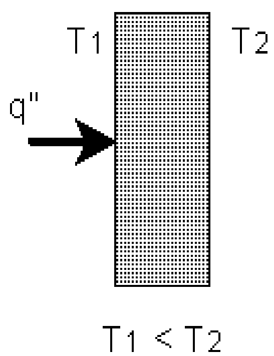
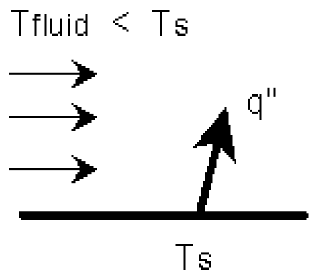
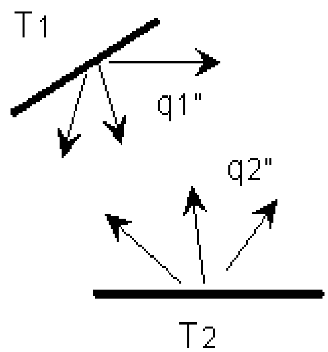
PROJECT: Laser RamanSpectroscopy

DATE: 03/6/01

ANALYST: M.Brown

HEAT TRANSFER CALCULATIONS:

<table>
<tr><th>Conduction through solid or a stationary fluid</th><th>Convection from a surface to a moving fluid</th><th>Net radiation exchange between two surfaces</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
</table>

ASSUMPTIONS: REF: Fundamentals of Heat & Mass Transfer pp 595

The CCD camera in the Laser Raman Spectrometer requires 25W of heat to be removed from the device. Two cooling ports exist for this purpose the CCD specification requires cooling water to be pumped at .75 lpm and a temperature of 10 degrees celsius.

Potential & kinetic energy changes are negligible.

Negligible tube thermal resistance & fouling.

Constant properties.

Fully developed conditions exist.

PROPERTIES:

Tube Material:Aluminum
thermal conductivity = 177 W/m * K

Viscosity Seawater $\mu_{sw} := 1.221 \times 10^{6} \cdot N \cdot \frac{s}{m^2}$

Viscosity Cooling water $\mu_{cw} := 631 \times 10^{6} \cdot N \cdot \frac{s}{m^2}$

Thermal Conductivity Cooling water $k_{cw} := .634 \cdot \frac{W}{m \cdot K}$

Assume seawater 4degC $T_{ci} := 277 \cdot K$

Flow rate = .75 LPM @ 10 degrees C

Celsius = 273.15 Kelvin

Seawater
Specific Heat @ Constant pressure $c_{p1} := 4189 \frac{J}{kg \cdot K}$

Pure water
Specific Heat @ Constant pressure $c_{p2} := 4179 \frac{J}{kg \cdot K}$

Thermal Conductivity Seawater $k_{sw} := .590 \cdot \frac{W}{m \cdot K}$

For a tube heat exchanger dissipating 25W of heat through a .25 ID X .50 OD tube that is cooled by seawater at 4 deg celsius, what is the length of tube required to cool the return water to 10 deg celsiuis (283 K)

Mass flow rate of hot fluid given .75 lpm @ 10 deg celsius = $.014 \cdot \frac{kg}{sec}$ $\qquad m_h := .014 \cdot \frac{kg}{sec}$

Assume sewater flow over outside of tube. $\qquad m_c := .005 \cdot \frac{kg}{sec}$ $\qquad$ Required Heat transfer rate $\qquad q := 25 \cdot W$

Assume Cooling water $\qquad T_{hi} := 285 \cdot K$

Cooling water return temp $\qquad T_{ho} := 283 \cdot K$

Energy Balance equation $\qquad q := m_h \cdot c_{p2} \cdot (T_{hi} - T_{ho})$

Equation 11.7b $\qquad T_{co} := \frac{q}{m_c \cdot c_{p1}} + T_{ci}$ $\qquad T_{co} = 278.194\,K$

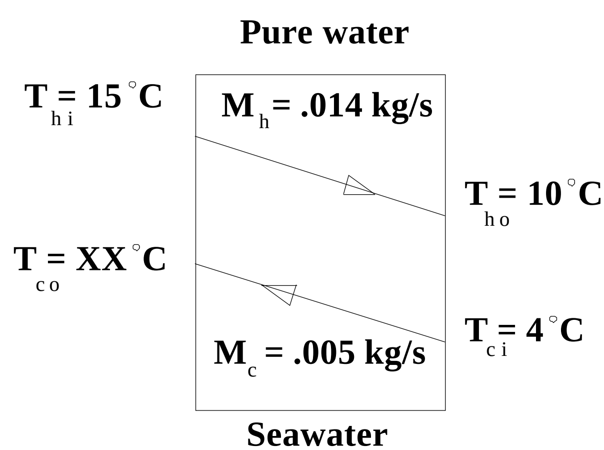
HEAT TRANSFER $\qquad$ q = UA ΔT_{lm}

Where U = Overall convection coeficient

Where A = $\pi D_i \cdot L$ $\qquad \Delta T_{lm}$ = Log Mean temperature difference

$$\Delta T_{lm} := \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln\left(\frac{T_{hi} - T_{co}}{T_{ho} - T_{ci}}\right)}$$

$\Delta T_{lm} = 6.395\,K$



Overall Heat Transfer Coefficient

$$U := \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}}$$

$D_i := .00635 \cdot m \qquad D_o := .0127 \cdot m$

Tube ID=.25in = .00635m

Laminar or Turbulent flow:

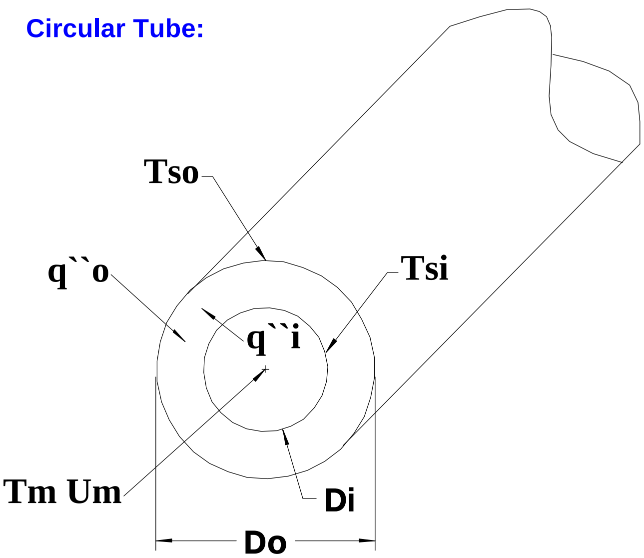
$$Re_D := 4 \frac{m_c}{\pi \cdot D_i \cdot \mu_{cw}} \qquad Re_D = 1.589 \times 10^{-9}$$

Laminar flow ReD < 2300

(Hydraulic Diameter) $D_h := D_o - D_i$

$D_h = 6.35 \times 10^{-3} m$

Circular Tube:



Nusselt numbers

$$N_{uo} := \frac{h_o \cdot D_h}{k_{sw}} \qquad N_{ui} := \frac{h_i \cdot D_h}{k_{cw}}$$

From Table 8.3
For uniform heat flux
at both surfaces

$N_{ui} := 6.6$

$N_{uo} := 5.0$

Where Di/Do = 0.50

h_o = Convection coefficient (outer)

$$h_o := \frac{N_{uo} \cdot k_{sw}}{D_h} \qquad h_o = 464.567 \frac{kg}{s^3 K}$$

h_i = Convection coefficient (inner)

$$h_i := \frac{N_{ui} \cdot k_{cw}}{D_h} \qquad h_i = 658.961 \frac{1}{m^2 K} W$$

Overall Heat Transfer Coefficient

$$U := \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}} \qquad U = 272.473 \frac{1}{m^2 K} W$$

Units check: = $q = 25 W$

$D_i = 6.35 \times 10^{-3} m$

$\Delta T_{lm} = 6.395 K$

Length of tube required:

$$L_{tube} := \frac{q}{U \cdot \pi \cdot D_i \cdot \Delta T_{lm}}$$

$L_{tube} = 0.719 m$