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3P04C

Given: $\overline{T_l} = 100\ °F$

$k_{water} = 1.07 \times 10^{-4}$ Btu/s ft F $= 0.3852$ Btu/hr ft F

$T_{gas} = 4500\ °F$

$\mu_{water} = 2.5 \times 10^{-5}$ lbf·s/ft^2

$\bar{c}_{water} = 1.3$ Btu/lb F

cooling dim: $1/4 \times 1/2$ in

$\dot{m}_{water} = 0.585$ lbm/s

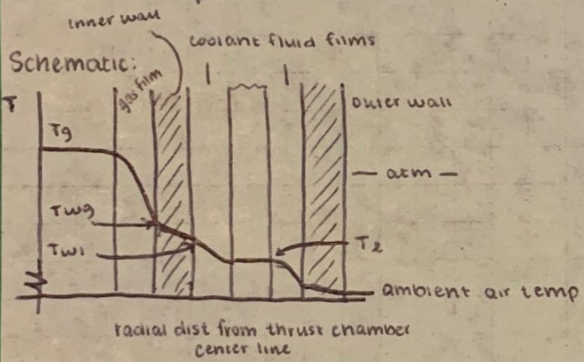
$t_{w,inner} = 1/8$ in

$q_{abs} = 1.3$ Btu/in^{2}s (also examine 1.0)

$k_{wall} = 26$ Btu/hr ft F

Find
a) Film coef. of coolant [h]
b) Wall temp on coolant side
c) Wall temp on gas side
d) Compare heat transfer coef equation here w/ one in textbook

Schematic:



Assumptions:
No losses

Basic Equations:

100x up

$$h_{liq} = 0.023\ \bar{c}_p\ \frac{\dot{m}_{water}}{A}\left(\frac{D v \rho}{\mu g_c}\right)^{-0.2}\left(\frac{\mu g_c \bar{c}_w}{k_w}\right)^{-2/3}$$ [HW4 PDF]

$$q_{conv} = h_{liq}\,(T_{wl} - T_\infty)$$

$$q_{cond} = -k\,(dt/dx)$$

Analysis:

a) Film coef. of fluid [h_{liq}]

$$h_\ell = 0.023\ \bar{C}_p\ \frac{\dot{m}_w}{A}\left(\frac{D v \rho}{\mu g_c}\right)^{-0.2}\left(\frac{\mu g_c \bar{C}_p}{K_w}\right)^{-2/3}$$

$\bar{C}_p = 1.3$ Btu/lbm°F
$\dot{m}_w = 0.585$ lbm/s
$A = 1/8\ in^2$
$D = \sqrt{4A/\pi} = 0.3989$ in
$\rho_w = 62.4\ lbm/ft^3$
$v = \dot{m}_w/\rho_w A = 0.585/(62.4 \times 1/8) = 0.075\ \frac{lbm\ ft^3}{s \cdot lbm\ in^2} \times \frac{144 in^2}{ft^2} = 10.8$ ft/s
$\mu = 2.5 \times 10^{-5}\ lbf s/ft^2$
$K_w = 1.07 \times 10^{-4}$ Btu/s ft °F

$$h_{liq} = 0.023 \times \frac{1.3\ Btu}{lbm°F} \times \frac{0.585\ lbm}{1/8\ in^2 s} \times \left[\frac{0.3989\ \cancel{in} \times 10.8\ \cancel{ft} \times 62.4\ \cancel{lbm}\ \cancel{ft^2}\ \cancel{lbf}\ \cancel{s^2} \times \cancel{ft}}{\cancel{sec}\ \cancel{ft^3} \times 2.5\times10^{-5}\ lbf \cdot \cancel{sec} \times 32.2\ \cancel{lbm}\ \cancel{ft} \times 12\ \cancel{in}}\right]^{-0.2}$$

$$\times \left[\frac{2.5\times10^{-5}\ lbf\ s \times 32.2\ lbm\ ft \times 1.3\ Btu\ \ s\ ft\ °F}{ft^2\ lbf\ s^2\ lbm\ °F \times 1.07\times10^{-4}\ Btu}\right]^{-2/3}$$

$h_{liq} = 0.139932\ Btu/in^2 s°F \times (27828.85)^{-0.2} \times (9.78037)^{-2/3}$

$h_{liq} = 0.139932\ (0.1291519)(0.2186569)\ Btu/in^2 s°F$

$\boxed{h_{liq} = 0.00395167\ Btu/in^2 s°F}$

b) Wall temp - coolant side (convec)

$q = h_\ell(T_w - T_\infty)$
$q = 1.3\ Btu/in^2 s$
$h_\ell = 0.00395\ Btu/in^2 s °F$
$T_\infty = \bar{T}_\ell = 100°F$

$$T_{wall} = \frac{q}{h_\ell} + T_\infty$$

$$T_{wall} = \frac{1.3\ Btu\ in^2 s°F}{in^2 s\ 0.00395\ Btu} + 100°F$$

$\boxed{T_{wall} = 429.114\ °F}$

c) wall temp - gas side (conduc.)

$$q = -k\left(\frac{dT}{dx}\right) = \frac{k}{t_w}\left(T_{wg} - T_{wl}\right)$$

$q = 1.3 \text{ Btu/in}^2\text{s}$

$k_{wall} = 26 \text{ Btu/hr ft °F}$

$t_w = 1/8 \text{ in}$

$T_{wl} = 429.114 \text{ °F}$

$$T_{wg} = \frac{q t_w}{k} + T_{wl}$$

$$T_{wg} = \frac{1.3 \text{ Btu} \mid \frac{1}{8} \text{ in} \mid \text{hr ft °F} \mid 12 \text{ in} \mid 3600 \text{ sec}}{\text{in}^2 \text{s} \mid 26 \text{ Btu} \mid \text{ft} \mid \text{hr}} + 429.114 \text{ °F}$$

$$T_{wg} = 270 \text{ °F} + 429.114 \text{ °F}$$

$$\boxed{T_{wg} = 699.114 \text{ °F}}$$