a) Calculate pressure drop req'd to circulate water

→ EES Function

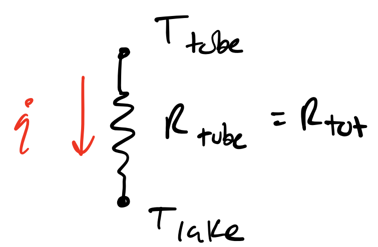
→ $\boxed{\Delta P = 231.005 \, (kPa)}$

b) Find $\dot{q}_{cool}$ BTU/hr by finding Pump power & compressor power

comp: f.

→ $\boxed{\dot{q}_{cool} = 34862 \ \text{BTU/hr}}$

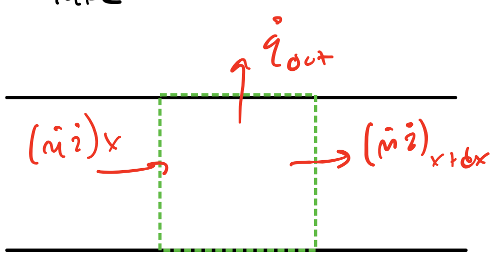
c) R_{tot} between water in tube & lake water



$$R_{tube} = R_{cyl} = \frac{\ln\left(\frac{r_{out}}{r_{in}}\right)}{2\pi L k}$$

→ $R_{tub} =$

d)



$$\dot{q}_{out} = \underbrace{\frac{T_m - T_{lake}}{R_{tot}}}_{\dot{q}_{tot}} \cdot \underbrace{\frac{dx}{L}}$$

$$\cancel{(\dot{m} i)_x} - \frac{T_m - T_{lake}}{R_{tot} L} \cancel{dx} - \left[\cancel{(\dot{m} i)_x} + \frac{d(\dot{m} i)_x}{dx} \cancel{dx} \right] = 0$$

$$\rightarrow \frac{d(\dot{m} i)_x}{dx} = \int -\frac{T_m - T_{lake}}{R_{tot} L} dx = \int \dot{m} c_p \frac{dT_m}{dx} dx$$

$$\rightarrow T_m = \frac{-T_m + T_{lake}}{R_{tot} L \dot{m} C_p} x + C_1$$

$$T_m(x=0) = T_{out} \rightarrow C_1 = T_{out}$$

$$\rightarrow T_m = \frac{-T_m + T_{lake}}{R_{tot} L \dot{m} C_p} x + T_{out}$$

$$\rightarrow \boxed{T_{ret} = 28.61\ [C]}$$

e)

$$\dot{q} = (\dot{m} i)_f - (\dot{m} i)_i$$

$$\dot{q} = \dot{m}(i_2 - i_1)$$

$$\dot{q} = \dot{m}(c_p(T_2 - T_1))$$

$$\rightarrow \boxed{T_{out} = 32.98°C}$$

f)

$$\boxed{COP = 7.057}$$

g)

$$\boxed{L_{COP_{max}} = 153.3\ ft}$$

```
$unitsystem SI C Pa J

"
ME364 Homework 8
Fall 2023
"

Function f_w_dot_c(T)
   f_w_dot_c := (850 [W]) + (1.347 [W/F])*T + (9.9e-2 [W/F^2])*T^2
   {
   To evaluate the function, use the following example:
   >> f_w_dot_c( converttemp(C,F, T_ret) )
   }
End

"Given constants"
V_dot = 15 [gal/min]*convert(gal/min, m^3/s)                    "Coolant loop volumetric flow rate"
T_lake = converttemp(F, C, 60 [F])      "Lake water temperature"
q_dot_rej = 40000 [Btu/hr]*convert(Btu/hr, W)                   "Total heat rejection load"

P_ref = Po#                             "Assume that the water properties can be evaluated at atmospheric pressure"

eta_pump = 0.6 [-]                      "Pump efficiency"

h_bar_o = 250 [W/m^2-K]                 "External convection coefficient on the tube"
$ifnot parametrictable
$ifnot minmax
L = 200 [ft]*convert(ft, m)             "Tube length"
$endif
$endif
k_tube = 1.5 [W/m-K]                    "Tube wall conductivity"
D = 1 [in]*convert(in,m)                "Tube outer diameter"
a = (3/32) [in]*convert(in,m)           "Tube wall thickness"

T_out = converttemp(F, C, 100 [F])      "Assumed"
T_ret = T_lake                          "Assumed"

"part a"
T_film = (T_out+T_ret)/2
rho=density(Water,T=T_film,P=P_ref)
mu=viscosity(Water,T=T_film,P=P_ref)
m_dot = rho*V_dot
D_in = D-2*a
RelRough = 0                            "assumed"
Call pipeflow('Water',T_film,P_ref,m_dot,D_in,L,RelRough:h_T, h_H ,DELTAP, Nusselt_T, f, Re)

"part b"
w_dot_pump_out = V_dot*DELTAP      "pump power"
w_dot_comp =  f_w_dot_c(converttemp(C,F, T_ret))                "compressor power"

q_dot_rej = q_dot_cool + w_dot_pump_out + w_dot_comp            "sum of energy inputs"

"part c"
R_tube = ln(D/D_in)/(2*pi#*L*k_tube)
R_tot = R_tube

"part d"
cp = cp('Water',T=T_film,P=P_ref)
```

```
T_ret_s = (-T_ret_s+T_lake)/(R_tot*L*m_dot*cp)*L+T_out

"part e"
q_dot_rej = m_dot*cp*(T_out_new-T_ret_s)                        "new Tout calculated with Tret from part d"
//T_ret_new = (-T_ret_new+T_lake)/(R_tot*L*m_dot*cp)*L+T_out_new  "equation not used to solve for new Tret"

"part f"
COP = q_dot_cool/(w_dot_pump_out+w_dot_comp)

"part g"

w_dot_pump_out_g = V_dot*DELTAP  "pump power"
w_dot_comp_g =  f_w_dot_c(converttemp(C,F, T_ret_s))            "compressor power"
q_dot_rej = q_dot_cool_g + w_dot_pump_out_g + w_dot_comp_g      "sum of energy inputs"

COP_g = q_dot_cool_g/(w_dot_pump_out_g+w_dot_comp_g)
```

SOLUTION

Unit Settings: SI C Pa J mass deg

Maximization of COP_g(L) 20 iterations: Quadratic Approximations method (Rel. Tol=1.0E-04)

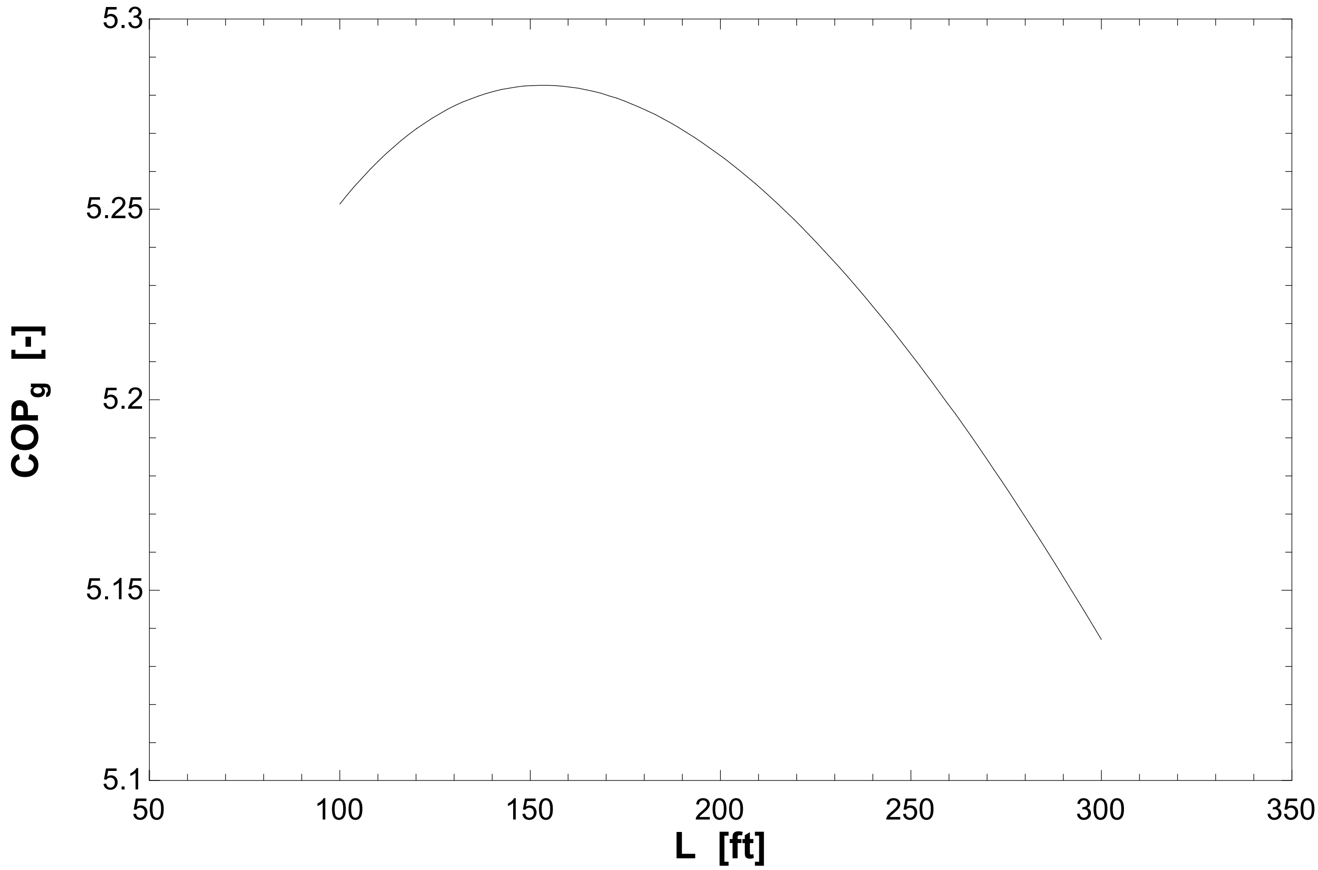
a = 0.002381 [m] {0.09375 [in]}	COP = 7.057 [-]
COP_g = 5.283 [-]	cp = 4181 [J/kg-C]
D = 0.0254 [m] {1 [in]}	ΔP = 177201 [Pa] {177.2 [kPa]}
D_{in} = 0.02064 [m]	η_{pump} = 0.6 [-]
f = 0.01962 [-]	$\overline{h}_o$ = 250 [W/m^2-K]
h_H = 11784 [W/m^2-K]	h_T = 11784 [W/m^2-K]
k_{tube} = 1.5 [W/m-K]	L = 46.73 [m] {153.3 [ft]}
μ = 0.0008572 [Pa-s]	$\dot{m}$ = 0.9431 [kg/s]
$Nusselt_T$ = 399.2 [-]	P_{ref} = 101325 [Pa]
$\dot{q}_{cool}$ = 10268 [W] {35036 [BTU/hr]}	$\dot{q}_{cool,g}$ = 9857 [W]
$\dot{q}_{rej}$ = 11723 [W]	Re = 67879 [-]
$RelRough$ = 0 [-]	ρ = 996.6 [kg/m^3]
R_{tot} = 0.0004715 [C/W]	R_{tube} = 0.0004715 [K/W]
T_{film} = 26.67 [C]	T_{lake} = 15.56 [C]
$T_{out,new}$ = 32.98 [C]	T_{ret} = 15.56 [C]
$T_{ret,s}$ = 30.01 [C]	$\dot{V}$ = 0.0009464 [m^3/s]
$\dot{w}_{comp}$ = 1287 [W]	$\dot{w}_{comp,g}$ = 1698 [W]
$\dot{w}_{pump,out}$ = 167.7 [W]	$\dot{w}_{pump,out,g}$ = 167.7 [W]

No unit problems were detected.

KEY VARIABLES

Maximization of COP_g(L) 20 iterations: Quadratic Approximations method (Rel. Tol=1.0E-04)

ΔP = 177201 [Pa] {177.2 [kPa]}	*a) pressure drop required to circulate water through lake*
$\dot{q}_{cool}$ = 10268 [W] {35036 [BTU/hr]}	*b) cooling provided to cabin*
R_{tube} = 0.0004715 [K/W]	*c) total thermal resistance between tube water and lake water*
$T_{ret,s}$ = 30.01 [C]	*d) water temperature returning from lake*
$T_{out,new}$ = 32.98 [C]	*e) new Tout using Tret from d)*
COP = 7.057 [-]	*f) COP*
L = 46.73 [m] {153.3 [ft]}	*g) maximized COP with L*


5.3
5.25
5.2
5.15
5.1
COP_g [-]
50
100
150
200
250
300
350
L [ft]