CALCULATION Water cooling process SHEET 1 OF 1

CALCULATION BY Cale Caldwell

DATE 19 April 2010

Assumptions

steady state conditions; heat distributed evenly over entire cylinder; no heat lost to surroundings; uniform heat flux

$Q := 2500\text{kW}$ Heat to be removed

Coolant is Water

$c := 4180 \frac{J}{kg \cdot K}$ Specific heat

$\rho := 998 \frac{kg}{m^3}$ Density

$k_w := .6154 \frac{W}{K \cdot m}$ Thermal conductivity

$\mu := .000798 N \cdot \frac{s}{m^2}$ Dynamic viscosity

Flow Rate Calculation

$T1 := 293K$ Coolant inlet temperature (assumed)

$T2 := 313K$ Coolant outlet temperature (assumed)

$mdot := \frac{Q}{c \cdot (T2 - T1)}$ $mdot = 29.904 \frac{kg}{s}$

$flowrate := \frac{mdot}{\rho}$ $flowrate = 474.943\text{gpm}$

$flowrate = 29.964 \frac{L}{s}$

Cooling Cylinder

$L_1 := 10m$ Water flow length (inlet and outlet at same end)

$r_i := 35cm$ Inside radius

$r_o := 57cm$ Outside radius

$A_c := \pi \cdot \left(r_o^2 - r_i^2 \right)$ $A_c = 0.636m^2$ Cylinder cross-sectional area

Tubes

$d := .622in$ — Tube diameter (1/2in pipe, schedule 10)

$v := 5\frac{m}{s}$ — Velocity of coolant (assumed)

$A_s := \pi \cdot d \cdot L_1$ — Surface area

$$n := \frac{\left(\frac{flowrate}{v}\right)}{\left(\pi \cdot \frac{d^2}{4}\right)} \qquad n = 30.57$$

Number of tubes required

$$R_A := \frac{\left(n \cdot \pi \cdot \frac{d^2}{4}\right)}{A_c} \qquad R_A = 9.425 \times 10^{-3}$$

Area ratio

.94 percent of the cross section is water

Heat Transfer Coefficient

$$Re := v \cdot d \cdot \frac{\rho}{\mu} \qquad Re = 9.879 \times 10^4$$

Reynold's number

$$Pr := c \cdot \frac{\mu}{k_w}$$

Prandtl number

$$f := (.79 \cdot \ln(Re) - 1.64)^{-2}$$

Friction factor

$$Nu_d := \frac{\left[\left(\frac{f}{8}\right) \cdot (Re - 1000) \cdot Pr\right]}{\left[1 + 12.7 \cdot \left(\frac{f}{8}\right)^{.5} \cdot \left(Pr^{\frac{2}{3}} - 1\right)\right]}$$

Nusselt number

$$h_1 := Nu_d \cdot \frac{k_w}{d} \qquad h_1 = 2.062 \times 10^4 \frac{W}{m^2 \cdot K}$$

Heat transfer coefficient

$$delT := \frac{Q}{\left(h_1 \cdot A_s\right) \cdot n} \qquad delT = 7.991\,K$$

Actual temperature difference from inlet to outlet