APPENDIX A: THERMO-ELASTIC COLLECTOR DESIGN PROGRAM

```
" h_fi = 300 W/m^2C
this program generates FR graphs for turbulent flow"

Procedure Nusselt(Re , Pr : Nus)
        If (Re < 2100) Then
                Nus := 3.66
        Else
                Nus := 0.023*Re^(4/5)*Pr^(1/3)
        EndIf
End Nusselt

k = 0.1 "W/m^2 C; thermal conductivity"
T_a = 20 "C; ambient temperature"
T_f = 35 "C; fluid temperature"
S = 1000 "W/m^2; absorbed radiation"
U_t = 7 "W/m^2; top heat transfer coefficient"
U_b = 1 "W/m^2; back heat transfer coefficient"
{h_f = 300 "W/m^2; heat transfer coefficent to fluid at wall"}
W = 0.03 "m; fin width"
D = 0.01 "m; tube diameter"
{delta_f = 0.01 "m; fin thickness"}
delta_t = 0.005 "m; tube wall thickness"
A_c = 1 "m^2; collector area"
{m_dot = 0.015 "kg/s; fluid mass flow rate"}
C_p = 4180 "J/kg C; water specific heat"
k_fluid = 0.628
mu = 0.000655 "Pa s; absolute viscosity of water at 40 C"
Pr = 4.34

Re = 4*m_dot/(pi*D*mu)

call Nusselt(Re, Pr : Nus)
h_f = Nus*k_fluid/D
m_f = sqrt((U_t+U_b)/(k*delta_f))
m_t = sqrt((U_t+h_f)/(k*delta_t))
m_b = sqrt((U_b+h_f)/(k*delta_t))
```

```
"energy transfer from fin to base point"
q_fin = -m_f*k*delta_f*(T_b - T_a - (S/(U_t+U_b)))*tanh(m_f*(W-D)/2)
"energy transfer from tube top half to base point"
q_top = -m_t*k*delta_t*(T_b - (1/(U_t+h_f))*(U_t*T_a + h_f*T_f +
S))*tanh(m_t*pi*D/4)
"energy transfer from tube bottom half to base point"
q_bot = -m_b*k*delta_t*(T_b - (1/(U_b+h_f))*(U_b*T_a +
h_f*T_f))*tanh(m_b*pi*D/4)
"energy transfer from base point to fliud"
q_end = h_f*delta_t*(T_b - T_f)

"energy balance on base point"
q_fin + q_top + q_bot = q_end

"energy transfered from top half of tube to water"
q_u_top = integral(q_flux_t,x_t,0,pi*D/4)
q_flux_t = h_f*(T_top - T_f)
(T_top - (1/(U_t+h_f))*(U_t*T_a + h_f*T_f + S))/(T_b - (1/(U_t+h_f))*(U_t*T_a +
h_f*T_f + S)) = cosh(m_t*x_t)/cosh(m_t*pi*D/4)

"energy transfered from bottom half of tube to water"
q_u_bot = integral(q_flux_b,x_b,0,pi*D/4)
q_flux_b = h_f*(T_bot - T_f)
(T_bot - (1/(U_b+h_f))*(U_b*T_a + h_f*T_f))/(T_b - (1/(U_b+h_f))*(U_b*T_a +
h_f*T_f)) = cosh(m_b*x_b)/cosh(m_b*pi*D/4)

"total energy transfered from fin and tube to water"
q`_w = q_end + q_u_top + q_u_bot

"gains if everything is at Tf : gains = S - losses"
q_u_tf = S*((W-D)/2+pi*D/4) - ((W-D)/2+pi*D/4)*(U_t+U_b)*(T_f - T_a)

"incident radiation"
incident = S*((W-D)/2+pi*D/4)

"F` = q_actual / q_T=Tf"
F` = q`_w/q_u_tf

FR = (m_dot*C_p)/(A_c*(U_t+U_b))*(1-exp((-A_c*F`*(U_t+U_b))/(m_dot*C_p)))
{(m_dot*C_p)/(A_c*(U_t+U_b))*(1-exp(A_c*F`*(U_t+U_b)/(m_dot*C_p)))}

x_ax = m_dot/A_c
```

APPENDIX B: THERMAL AND ECONOMIC ANALYSIS PROGRAMS

“This program is used to calculate the thermal penalty associated with a three-season system”

```
FUNCTION DoY_(Month)
    Month = round(Month)
    If Month = 0 Then DoY_= 355
    If Month = 1 Then DoY_ = 1
    If Month = 2 Then DoY_ = 32
    If Month = 3 Then DoY_ = 60
    If Month = 4 Then DoY_ = 91
    If Month = 5 Then DoY_ = 121
    If Month = 6 Then DoY_ = 152
    If Month = 7 Then DoY_ = 182
    If Month = 8 Then DoY_ = 213
    If Month = 9 Then DoY_ = 244
    If Month = 10 Then DoY_ = 274
    If Month = 11 Then DoY_ = 305
    If Month = 12 Then DoY_ = 335
    If Month = 13 Then DoY_ = 355
END

FUNCTION slope3_(FF,LF,lat)
    FFn = DoY_(FF) "day of year corresponding to first fall freeze"
    LFn = DoY_(LF) "day of year corresponding to last spring freeze"
    springdec = Dec_(LFn) "declination at last spring freeze"
    falldec = Dec_(FFn) "declination at first fall freeze"
    mindec = min(falldec,springdec) "calculates the minimum of these two"
    If (5>LF) Then
        maxdec = Dec_(182)
    Else
        maxdec = 23.45
    EndIf
    slope3_ = lat - ((maxdec+mindec)/2)
END
```

```
Function
F_R`\F_R_(A_c,FrUl,MassFR_col,C_p`col,MassFR_tk,C_p`tk,Effect_CHX)
{Equation 10.2.3}
    CollCapRate=MassFR_col*C_p`col
    TankCapRate=MassFR_tk*C_p`tk
    CapRateMin=min(CollCapRate,TankCapRate)
    X=A_c*FrUl/CollCapRate
    Y=CollCapRate/(Effect_CHX*CapRateMin)
    F_R`\F_R_=(1+X*(Y-1))^(-1)
END

FUNCTION MonthFlag_(i,FF,LF)
    If (i>LF) and (i<FF) then
        MonthFlag_ := 1
    Else
        MonthFlag_ := 0
    EndIf
END

StoreCap = 81.49

"data specific to three season system"
{slope3 = 28 "collector slope"}
C_p`col3 = 4190 "J/kgC; specific heat of collector loop fluid"
Effect_CHX3 = 1 "heat exchanger effectiveness:"
{A_c3 = 7.5 "m^2; collector area"}

"data specific to four season system"
slope4 = lat "collector slope"
C_p`col4 = 3350 "J/kgC; specific heat of collector loop fluid"
Effect_CHX4 = 0.2 "heat exchanger effectiveness"
A_c4 = A_c3 "m^2; collector area"

"system parameters"
T_set = 60 "tank temperature set point"
draw = 300 "l; daily water draw"
UA_tk = 0 "W/C; tank losses THESE AREN' INCLUDED YET"
GrRef = 0.2 "ground reflectance"

"collector parameters"
FrUl = 4.86 "W/m^2C; efficiency curve slope"
Frta_n = 0.741 "efficiency curve intercept"
C_p`tk = 4190 "J/kgC; specific heat of tank loop fluid"
MassFR_col3 = 0.015*A_c3 "kg/s; collector loop flow rate"
```

```
MassFR_tk3 = 0.015*A_c3 "kg/s; tank loop flow rate"
MassFR_col4 = 0.015*A_c4 "kg/s; collector loop flow rate"
MassFR_tk4 = 0.015*A_c4 "kg/s; tank loop flow rate"
T_ref = 100 "C; empirically derived reference temperature"

tabar\ta_n = 0.96 "TauAlphaIncAng_(Ncov,IncAng,KL,RefrInd,Alpha_n) "

F_R`\F_R3 =
F_R`\F_R_(A_c3,FrUl,MassFR_col3,C_p`col3,MassFR_tk3,C_p`tk,Effect_CHX3)
F_R`\F_R4 =
F_R`\F_R_(A_c4,FrUl,MassFR_col4,C_p`col4,MassFR_tk4,C_p`tk,Effect_CHX4)



Lat = lookup(TableRun#,#latitude)

FF = Lookup(TableRun#,#FF) "month number in which first freeze of the year
occurs (Fall)"
LF = Lookup(TableRun#,#LF) "month number in which last freeze of the year occurs
(Spring)"

"the slope of the three season system is the average declination during its operating
period"
slope3 = slope3_(FF,LF,lat)

duplicate i=1,12 "repeat for each month of the year"
    "weather data"
    n[i] = AveDay_(i) "mean day of the month"
    DIM[i] = NumDay_(i) "number of days in the month"
    Nhim[i] = DIM[i]*24 "hr; number of hours in the month"
    Time[i] = Nhim[i]*3600 "s; number of seconds in the month"
    Hbar[i] = Lookup(TableRun#,(2+i))*convert(kJ,MJ) "MJ/m^2; monthly average
daily radiation incident on horizontal"
    Tbar_a[i] = Lookup(TableRun#,(14+i)) "C; monthly average ambient
temperature"
    T_mains[i] = (sum(Tbar_a[i],i=1,12))/12 "C; mains water temperature for well
water"
    {T_mains[i] = Tbar_a[i] "C; mains water temperature for surface source water"}
    flag[i] = MonthFlag_(i,FF,LF)

    "load data"
    Load[i] = (T_set - T_mains[i])*C_p`tk*draw*DIM[i] { + losses} "J"

    "incident radiation"
    H_Tbar3_LJ[i] = H_TBAR`LJ_(Hbar[i],Lat,n[i],slope3,GrRef)*convert(MJ,J)
"J"
```

```
    H_Tbar3_total[i] = H_Tbar3_LJ[i]*A_c3*DIM[i]
    H_Tbar4_LJ[i] = H_TBAR`LJ_(Hbar[i],Lat,n[i],slope4,GrRef)*convert(MJ,J)
"J"
    H_Tbar4_total[i] = H_Tbar4_LJ[i]*A_c4*DIM[i]

    "monthly solar fraction"
    f3[i] =
SolFract`HW_(FrUl,F_R`\F_R3,T_ref,Tbar_a[i],Time[i],A_c3,Load[i],Frta_n,tabar\t
a_n,H_Tbar3_LJ[i],DIM[i],StoreCap,T_set,T_mains[i])*Flag[i]
    f4[i] =
SolFract`HW_(FrUl,F_R`\F_R4,T_ref,Tbar_a[i],Time[i],A_c4,Load[i],Frta_n,tabar\t
a_n,H_Tbar4_LJ[i],DIM[i],StoreCap,T_set,T_mains[i])

    "auxiliary energy requirement"
    aux3[i] = (1 - f3[i])*Load[i]  "J"
    aux4[i] = (1-f4[i])*Load[i]         "J"
end

aux_anual3 = sum(aux3[i],i=1,12)
aux_anual4 = sum(aux4[i],i=1,12)
L_anual = sum(Load[i],i=1,12)
F_anual3 = sum(f3[i]*Load[i],i=1,12)/sum(Load[i],i=1,12)
F_anual4 = sum(f4[i]*Load[i],i=1,12)/sum(Load[i],i=1,12)
F_anual4 = 0.75
penalty = 100*(F_anual4 - F_anual3)
```

“This program is used to calculate economic sensitivities for both three and four-season systems.”

```
FUNCTION DoY_(Month)
    Month = round(Month)
    If Month = 0 Then DoY_= 355
    If Month = 1 Then DoY_ = 1
    If Month = 2 Then DoY_ = 32
    If Month = 3 Then DoY_ = 60
    If Month = 4 Then DoY_ = 91
    If Month = 5 Then DoY_ = 121
    If Month = 6 Then DoY_ = 152
    If Month = 7 Then DoY_ = 182
    If Month = 8 Then DoY_ = 213
    If Month = 9 Then DoY_ = 244
    If Month = 10 Then DoY_ = 274
    If Month = 11 Then DoY_ = 305
    If Month = 12 Then DoY_ = 335
    If Month = 13 Then DoY_ = 355
END

FUNCTION slope3_(FF,LF,lat)
    FFn = DoY_(FF) "day of year corresponding to first fall freeze"
    LFn = DoY_(LF) "day of year corresponding to last spring freeze"
    springdec = Dec_(LFn) "declination at last spring freeze"
    falldec = Dec_(FFn) "declination at first fall freeze"
    mindec = min(falldec,springdec) "calculates the minimum of these two"
    If (5>LF) Then
        maxdec = Dec_(182)
    Else
        maxdec = 23.45
    EndIf
    slope3_ = lat - ((maxdec+mindec)/2)
END

Function
F_R`\F_R_(A_c,FrUl,MassFR_col,C_p`col,MassFR_tk,C_p`tk,Effect_CHX)
{Equation 10.2.3}
    CollCapRate=MassFR_col*C_p`col
    TankCapRate=MassFR_tk*C_p`tk
    CapRateMin=min(CollCapRate,TankCapRate)
    X=A_c*FrUl/CollCapRate
    Y=CollCapRate/(Effect_CHX*CapRateMin)
    F_R`\F_R_=(1+X*(Y-1))^(-1)
END
```

```
FUNCTION MonthFlag_(i,FF,LF)
    If (i>LF) and (i<FF) then
        MonthFlag_ := 1
    Else
        MonthFlag_ := 0
    EndIf
END

StoreCap = 81.49

"data specific to three season system"
{slope3 = 28 "collector slope"}
C_p`col3 = 4190 "J/kgC; specific heat of collector loop fluid"
Effect_CHX3 = 1 "heat exchanger effectiveness:"
{A_c3 = 7.5 "m^2; collector area"}

"data specific to four season system"
slope4 = lat "collector slope"
C_p`col4 = 3350 "J/kgC; specific heat of collector loop fluid"
Effect_CHX4 = 0.2 "heat exchanger effectiveness"
A_c4 = A_c3 "m^2; collector area"

"system parameters"
T_set = 60 "tank temperature set point"
draw = 300 "l; daily water draw"
UA_tk = 0 "W/C; tank losses THESE AREN' INCLUDED YET"
GrRef = 0.2 "ground reflectance"

"collector parameters"
FrUl = 4.86 "W/m^2C; efficiency curve slope"
Frta_n = 0.741 "efficiency curve intercept"
C_p`tk = 4190 "J/kgC; specific heat of tank loop fluid"
MassFR_col3 = 0.015*A_c3 "kg/s; collector loop flow rate"
MassFR_tk3 = 0.015*A_c3 "kg/s; tank loop flow rate"
MassFR_col4 = 0.015*A_c4 "kg/s; collector loop flow rate"
MassFR_tk4 = 0.015*A_c4 "kg/s; tank loop flow rate"
T_ref = 100 "C; empirically derived reference temperature"

"economic parameters"
{C_A = 200 "$; area dependent costs"
C_E3 = 1000 "$; area independent costs"
C_E4 = 1100 "$; area independent costs"

P_Eww = 0.0668
```

```
P_Ess = 0.0668

P_Es = P_Ew
N_payback3 = 16.82

P_Eww = P_Ew
P_Ess = P_Es

increase = 100*(P_Es - P_Eww)/(P_Ess - P_Eww)

C_F1[1] = P_Ew*(1/0.0036) ; C_F1[2] = P_Ew*(1/0.0036) ; C_F1[3] =
P_Ew*(1/0.0036) "$/GJ; monthly varrying cost of fuel"
C_F1[4] = P_Ew*(1/0.0036) ; C_F1[5] = P_Ew*(1/0.0036) ; C_F1[6] =
P_Es*(1/0.0036)
C_F1[7] = P_Es*(1/0.0036) ; C_F1[8] = P_Es*(1/0.0036) ; C_F1[9] =
P_Es*(1/0.0036)
C_F1[10] = P_Ew*(1/0.0036) ; C_F1[11] = P_Ew*(1/0.0036) ; C_F1[12] =
P_Ew*(1/0.0036)
}
tabar\ta_n = 0.96 {1 - 0.19*((1/cos(theta))-1) }
"TauAlphaIncAng_(Ncov,IncAng,KL,RefrInd,Alpha_n) "

F_R`\F_R3 =
F_R`\F_R_(A_c3,FrUl,MassFR_col3,C_p`col3,MassFR_tk3,C_p`tk,Effect_CHX3)
F_R`\F_R4 =
F_R`\F_R_(A_c4,FrUl,MassFR_col4,C_p`col4,MassFR_tk4,C_p`tk,Effect_CHX4)


Lat = lookup(59,#latitude)

FF = Lookup(59,#FF) "month number in which first freeze of the year occurs (Fall)"
LF = Lookup(59,#LF) "month number in which last freeze of the year occurs
(Spring)"

"the slope of the three season system is the average declination during its operating
period"
slope3 = slope3_(FF,LF,lat)

duplicate i=1,12 "repeat for each month of the year"
    "weather data"
    n[i] = AveDay_(i) "mean day of the month"
    DIM[i] = NumDay_(i) "number of days in the month"
    Nhim[i] = DIM[i]*24 "hr; number of hours in the month"
    Time[i] = Nhim[i]*3600 "s; number of seconds in the month"
    Hbar[i] = Lookup(59,(2+i))*convert(kJ,MJ) "MJ/m^2; monthly average daily
radiation incident on horizontal"
```

```
    Tbar_a[i] = Lookup(59,(14+i)) "C; monthly average ambient temperature"
    T_mains[i] = (sum(Tbar_a[i],i=1,12))/12 "C; mains water temperature for well
water"
    {T_mains[i] = Tbar_a[i] "C; mains water temperature for surface source water"}
    flag[i] = MonthFlag_(i,FF,LF)

    "load data"
    Load[i] = (T_set - T_mains[i])*C_p`tk*draw*DIM[i] { + losses} "J"

    "incident radiation"
    H_Tbar3_LJ[i] = H_TBAR`LJ_(Hbar[i],Lat,n[i],slope3,GrRef)*convert(MJ,J)
"J"
    H_Tbar3_total[i] = H_Tbar3_LJ[i]*A_c3*DIM[i]
    H_Tbar4_LJ[i] = H_TBAR`LJ_(Hbar[i],Lat,n[i],slope4,GrRef)*convert(MJ,J)
"J"
    H_Tbar4_total[i] = H_Tbar4_LJ[i]*A_c4*DIM[i]

    "monthly solar fraction"
    f3[i] =
SolFract`HW_(FrUl,F_R`\F_R3,T_ref,Tbar_a[i],Time[i],A_c3,Load[i],Frta_n,tabar\t
a_n,H_Tbar3_LJ[i],DIM[i],StoreCap,T_set,T_mains[i])*Flag[i]
    f4[i] =
SolFract`HW_(FrUl,F_R`\F_R4,T_ref,Tbar_a[i],Time[i],A_c4,Load[i],Frta_n,tabar\t
a_n,H_Tbar4_LJ[i],DIM[i],StoreCap,T_set,T_mains[i])

    "auxiliary energy requirement"
    aux3[i] = (1 - f3[i])*Load[i]  "J"
    {cost3[i] = aux3[i]*C_F1[i]/1E9 "cost of electricity with solar collector system"}
    aux4[i] = (1-f4[i])*Load[i]          "J"
    {cost4[i] = aux4[i]*C_F1[i]/1E9 "cost of electricity with solar collector system"
    fullcost[i] = load[i]*C_F1[i]/1E9 "cost of electricity without solar collector
system"}
end

aux_anual3 = sum(aux3[i],i=1,12)
aux_anual4 = sum(aux4[i],i=1,12)
L_anual = sum(Load[i],i=1,12)
F_anual3 = sum(f3[i]*Load[i],i=1,12)/sum(Load[i],i=1,12)
F_anual4 = sum(f4[i]*Load[i],i=1,12)/sum(Load[i],i=1,12)
F_anual4 = 0.5
penalty = 100*(F_anual4 - F_anual3)
{cost_anual3 = sum(cost3[i],i=1,12) "anual cost of auxiliary energy"
cost_anual4 = sum(cost4[i],i=1,12) "anual cost of auxiliary energy"
savings_anual3 = sum(fullcost[i],i=1,12) - cost_anual3 "anual solar savings"
savings_anual4 = sum(fullcost[i],i=1,12) - cost_anual4 "anual solar savings"
```

```
init_invest3 = C_A*A_c3 + C_E3
init_invest4 = C_A*A_c4 + C_E4
N_payback3 = init_invest3 / savings_anual3
N_payback4 = init_invest4 / savings_anual4}
```

APPENDIX C: FOUR-SEASON SYSTEM TRNSYS DECK

```
******* FOUR-SEASON SYSTEM *******

ASSIGN  E:\TRNSYS\4SEAS.LST              6
ASSIGN  C:\TRNWIN\WEATHER\WDATA.DAT      10
ASSIGN  E:\TRNSYS\4SEAS.PLT             11
ASSIGN  E:\TRNSYS\4SEAS.OUT             12

CONSTANTS 18
START = 1
STOP = 8760
RHOG = 0.2
CPC = 3.5
CPT = 4.19
FPAR = 0
PUMPOW = 1000
GAMMA = 0
UDB = 0
LDB = 0
TMAX = 97
TMIN = 87
FLOWRATE = 338
EFFECT = 0.2
CITY = 137
LAT = 42.75
AREA = 6.386
TMAINS = 8.092

EQUATIONS 1
EQUATIONS BETA = LAT

SIMULATION  START   STOP  0.25
WIDTH  72
LIMITS 75 50
TOLERANCES .001 .001

UNIT 1 TYPE 54 WEATHER GENERATOR
PARAMETERS 6
*UNITS  LU  CITY#  TEMP-MODEL  RAD-CORR  RAND
1       10  CITY   1           1         1

UNIT 2 TYPE 16 RADIATION PROCESSOR
PARAMETERS 9
*MODE  TRACK-MODE  SURF-MODE  DAY  LAT  SC    SHFT  SMOOTH  IE
7      1           1          1    LAT  4871  0     0       -1
```

```
INPUTS 7
* I   IDN    TD1    TD2   RHOG  SLOPE  AZIMUTH
1,7   1,8   1,19   1,20  0,0   0,0    0,0
0.0   0.0   0.0    1.0    RHOG  BETA   GAMMA

UNIT 3 TYPE 2 SOLAR PUMP CONTROLLER
PARAMETERS 4
*CYC/TSTEP  UDB  LDB  HILIM-CUTOUT
5           0    0    100
INPUTS 4
*THOT TCOLD HILIM-CUTOUT  INPUT-CNTRL
8,1   4,5   4,6           3,1
20.   20.   100.          0.0

UNIT 4 TYPE 60 STRATIFIED FLUID STORAGE TANK
PARAMETERS 32
*INLET POSITION MODE, TANK VOLUME, TANK HEIGHT, PERIMETER, HEIGHT INLET
1
*HEIGHT OUTLET 1, HEIGHT INLET 2, HEIGHT OUTLET 2, CP, RHO, UTANK, K,
DELTA K,
*T-BOIL, AUX MODE, HT AUX1, HT STAT1, T SET1, DEL T DB1, QAUX1, HT AUX2,
HT STAT2,
*T SET2, DEL TDB2, QAUX2, UA FLUE, T FLUE, CRIT FRACTION, GAS AUX, HX
MODE, UMODE
1  0.3028  1.5  -1  1.5  0.1  0.1  1.5  4.19  1000.  0.  2.304  0.
100.  1
1.2  1.2  60  0  16000  0.7  0.7  60  0  16000  0.  20.  10  0  0   0  0
INPUTS 9
*MDOT1 IN, MDOT1 OUT, MDOT2 IN, MDOT2 OUT, T1 IN, T2 IN, T ENV, GAMMA1,
GAMMA2
6,4  6,4  0,0  0,0   6,3  0,0  0,0  0,0  0,0
200. 200. -2.  12.1  20.  TMAINS  20.  1.0  1.0
DERIVATIVES 5
20 20 20 20 20

EQUATIONS 1
*FOUR SEASON SYSTEM
CNTRL = [3,1]

UNIT 5 TYPE 3 TANK LOOP PUMP
PARAMETERS 4
*MAX-FLOW  SPEC-HEAT  MAX-POWER  FRAC-2-THERM
FLOWRATE   CPT        1000       FPAR
INPUTS 3
*T-IN  MFLOW-IN  CONTROL-FUNC
4,5    4,2       CNTRL
*4,5    4,2       CNTRLFUNCSC
20.    200.      1.0

UNIT 6 TYPE 5 HEAT EXCHANGER
PARAMETERS 4
*MODE = CONST EFF,  EFFECTIVNESS, CP HOT SIDE, CP COLD SIDE
4  EFFECT  CPC  CPT
INPUTS 4
*T HOT IN, MDOT HOT, T COLD IN, MDOT COLD
8,1    8,2    5,1   5,2
```

```
20.    200.   20.   200.

UNIT 7 TYPE 3 COLLECTOR LOOP PUMP
PARAMETERS 4
*MAX-FLOW  SPEC-HEAT  MAX-POWER  FRAC-2-THERM
FLOWRATE   CPC        1000       FPAR
INPUTS 3
*T-IN  MFLOW-IN  CONTROL-FUNC
6,1    6,2       CNTRL
*6,1    6,2       CNTRLFUNCSC
20.    200.      1.0

UNIT 8 TYPE 1 SOLAR COLLECTOR
PARAMETERS 14
*MODE, SERIES, AREA, CP FLUID, EFFICIENCY MODE, G TEST, AO, A1
*A2, EPSILON HTX, CP TANK, OPTICAL MODE, 1ST ORDER INC ANG MOD, 2ND
ORDER
1  1  AREA  CPC  1  338   0.741  17.496  0.0   -1  CPT  1  0.190  0
INPUTS 10
*TIN, MDOT IN, MDOT COLD SIDE, TAMB, ITILT, IHOR, I DIF, RHOG, INCANG,
SLOPE
7,1   7,2    0,0  1,4   2,6   2,4   2,5   0,0   2,9   0,0
20.   200.0  0.0  15.6  0.0   0.0   0.0   RHOG  0.0   BETA

EQUATIONS 1
WATER_REQ = [4,11]-[4,10]

UNIT 10 TYPE 24 INTEGRATOR
PARAMETERS 1
*TIME INTERVAL OVER WHICH TO BE IN TEGRATED
-1
INPUTS 3
*SOLAR RADIATION, USEFUL ENERGY TO TANK, QAUX FROM TANK
2,6  WATER_REQ 4,12
0.0  0.0       0.0

EQUATIONS 3
Q_SOLAR = [10,1]/1000000*AREA
Q_LOAD = [10,2]/1000000
Q_AUX = [10,3]/1000000

UNIT 9 TYPE 65 ONLINE PRINTER
PARAMETERS 14
4 1 -100 100 -0.5 8 1 1 3 20 7 0 2 0
INPUTS 5
1,4  8,1  4,6  4,5  CNTRL
TAMB COLOUT TANKTOP TANKBOT CONTROL
LABELS 4
C kg/hr
Temp vs. Time
Flowrate into Tank vs. Time

UNIT 14 TYPE 25 YEARLY VALUE PRINTER
PARAMETERS 5
```

```
*TIME INTERVAL AT WHICH PRINTING WILL OCCUR , TIME AT WHICH PRINTING
STARTS
*TIME AT WHICH PRINTING FINISHES, LOGICAL UNIT, UNITS
-1 START STOP 12 1
INPUTS 3
Q_SOLAR Q_LOAD Q_AUX
Q_SOLAR Q_LOAD Q_AUX
GJ GJ GJ

END
```

APPENDIX D: THREE-SEASON SYSTEM TRNSYS DECKS

```
********* THIS FILE MODELS A THREE-SEASON SYSTEM *********
*********            NO RECURCULATION            *********


ASSIGN  E:\TRNSYS\3SEAS.LST              6
ASSIGN  C:\TRNWIN\WEATHER\WDATA.DAT      10
ASSIGN  E:\TRNSYS\3SEAS.PLT             11
ASSIGN  E:\TRNSYS\3SEAS.OUT             12

CONSTANTS 19
START = 1
STOP = 8760
RHOG = 0.2
CPC = 4.19
CPT = 4.19
FPAR = 0
PUMPOW = 1000
GAMMA = 0
UDB = 0
LDB = 0
TMAX = 97
TMIN = 87
FLOWRATE = 338
EFFECT = 1
CITY = 137
LAT = 42.93
AREA = 6.948
BETA = 39.07
TMAINS = 8.092

SIMULATION  START   STOP  0.25
WIDTH  72
LIMITS 75 50
TOLERANCES .001 .001

UNIT 1 TYPE 54 WEATHER GENERATOR
PARAMETERS 6
*UNITS  LU  CITY#  TEMP-MODEL  RAD-CORR  RAND
1       10  CITY   1           1         1

UNIT 2 TYPE 16 RADIATION PROCESSOR
PARAMETERS 9
*MODE  TRACK-MODE  SURF-MODE  DAY  LAT  SC    SHFT  SMOOTH  IE
7      1           1          1    LAT  4871  0     0       -1
INPUTS 7
```

```
* I   IDN    TD1    TD2   RHOG  SLOPE  AZIMUTH
1,7   1,8   1,19   1,20  0,0   0,0    0,0
0.0   0.0   0.0    1.0    RHOG  BETA   GAMMA

UNIT 3 TYPE 2 SOLAR PUMP CONTROLLER
PARAMETERS 4
*CYC/TSTEP  UDB  LDB  HILIM-CUTOUT
5           0    0    100
INPUTS 4
*THOT TCOLD HILIM-CUTOUT  INPUT-CNTRL
8,1   4,5   4,6           3,1
20.   20.   100.          0.0

UNIT 4 TYPE 60 STRATIFIED FLUID STORAGE TANK
PARAMETERS 32
*INLET POSITION MODE, TANK VOLUME, TANK HEIGHT, PERIMETER, HEIGHT INLET
1
*HEIGHT OUTLET 1, HEIGHT INLET 2, HEIGHT OUTLET 2, CP, RHO, UTANK, K,
DELTA K,
*T-BOIL, AUX MODE, HT AUX1, HT STAT1, T SET1, DEL TDB1, QAUX1, HT AUX2,
HT STAT2,
*T SET2, DEL TDB2, QAUX2, UA FLUE, T FLUE, CRIT FRACTION, GAS AUX, HX
MODE, UMODE
1  0.3028  1.5  -1  1.5  0.1  0.1  1.5  4.19  1000.  0.  2.304  0.
100.  1
1.2  1.2  60  0  16000  0.7  0.7  60  0  16000  0.  20.  10  0  0  0  0
INPUTS 9
*MDOT1 IN, MDOT1 OUT, MDOT2 IN, MDOT2 OUT, T1 IN, T2 IN, T ENV, GAMMA1,
GAMMA2
6,4  6,4  0,0  0,0   6,3  0,0  0,0  0,0  0,0
200. 200. -2.  12.1  20.  TMAINS  20.  1.0  1.0
DERIVATIVES 5
20 20 20 20 20

UNIT 11 TYPE 14 THREE SEASON SYSTEM FLOWRATE FORCING FUNCTION
PARAMETERS 10
1  0  3624  0  3624  1  6552  1  6552  0
*1  0  2880  0  2880  1  7296  1  7296  0

EQUATIONS 1
*THREE SEASON SYSTEM
CNTRL = [11,1]*[3,1]

UNIT 5 TYPE 3 TANK LOOP PUMP
PARAMETERS 4
*MAX-FLOW  SPEC-HEAT  MAX-POWER  FRAC-2-THERM
FLOWRATE   CPT        1000       FPAR
INPUTS 3
*T-IN  MFLOW-IN  CONTROL-FUNC
4,5    4,2       CNTRL
20.    200.      1.0

UNIT 6 TYPE 5 HEAT EXCHANGER
PARAMETERS 4
*MODE = CONST EFF,  EFFECTIVNESS, CP HOT SIDE, CP COLD SIDE
4  EFFECT  CPC  CPT
```

```
INPUTS 4
*T HOT IN, MDOT HOT, T COLD IN, MDOT COLD
8,1    8,2   5,1   5,2
20.    200.   20.   200.

UNIT 7 TYPE 3 COLLECTOR LOOP PUMP
PARAMETERS 4
*MAX-FLOW  SPEC-HEAT  MAX-POWER  FRAC-2-THERM
FLOWRATE   CPC        1000       FPAR
INPUTS 3
*T-IN  MFLOW-IN  CONTROL-FUNC
6,1    6,2       CNTRL
20.    200.      1.0

UNIT 8 TYPE 1 SOLAR COLLECTOR
PARAMETERS 14
*MODE, SERIES, AREA, CP FLUID, EFFICIENCY MODE, G TEST, AO, A1
*A2, EPSILON HTX, CP TANK, OPTICAL MODE, 1ST ORDER INC ANG MOD, 2ND
ORDER
1  1  AREA  CPC  1  338   0.741  17.496  0.0   -1  CPT  1  0.190  0
INPUTS 10
*TIN, MDOT IN, MDOT COLD SIDE, TAMB, ITILT, IHOR, IDIF, RHOG, INCANG,
SLOPE
7,1   7,2    0,0  1,4   2,6   2,4   2,5   0,0   2,9   0,0
20.   200.0  0.0  15.6  0.0   0.0   0.0   RHOG  0.0   BETA

EQUATIONS 1
WATER_REQ = [4,11]-[4,10]

UNIT 10 TYPE 24 INTEGRATOR
PARAMETERS 1
*TIME INTERVAL OVER WHICH TO BE INTEGRATED
-1
INPUTS 3
*SOLAR RADIATION, USEFUL ENERGY TO TANK, QAUX FROM TANK
2,6  WATER_REQ 4,12
0.0  0.0       0.0

EQUATIONS 3
Q_SOLAR = [10,1]/1000000*AREA
Q_LOAD = [10,2]/1000000
Q_AUX = [10,3]/1000000

UNIT 9 TYPE 65 ONLINE PRINTER
PARAMETERS 14
4 1 -100 100 -0.5 8 1 1 3 20 7 0 2 0
INPUTS 5
1,4  8,1  4,6  4,5  CNTRL
TAMB COLOUT TANKTOP TANKBOT CONTROL
LABELS 4
C kg/hr
Temp vs. Time
Flowrate into Tank vs. Time

UNIT 14 TYPE 25 YEARLY VALUE PRINTER
```

```
168
PARAMETERS 5
*TIME INTERVAL AT WHICH PRINTING WILL OCCUR, TIME AT WHICH PRINTING
STARTS
*TIME AT WHICH PRINTING FINISHES, LOGICAL UNIT, UNITS
-1 START STOP 12 1
INPUTS 3
Q_SOLAR Q_LOAD Q_AUX
Q_SOLAR Q_LOAD Q_AUX
GJ GJ GJ

END
```

```
********* THIS FILE MODELS A THREE SEASON SYSTEM *********
*********            WITH RECURCULATION          *********

ASSIGN  D:\TRNSYS\3RECIRC.LST              6
ASSIGN  C:\TRNWIN\WEATHER\WDATA.DAT      10
ASSIGN  D:\TRNSYS\3RECIRC.PLT             11
ASSIGN  D:\TRNSYS\3RECIRC.OUT             12

CONSTANTS 20
START = 1
STOP = 8760
RHOG = 0.2
CPC = 4.19
CPT = 4.19
FPAR = 0
PUMPOW = 1000
GAMMA = 0
UDB = 0
LDB = 0
TMAX = 97
TMIN = 87
FLOWRATE = 338
EFFECT = 1
CITY = 192
LAT = 46.47
BETA = 36.85
AREA = 6.948
TMAINS = 4.417
PUA = 5

SIMULATION  START   STOP  0.25
WIDTH  72
LIMITS 75 50
TOLERANCES .001 .001

UNIT 1 TYPE 54 WEATHER GENERATOR
PARAMETERS 6
*UNITS  LU  CITY#  TEMP-MODEL  RAD-CORR  RAND
1       10  CITY   1           1         1

UNIT 2 TYPE 16 RADIATION PROCESSOR
PARAMETERS 9
*MODE  TRACK-MODE  SURF-MODE  DAY  LAT  SC    SHFT  SMOOTH  IE
7      1           1          1    LAT  4871  0     0       -1
INPUTS 7
* I   IDN    TD1    TD2   RHOG  SLOPE  AZIMUTH
1,7   1,8   1,19   1,20  0,0   0,0    0,0
0.0   0.0   0.0    1.0    RHOG  BETA   GAMMA

UNIT 3 TYPE 2 SOLAR PUMP CONTROLLER
PARAMETERS 4
*CYC/TSTEP  UDB  LDB  HILIM-CUTOUT
5           0    0    100
INPUTS 4
```

```
*THOT TCOLD HILIM-CUTOUT  INPUT-CNTRL
8,1   4,5   4,6           3,1
20.   20.   100.          0.0

UNIT 12 TYPE 2 FREEZE PROTECTION CONTROLLER
PARAMETERS 4
*CYC/TSTEP  UDB  LDB  HILIM-CUTOUT
5           0    0    100
INPUTS 4
*THOT TCOLD HILIM-CUTOUT  INPUT-CNTRL
1,4   0,0   4,6           12,1
20.   5.    100.          0.0

UNIT 4 TYPE 60 STRATIFIED FLUID STORAGE TANK
PARAMETERS 32
*INLET POSITION MODE, TANK VOLUME, TANK HEIGHT, PERIMETER, HEIGHT INLET
1
*HEIGHT OUTLET 1, HEIGHT INLET 2, HEIGHT OUTLET 2, CP, RHO, UTANK, K,
DELTA K,
*T-BOIL, AUX MODE, HT AUX1, HT STAT1, T SET1, DEL TDB1, QAUX1, HT AUX2,
HT STAT2,
*T SET2, DEL TDB2, QAUX2, UA FLUE, T FLUE, CRIT FRACTION, GAS AUX, HX
MODE, UMODE
1  0.3028  1.5  -1  1.5  0.1  0.1  1.5  CPT  1000.  0.  2.304  0.  100.
1
1.2  1.2  60  0  16000  0.7  0.7  60  0  16000  0.  20.  10  0  0  0  0
INPUTS 9
*MDOT1 IN, MDOT1 OUT, MDOT2 IN, MDOT2 OUT, T1 IN, T2 IN, T ENV, GAMMA1,
GAMMA2
6,4  6,4  0,0  0,0   6,3  0,0  0,0  0,0  0,0
200. 200. -2.  12.1  20.  TMAINS  20.  1.0  1.0
DERIVATIVES 5
20 20 20 20 20

UNIT 11 TYPE 14 THREE SEASON SYSTEM FLOWRATE FORCING FUNCTION
PARAMETERS 10
1  0  2880  0  2880  1  7296  1  7296  0  8760  0

EQUATIONS 4
*THREE SEASON SYSTEM
CNTRLFUNCSC = [11,1]*[3,1]
CNTRLFUNCFP = [11,1]*NOT([12,1])
CNTRL = GT((CNTRLFUNCSC+CNTRLFUNCFP),0)
VAR = 5

UNIT 5 TYPE 3 TANK LOOP PUMP
PARAMETERS 4
*MAX-FLOW  SPEC-HEAT  MAX-POWER  FRAC-2-THERM
FLOWRATE   CPT        1000       FPAR
INPUTS 3
*T-IN  MFLOW-IN  CONTROL-FUNC
4,5    4,2       CNTRL
20.    200.      1.0

UNIT 6 TYPE 5 HEAT EXCHANGER
PARAMETERS 4
```

```
*MODE = CONST EFF,  EFFECTIVNESS, CP HOT SIDE, CP COLD SIDE
4  EFFECT  CPC  CPT
INPUTS 4
*T HOT IN, MDOT HOT, T COLD IN, MDOT COLD
13,1    13,2    5,1   5,2
20.    200.   20.   200.

UNIT 7 TYPE 3 COLLECTOR LOOP PUMP
PARAMETERS 4
*MAX-FLOW  SPEC-HEAT  MAX-POWER  FRAC-2-THERM
FLOWRATE   CPC        1000       FPAR
INPUTS 3
*T-IN  MFLOW-IN  CONTROL-FUNC
6,1    6,2       CNTRL
20.    200.      1.0

UNIT 12 TYPE 31 PIPING FROM HEAT EXCHANGER TO COLLECTOR
PARAMETERS 6
*IN DIAM, LENGTH, UA, DENS, CP, INITIAL TEMP
0.01  20  PUA  1000  CPC  20
INPUTS 3
*TIN, MDOT IN, TENV
7,1  7,2   0,0
20.  200.  20.

UNIT 8 TYPE 1 SOLAR COLLECTOR
PARAMETERS 14
*MODE, SERIES, AREA, CP FLUID, EFFICIENCY MODE, G TEST, AO, A1
*A2, EPSILON HTX, CP TANK, OPTICAL MODE, 1ST ORDER INC ANG MOD, 2ND
ORDER
1  1  AREA  CPC  1  338   0.741  17.496  0.0   -1  CPT  1  0.190  0
INPUTS 10
*TIN, MDOT IN, MDOT COLD SIDE, TAMB, ITILT, IHOR, IDIF, RHOG, INCANG,
SLOPE
12,1   12,2   0,0  1,4   2,6   2,4   2,5   0,0   2,9   0,0
20.  200.0  0.0  15.6  0.0   0.0   0.0   RHOG  0.0   BETA

UNIT 13 TYPE 31 PIPING FROM COLLECTOR TO HEAT EXCHANGER
PARAMETERS 6
*IN DIAM, LENGTH, UA, DENS, CP, INITIAL TEMP
0.01  20  PUA  1000  CPC  20
INPUTS 3
*TIN, MDOT IN, TENV
8,1  8,2   0,0
20.  200.  20.

EQUATIONS 1
WATER_REQ = [4,11]-[4,10]

UNIT 10 TYPE 24 INTEGRATOR
PARAMETERS 1
*TIME INTERVAL OVER WHICH TO BE INTEGRATED
-1
INPUTS 3
*SOLAR RADIATION, USEFUL ENERGY TO TANK, QAUX FROM TANK
```

```
2,6  WATER_REQ 4,12
0.0  0.0       0.0

EQUATIONS 3
Q_SOLAR = [10,1]/1000000*AREA
Q_LOAD = [10,2]/1000000
Q_AUX = [10,3]/1000000

UNIT 9 TYPE 65 ONLINE PRINTER
PARAMETERS 14
5 1 -100 100 -0.5 8 1 1 3 20 7 0 2 0
INPUTS 6
1,4  VAR  8,1  4,6  4,5  CNTRL
TAMB 5 COLOUT TANKTOP TANKBOT CONTROL
LABELS 4
C kg/hr
Temp vs. Time
Flowrate into Tank vs. Time

UNIT 14 TYPE 25 YEARLY VALUE PRINTER
PARAMETERS 5
*TIME INTERVAL AT WHICH PRINTING WILL OCCUR, TIME AT WHICH PRINTING
STARTS
*TIME AT WHICH PRINTING FINISHES, LOGICAL UNIT, UNITS
-1 START STOP 12 1
INPUTS 3
Q_SOLAR Q_LOAD Q_AUX
Q_SOLAR Q_LOAD Q_AUX
GJ GJ GJ

END
```

APPENDIX E: EUSESIA TRNSED DECK

******* FOUR SEASON SYSTEM *******

```
*TRNSED
ASSIGN C:\EUSESIA\SYSTEMS\SDHW1TNK.LST       6
ASSIGN C:\EUSESIA\SYSTEMS\SDHW1TNK.OUT      10
ASSIGN C:\EUSESIA\SYSTEMS\SDHW1TNK.PLT      22
ASSIGN C:\EUSESIA\SYSTEMS\HRDRAW.DAT        15


**************************************************************
*  This file predicts the required electric input to a solar *
* domestic hot water system                                  *
**************************************************************

*|* Utility Location
ASSIGN c:\EUSESIA\systems\MLKWTR91.DAT 14
*|< City in which utility is located in
|C:\EUSESIA\SYSTEMS\CITIES.DAT|1|2|0
EQUATIONS 1
LAT =  4.2950E+0001
*|< City in which utility is located in
|C:\EUSESIA\SYSTEMS\CITIES.DAT|0|3|0
ASSIGN c:\EUSESIA\systems\MLKMAIN.DAT 16
*|< City in which utility is located in
|C:\EUSESIA\SYSTEMS\CITIES.DAT|0|4|0
*|*

***  SYSTEM PARAMETERS  ***
EQUATIONS  6
TSET = 60
TENV = 18
TI = 6.9
*
*  Determine the required draw from the tank.  The following equations
*  account for the tempering valve.  They result from simplified mass
*  and energy balances where Cp is assumed constant.
TDIFF = MAX(0.000001,([4,3]-[39,1]))
TNKDRW = MIN(1,((TSET-[39,1])/TDIFF))
MLOAD = [29,1]*TNKDRW
*
***   STANDARD ELECTRIC HOT WATER TANK   ***
* Volume:  80 gallon tank -> .3028 m3;
* Height:  4.89 ft -> 1.4905 m
```

```
* R-value: 16.7 (hr-ft2-F/Btu) -> ULOSS=1/R
*              .0489194(hr-m2-C/kJ)/(hr-ft2-F/Btu)

*|* Tank Parameters
EQUATIONS 7
TNKSIZE =  8.0000E+0001
*| Tank size                               |gal|gal|0|1|0|1000.00|0
TSIZE = .0037854*TNKSIZE
HEIGHT1 =  4.8900E+0000
*| Tank height                             |ft|ft|0|1|0|0030.00|0
HEIGHT = .3048*HEIGHT1
RVAL =  1.6700E+0001
*| Insulation R-Value                      |hr-ft2-F/Btu|hr-ft2-
F/Btu|0|1|0|1000.00|0
RVAL1 = RVAL *.0489194
ULOSS = 1/RVAL1
*|*

EQUATIONS 3
NODES = 3
Tdbnd = 0.0
Qmax = 4.5*3600

*|* Solar Collector Parameters
EQUATIONS 8
COL =  2.0000E+0000
*| Number of collectors in array           |||0|1|1|000100|0
AREA1 =  6.0000E+0001
*| Area of a single collector              |ft2|ft2|0|1|0|100.00|0
AREA = COL*AREA1*.0929
FRta =  7.0000E-0001
*| FRta of collector (Intercept efficiency)|||0|1|0|001.00|3
FRUL1 =  7.4900E-0001
*| FRUL of collector (- slope of eff. curve)|Btu/hr-ft2-F|Btu/hr-ft2-
F|0|1|0|10.000|0
FRUL = 20.4418*FRUL1
SLOPE =  3.8000E+0001
*| Collector slope
|degrees|degrees|0|1|0|0090.0|0
GAMMAI=  0.0000E+0000
*| Collector azimuth angle                 |degrees|degrees|0|1| -
90|0090.0|0
*|*

*|* Heat Exchanger Parameters
EQUATIONS 3
EFF = -1.00000E+0000
*| Heat exchanger effectiveness (-1 => no hx) |||0|1|-1|01.000|3
CPH1 =  5.7700E-0001
*| Specific heat of collector side fluid      |Btu/lbm-R|Btu/lbm-
R|0|1|0|10.000|0
CPHOT = 4.1868*CPH1
*|*

*|* Pump Parameters
EQUATIONS 2
```

```
PMPPOW =  5.0000E+0001
*| Pumping power                                 |W|W|0|1|0|10000.0|0
PPUMP = PMPPOW * 3.6
*|*

*|* Daily Water Draw
EQUATIONS 3
FACTOR = 3.7853
MLTPLY =  6.9000E+0001
*| Average daily water draw (69 gal/day standard)
|gal/day|gal/day|0|1|0|100.0|0
SCALE = FACTOR*MLTPLY/69
* Standard draw based on approximately 69 gal/day.  MLTPLY allows the
*  user to scale the draw as seen fit.  By setting the value to 69 the
*  draw remains the same.
*|*

*** SIMULATION PARAMETERS ***
EQUATIONS 4
START = 1
START1 = START-48
STOP = 8760
step = .1

EQUATIONS 4
RHOG=2.0000E-01
STRTDAY = INT(START1/24)
SC=4871
SHIFT=0.0

** Calculate the critical timestep for the system.
** Use STEP < t_critical as a safety factor
** Calculation done assuming an instantaneous draw will
**  be no more than 10 gal/hr
*EQUATIONS 6
*MASSTANK = TNKSIZE*FACTOR
*MCOLL = 325
*MLOADMAX = 10*FACTOR
*TCRIT = (MASSTANK/NODES)/(MCOLL+MLOADMAX)
*STEP1 = TCRIT/2
*STEP = MIN(STEP1,1)



SIMULATION START1 STOP STEP
LIMITS 120 120 120
TOLERANCES 0.001 0.001
WIDTH 72

UNIT 19 TYPE 9   DATA READER FOR WEATHER
PARAMETERS 14
* MODE  N  dT(HOURS)   DUMHOURS    Tdb(C)  I(kJ/m2-hr)
  -2    3     1           -1 1 0    -2 1 0  -3 1 0
*      LU FRMT
       14   0
```

```
*OUTPUTS: 2,Tdb 3,I

UNIT 29 TYPE 9 DATA READER FOR WATER DRAWS
*WATER DRAWS:  (GAL/HR) - CONVERT TO KG/HR
* USE FACTOR 3.7853, FURTHER SCALING DONE WITH MLTPLY/69
PARAMETERS 8
* MODE  N   STEP  DRAWS   MULT   ADD   LU   FRMT
  -2    1     1   -1      SCALE   0.    15    0
*OUTPUTS: 1,DRAW(KG/HR)

UNIT 5 TYPE 14 THREE SEASON SYSTEM FORCING FUNCTION
PARAMETERS 12
START1 0 2880 0 2880 1 7296 1 7296 0 STOP 0

UNIT 39 TYPE 9  DATA READER FOR MAINS WATER TEMPERATURE
* CHANGES MONTHLY BUT READ IN DAILY (24 HOURS) FRO M F-CHART FILE
PARAMTERS 8
* MODE   N  dT(HOURS) TMAINS   LU  FRMT
   -2    1     24     -1 1 0   16   0
*OUTPUTS: 1, TMAINS

UNIT 16 TYPE 16 RADIATION PROCESSOR
PARAMETERS 8
* RADMODE TRACKMODE TILTMODE  DAY      LAT  SC  SHIFT  SMOOTH
    3         1        1     STRTDAY   LAT  SC  SHIFT    2
INPUTS 6
* I(kJ/m2-hr)  td1    td2    RHOG    BETA1    GAMMAI  INext(IF
SMOOTH=1)
 19,3          19,19  19,20  RHOG    SLOPE    GAMMAI  19,23
 0.0           0.0    0.0    RHOG    SLOPE    GAMMAI  0.0
*OUTPUTS: 1,Io 2,THETAz 3,GAMMAs 4,I 5,Id 6,IT1 7,IbT1 8,IdT1 9,THETA1
*         10,BETA1 11,IT1

EQUATIONS 3
RADT = [16,6]*[5,1]
RAD = [16,4]*[5,1]
RADD = [16,5]*[5,1]


UNIT 1 TYPE 1 COLLECTOR
PARAMETERS 14
* MODE N  AREA  Cp   EFFMD  G   ao    a1    a2  EFF CpHX  OPTMD   bo  b1
   1   1  AREA  4.19   1    50  FRta  FRUL  0.  EFF CPHOT   1    0.1
0.0
INPUTS 10
* Ti  mCOLL(kg/hr) mHX  Tamb   It    I    Id    RHOG  THETA BETA(SLOPE)
 3,1  3,2          3,2  19,2  RADT  RAD  RADD   0,0    16,9   16,10
 TI   0.0          0.0  20.0   0.0  0.0   0.0   RHOG    0.0    40.0
*OUPUTS: 1, To 2,mo 3,Qgain(KJ/HR) 4,Tco


EQUATIONS 2
DEADH = 0
DEADL = 0

UNIT 2 TYPE 2 PUMP CONTROLLER
```

```
PARAMETERS 4
* NSTK dThigh dTlow  Tmax
   11  DEADH  DEADL   100
INPUTS 4
* Th   Tl    TIN  GAMMAI
  1,4  4,1   0,0   2,1
  15.  TI     100    0.
*OUTPUTS: 1,GAMMAo (CONTROL FUNCTION)

UNIT 3 TYPE 3 PUMP
PARAMETERS 4
* mMAX    Cp    Pmax(KJ/HR)   fpar
  325.    4.19    PPUMP        0.
INPUTS 3
*  Ti    mi   GAMMA
  4,1    4,2   2,1
   TI    0.0    0.0
*OUTPUTS: 1,To 2,mo 3,Ppump

EQUATIONS 1
HGT = -HEIGHT

UNIT 4 TYPE 4  SOLAR STORAGE TANK
PARAMETERS 20
*MODE   VOL   CPF    RHO    UT    HI     AUXMOD    NODE1   NODETI
  2    TSIZE  4.19  1000  ULOSS  HGT      1         1       1
*TSET   DTDB   QAUX1     NODE2   NODET2   TSET2   DTDB2   QAUX2
 TSET    0     QMAX        1       1       TSET     0     0.0
*UAFLUE   TFLUE   TBOIL
  0.0     TENV   100
INPUTS 5
* TH   MH   TL    ML     TENV
 1,1   1,2  39,1  MLOAD  0,0
 0.0   0.0  TI    0.0    TENV
DERIVATIVES NODES
TSET TSET TSET TSET TSET TSET TSET TSET TSET
*UNIT 4 OUTPUTS:
*OUTPUTS: 1,Trtn 2,m_rtnCOLL 3,Tload 4,m_load 5,Qenv,loss 6,Qs
*         7,dEtank 8,Qaux1


UNIT 24 TYPE 24  INTEGRATOR
PARAMETERS 1
*DT RESET
   1
INPUTS 2
4,8  3,3
0.0  0.0

EQUATIONS 2
* Electric input required (auxiliary heater + collector pump power)
ELECDMND = ([24,1]+[24,2])/3600
QAUX = ([24,1])/3600
```

```
UNIT 25 TYPE 25  PRINTER
PARAMETERS 4
* DT  TON  TOFF  LU
   1 START STOP 10
INPUTS 1
elecdmnd
elcdmd


UNIT 26 TYPE 25  plotting PRINTER
PARAMETERS 4
* DT  TON  TOFF  LU
   1 START STOP  22
INPUTS 1
elecdmnd
elcdmd

*|* Display Options
EQUATIONS 2
IREF = 1/(STEP+.00001)
SWITCH =  1.0000E+0000
*| On-line graphic display (1=yes, -1=no)      |||0|1|-2|2|0

UNIT 65 TYPE 65  ON-LINE PRINTER
PARAMETERS 14
*NTOP  NBOT  YMIN1  YMAX1  YMIN2  YMAX2  IREF  IUP  UNITS
 2     1     0       5     0        80   IREF     1     3
*NPIC  GRID  STOP  SYMBOLS  OUTPUT
  1     7     0       2     SWITCH
INPUTS 3
 QAUX  ELECDMND  MLOAD
 Qaux  ElecDmnd  Mtank
LABELS 4
 kW  kg/hr
 Average System Demand
 Tank Draw

END
```