \frac{3.67}{4} = .918 = F_{ij}$$

USE $F_{ij} = .65$ as a conservative factor

$$h_r = \left(\frac{\varepsilon_f \varepsilon_s}{\varepsilon_f + \varepsilon_s - \varepsilon_f \varepsilon_s}\right)(F_{ij})(\sigma)\left(T_g^2 - T_s^2\right)(T_g + T_s)$$

$T_g = 650°C = 950°K$
$T_s = 70°C = 343K$
$\varepsilon_f = 1$ (black body)
$\varepsilon_s = .8$ (gray steel)
$\sigma = 5.07 \times 10^{-8}$
$F_{ij} = .65$

$h_r = 38.89 \ W/m^2K$

$$U = \left(\frac{1}{h_1} + \frac{t}{k_2} + \frac{1}{h_3 + h_4} \right)^{-1}$$

$$= \left(\frac{1}{95.5} + \frac{.00635}{50} + \frac{1}{5.212 + 38.89} \right)^{-1}$$

$$U = 30.05 \ W/m^2K$$

At max flow rate

$\dot{m} = 0.01645 \ kg/s \rightarrow Q = 3787.28 \ W$

$P = 3(.0254) = .0762$

$$L = \frac{Q}{U(P)(T_{fire} - \bar{T}_w)} = \frac{3787.28 \ W}{(30.05 \ W/m^2K)(.0762)(607.5K)}$$

$L = 2.72 \ m$ — {length needed to heat water from 15°C to 70°C

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at max flow rate need L_x length of pipe to maintain water at 70°C for 60 s.

$\dot{m} = 0.01645 \ kg/s \quad A = .0190^2 = 3.629 \times 10^{-4} \ m^2$

$m = V\rho = LA\rho$

$$L = \frac{m}{A\rho} = \frac{\dot{m}t}{A\rho} = \frac{(0.01645 \ kg/s)(60s)}{(3.629 \times 10^{-4} \ m^2)(1000 \ kg/m^3)} = 2.7197$$

$\dot{m}$ [kg/s]

$\dot{V}$ [m³/s]

Total mass in system. w/ L = 2.72 m

$V = AL = (3.629 \times 10^{-4} m^2)(2.72 m)$

$V = 9.871 \times 10^{-4} m^3$

$m = (V)\rho = (9.871 \times 10^{-4} m^3)(1000 kg/m^3)$

$m = .9871 kg$

$t = \frac{m}{\dot{m}} = \frac{.9871 kg}{.01645 kg/s} = 60.00 s$

$t = \frac{AL\rho}{\dot{m}}$

$m = .9871 kg$

Energy needed to heat mass of water in pipe from 15-70°C. [J]

$Q = \dot{m} c_p (\Delta T) \rightarrow E = m c_p (\Delta T)$

$= (.9871 kg)(4186 \frac{J}{kgK})(55°K)$

$E = 227260.033 J$

$Q = \frac{E}{t}$ $[W] = [\frac{J}{s}]$

$= \frac{227260}{60} = 3787.6$

TOTAL PIPE LENGTH = (2.72)2 = 5.44 ≈ 5.5 m

5.5 m ≡ TOTAL LENGTH OF PIPE