Appendix B

Simple Calculations Using EES Software

B.1 Calculation of Reynolds number

rho = density of oil=900[kg/m^3]

mu = coefficient of dynamic viscosity of thermal oil =0.027[kg/m-s]

d = helical coil tube diameter=0.005[m]

Q = flow rate of oil through helical coil tube=5.88[l/min]*convert(l/min,m^3/s)

A_c = area of cross section of tube of flow=(pi#/4)*d^2

v = velocity of flow=Q/A

Re = Reynolds number=rho*v*d/mu

B.2 Calculation of Prandtl number

C_p = specific heat capacity of oil =2061[J/kg-K]

k_con = thermal conductivity of oil=0.165[W/m-k]

b = pitch of the helical coil tube=24.38[mm]*convert(mm,m)

gama = dimensionless pitch of coil=b/(pi#*D_c)

Pr = Prandtl Number=mu*C_p/k_con

B.3 Calculation of curvature ratio

D_c = 0.025[m]

Delta = curvature ratio=d/D_c

B.4 Calculation of Dean number

De = Re*(delta)^0.5

B.5 Calculation of helix number

He = De/(1+(gama)^2)^0.5

B.6 Experimental determination of h

m_dot = 0.0882[kg/s] “Mass flow rate of thermal oil “

C_p=2061[J/kg-k] “Specific heat capacity of HTF”

k_c=400[W/m-k] “Thermal conductivity of copper tube”

A_r=0.1137[m^2] "Receiver surface area"

t=0.001[m] "Thickness of the coil tube"

d=0.005[m] " Inner diameter of the coil tube"

L=5.172[m] " Total length of the helical coil"

T_i=53.3+273[K] " Inlet fluid temperature"

T_e=61.5+273[k] "Exit fluid temperature"

T_so=67.5+273[K] " Outer surface temperature of receiver tube"

T_m=(T_e+T_i)/2 "Mean fluid temperature"

Q_u= m_dot*C_p*(T_e-T_i) "Useful heat gain"

Q_u= (2*pi#*k_c*L*(T_si-T_so))/(LN((d+2*t)/d)) h=Q_u/(A_r* (T_si - T_m)) "Convective heat transfer coeficient between coil fluid interface"

B.7 Calculation of thermal efficiency

m_dot=0.0882[kg/s] "Mass flow rate of thermal oil"

C_p=2061[J/kg-k] "Specific heat capacity of HTF"

k_c=400[W/m-k] "Thermal conductivity of copper tube"

A_r=0.1137[m^2] "Receiver surface area"

t=0.001[m] "Thickness of the coil tube"

d=0.005[m] " Inner diameter of the coil tube"

L=5.172[m] " Total length of the helical coil"

A_a=2.2487[m^2] " Aperture area of PTC"

T_i=53.3+273[K] " Inlet fluid temperature"

T_e=61.5+273[k] "Exit fluid temperature"

T_so=67.5+273[K] " Outer surface temperature of receiver tube"

T_m=(T_e+T_i)/2 "Mean fluid temperature"

Q_u= m_dot*C_p*(T_e-T_i) "Useful heat gain"

Q_u= (2*pi#*k_c*L*(T_si-T_so))/(LN((d+2*t)/d))

h=Q_u/(A_r* (T_si - T_m)) "Convective heat transfer coeficient between coil fluid interface"

I_b=766[W/m^2] "beam solar radiation"

Eta=Q_u/(A_a*I_b) "Efficiency of experimental setup"

B.8 Calculation of pressure drop across the length of helical coil

m_dot=0.0882[kg/s] "Mass flow rate of thermal oil"

C_p=2061[J/kg-K] "Specific heat capacity of HTF" k_c=400[W/m-K] "Thermal conductivity of copper tube"

A_r=0.1137[m^2] "Receiver surface area"

t=0.001[m] "Thickness of the coil tube"

d=0.005[m] " Inner diameter of the coil tube"

D_c = 0.025[m] "Curvature diameter of helical coil tube"

L=5.172[m] " Total length of the helical coil"

A_a=2.2487[m^2] " Aperture area of PTC"

v=4.991[m/s] "Velocity of flow"

rho=900[kg/m^3] " Density of fluid"

Re=831.9 "Reynolda number"

f_coil = (344*(D_c/d)^(-0.5))/(1.56+LOG10(Re*(D_c/d)^(-0.5)))^5.33 “Friction factor of helical coil tube”

DELTA_P=f_coil*(L/d)*0.5*rho*v^2 " Required pressure drop across the length of helical coil"

B.9 Simple Solutions

Unit Settings: [J]/[K]/[bar]/[kg]/[degrees]

A_c = 0.00001963 [m^2]	b = 0.02438	C_p = 2061 [J/kg-K]	d = 0.005 [m]
He = 355.3	k_{con} = 0.165 [W/m-k]	μ = 0.027 [kg/m-s]	Pr = 337.3
De = 372	δ = 0.2	D_c = 0.025 [m]	gama = 0.3104
Q = 0.000098 [m^3/s]	Re = 831.9	ρ = 900 [kg/m^3]	v = 4.991 [m/s]

Unit Settings: [J]/[K]/[bar]/[kg]/[degrees]

A_r = 0.1137 [m^2]	C_p = 2061 [J/kg-k]	d = 0.005 [m]	h = 1293 [W/m^2-K]
t = 0.001 [m]	T_e = 334.5 [k]	T_i = 326.3 [K]	T_m = 330.4 [K]
k_c = 400 [W/m-k]	L = 5.172 [m]	$\dot{m}$ = 0.0882 [kg/s]	Q_u = 1491 [J]
T_{si} = 340.5 [K]	T_{so} = 340.5 [K]		

Unit Settings: [J]/[K]/[bar]/[kg]/[degrees]

A_a = 2.249 [m^2]	A_r = 0.1137 [m^2]	C_p = 2061 [J/kg-k]	d = 0.005 [m]
L = 5.172 [m]	$\dot{m}$ = 0.0882 [kg/s]	Q_u = 1491 [J]	t = 0.001 [m]
T_{so} = 340.5 [K]			
η = 0.8654	h = 1293 [W/m^2-K]	I_b = 766 [W/m^2]	k_c = 400 [W/m-k]
T_e = 334.5 [k]	T_i = 326.3 [K]	T_m = 330.4 [K]	T_{si} = 340.5 [K]

Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]

A_a = 2.249 [m^2]	A_r = 0.1137 [m^2]	C_p = 2061 [J/kg-K]	d = 0.005 [m]
L = 5.172 [m]	$\dot{m}$ = 0.0882 [kg/s]	Re = 831.9	ρ = 900 [kg/m^3]
ΔP = 928982 [Pa]	D_c = 0.025 [m]	f_{coil} = 8.012E-02	k_c = 400 [W/m-K]
t = 0.001 [m]	v = 4.991 [m/s]		