CALCULATION Water cooling process

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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

\[ c := 4180 \frac{\text{J}}{\text{kg} \cdot \text{K}} \]
Specific heat

\[ \rho := 998 \frac{\text{kg}}{\text{m}^3} \]
Density

\[ k_w := .6154 \frac{\text{W}}{\text{K} \cdot \text{m}} \]
Thermal conductivity

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

Flow Rate Calculation

\[ T_1 := 293 \text{K} \]
Coolant inlet temperature (assumed)

\[ T_2 := 313 \text{K} \]
Coolant outlet temperature (assumed)

\[ \text{mdot} := \frac{Q}{c(T_2 - T_1)} \]
\[ \text{mdot} = 29.904 \frac{\text{kg}}{\text{s}} \]

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

\[ \text{flowrate} = 29.964 \frac{\text{L}}{\text{s}} \]

Cooling Cylinder

\[ L_1 := 10 \text{m} \]
Water flow length (inlet and outlet at same end)

\[ r_i := 35 \text{cm} \]
Inside radius

\[ r_o := 57 \text{cm} \]
Outside radius

\[ A_c := \pi \left( r_o^2 - r_i^2 \right) \]
\[ A_c = 0.636 \text{m}^2 \]
Cylinder cross-sectional area
Tubes

d := .622 in

\[ v := \frac{5 \, \text{m}}{\text{s}} \]

Tube diameter (1/2 in pipe, schedule 10)

Velocity of coolant (assumed)

\[ A_s := \pi \cdot d \cdot L_1 \]

Surface area

\[ n := \left( \frac{\text{flowrate}}{v} \right) \]

Number of tubes required

\[ n = 30.57 \]

\[ R_A := \frac{n \cdot \pi \cdot d^2}{4} \]

Area ratio

\[ R_A = 9.425 \times 10^{-3} \]

.94 percent of the cross section is water

Heat Transfer Coefficient

\[ \text{Re} := v \cdot d \cdot \frac{\rho}{\mu} \]

Reynold's number

\[ \text{Re} = 9.879 \times 10^4 \]

\[ \text{Pr} := c \cdot \frac{\mu}{k_w} \]

Prandtl number

\[ f := (0.79 \cdot \ln(\text{Re}) - 1.64)^{-2} \]

Friction factor

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

Nusselt number

\[ h_1 := \frac{k_w}{d} \]

\[ h_1 = 2.062 \times 10^4 \frac{\text{W}}{\text{m}^2 \cdot \text{K}} \]

Heat transfer coefficient

\[ \text{delT} := \frac{Q}{(h_1 \cdot A_s) \cdot n} \]

Actual temperature difference from inlet to outlet

\[ \text{delT} = 7.991 \text{ K} \]