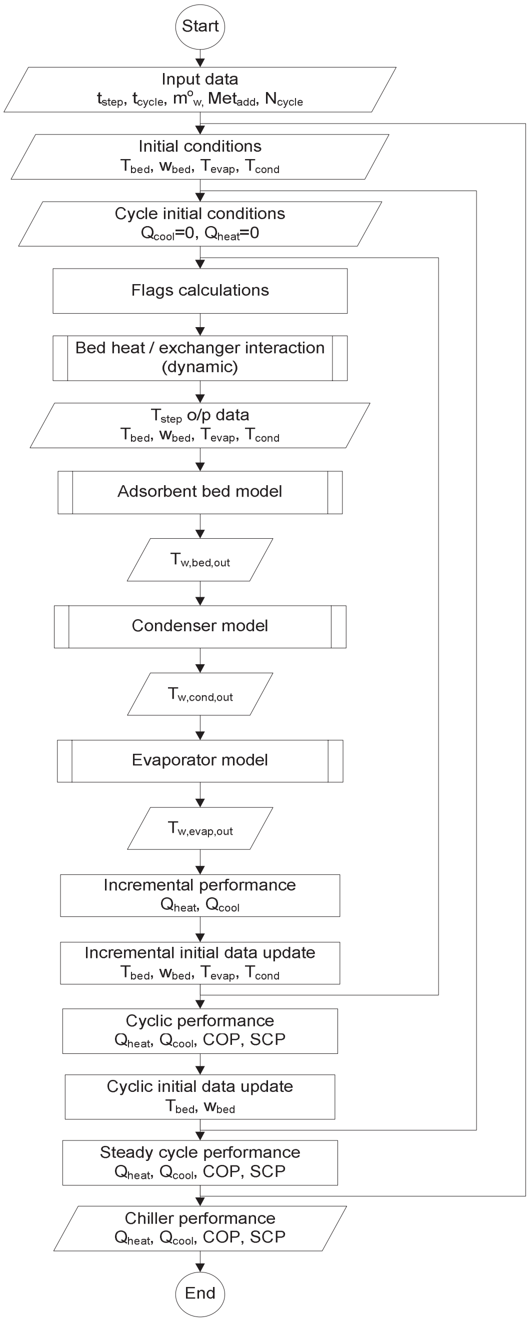
APPENDIX A

A.1 Home screen flow chart of the model



A.2 Home screen MATLAB code

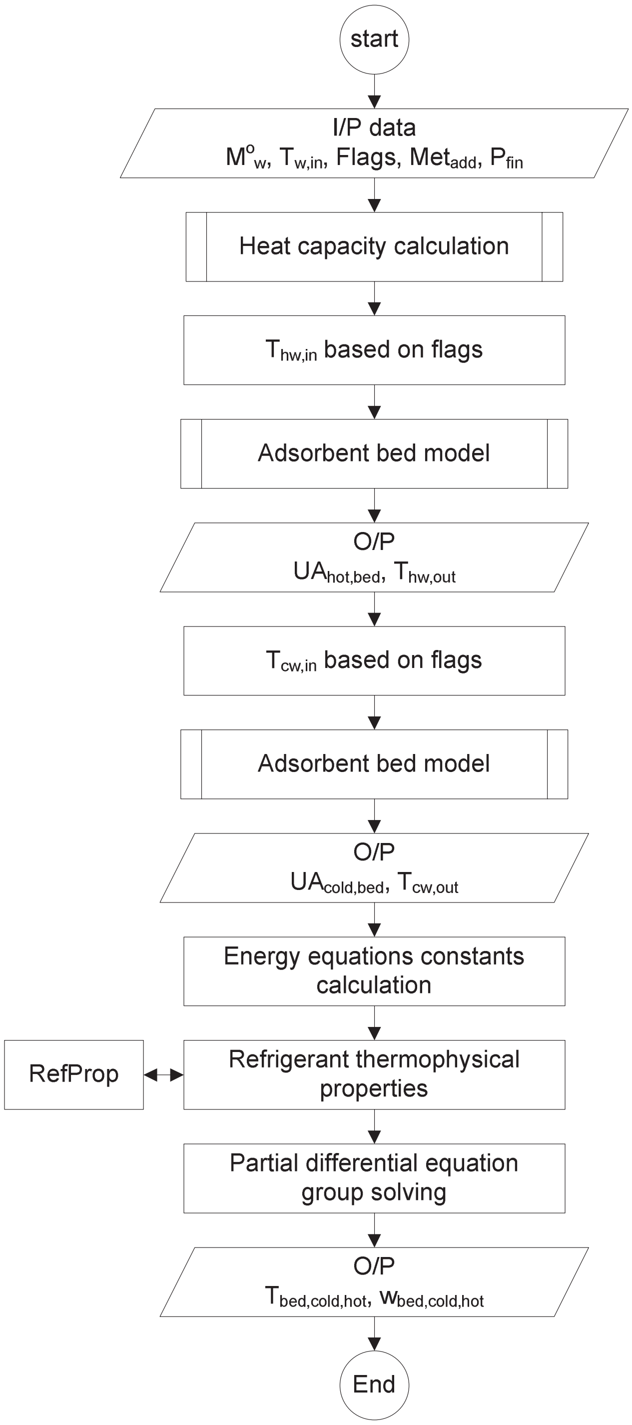
```
%This is the home screen of evaluating the performance of the adsorption
%chiller ADCM1-180
%===========================================================================
clear all; close all; clc;
% Input data
fin_pitch_bed_mm=1.1;        % Minimum fin spacing
Metal='Al'; Pge=15;          % Type of metal additives and the percentage
for i=1:19
fin_pitch_bed_mm=fin_pitch_bed_mm+0.1;
fin_pitch_bed=fin_pitch_bed_mm/1000;
N_cyc=8; Dtime=5;
t_normal=430; t_regen=30; t_htrec=20;
t_cycle=(t_normal+t_regen+t_htrec);
[MC_bed, MC_SBed, MC_Ad, M_bed_ads]=MCs(fin_pitch_bed, Metal, Pge);
M_ref_tot=185; M_ref_L_cond_MAX=50;
THW_in=(88.6+273); TCW_in=(29.5+273); TCHW_in=(11.1+273);
m_dot_HW=18.3; m_dot_CW=66.6; m_dot_CHW=19.7;
%===========================================================================
% Initial conditions
Time_i=0;
t=Time_i;
T_bed_i=27+273;
T_bed2_i=27+273;
T_evap_i=27+273;
T_cond_i=27+273;
W_bed2_i=0.05;
W_bed_i=0.05;
M_ref_L_cond=50*0.9;
M_ref_L_evap_i=M_ref_tot;
%===========================================================================
step=Dtime; S=0;
%---------------------------------------------------------------------------
for M=1:N_cyc
    Q_in=0;
    Q_evap=0;
    t_round=0;
%---------------------------------------------------------------------------
for L=1:step:t_cycle
    S=S+1
    t=t+step
    Time(S)=t;
%---------------------------------------------------------------------------
 t_round=t_round+step
if (t_round<=t_normal)
    FLAG1=1; FLAG3=1; FLAG4=0; FLAG5=1;
elseif ((t_round>t_normal)&(t_round<=(t_normal+t_regen)))
    FLAG1=1; FLAG3=0; FLAG4=1; FLAG5=0;
elseif ((t_round>(t_normal+t_regen))&(t_round<=(t_normal+t_regen+t_htrec)))
    FLAG1=0; FLAG3=1; FLAG4=0; FLAG5=0;
end;
%===========================================================================
Timerange2=[Time_i t];
Initialbed2=[W_bed2_i T_bed2_i T_cond_i W_bed_i T_bed_i T_evap_i
M_ref_L_evap_i];
%===========================================================================
option2=odeset('RelTol',1E-4,'AbsTol',1E-4);
```

```
Y=ode45(@ddydwdt,Timerange2,Initialbed2,option2,M_ref_L_cond,m_dot_HW,m_dot
_CW,m_dot_CHW,THW_in,TCW_in,TCHW_in,FLAG1,FLAG3,Dtime,FLAG4,FLAG5,fin_pitch
_bed_mm,Metal,Pge);
%-----------------Hot Bed Parameters---------------------------------------
Y2_t=deval(Y,t);
W_bed2(S)=Y2_t(1);
T_bed2(S)=Y2_t(2);
T_cond(S)=Y2_t(3);
%-----------------Cold Bed Parameters--------------------------------------
W_bed(S)=Y2_t(4);
T_bed(S)=Y2_t(5);
T_evap(S)=Y2_t(6);
%-----------------Evaporator Parameters------------------------------------
M_ref_L_evap(S)=Y2_t(7);
%==========================================================================
TB=T_bed(S); TB2=T_bed2(S); TE=T_evap(S); TC=T_cond(S);
%--------------------------------------------------------------------------
if ((FLAG1==1)&&(FLAG3==1))
    T_w_bed_in2=THW_in; m_dot_water_bed2=m_dot_HW;

T_w_bed_out2=BedTwo(TB2,T_w_bed_in2,m_dot_water_bed2,fin_pitch_bed,Metal,Pg
e);
    T_w_bed_in=TCW_in; m_dot_water_bed=m_dot_CW;

T_w_bed_out=BedTwo(TB,T_w_bed_in,m_dot_water_bed,fin_pitch_bed,Metal,Pge);
elseif ((FLAG1==0)&&(FLAG3==1))
    T_w_bed_in2=TCW_in; m_dot_water_bed2=m_dot_CW;

T_w_bed_out2=BedTwo(TB2,T_w_bed_in2,m_dot_water_bed2,fin_pitch_bed,Metal,Pg
e);
    T_w_bed_in=T_w_bed_out2; m_dot_water_bed=m_dot_CW;

T_w_bed_out=BedTwo(TB,T_w_bed_in,m_dot_water_bed,fin_pitch_bed,Metal,Pge);
end
%-----------------Cooling Water Stream Temp--------------------------------
if ((FLAG1==1)&&(FLAG3==1))
    T_w_cond_in=T_w_bed_out; m_dot_water_cond=m_dot_CW;
elseif ((FLAG1==1)&&(FLAG3==0))
    T_w_cond_in=TCW_in; m_dot_water_cond=m_dot_CW;
elseif ((FLAG1==0)&&(FLAG3==1))
    T_w_cond_in=T_w_bed_out; m_dot_water_cond=m_dot_CW;
end
TCW_inn(S)=TCW_in;
TCW_out(S)=CondTwo(TC,T_w_cond_in,m_dot_water_cond,Dtime);
%-----------------Hot Water Steam Temp-------------------------------------
if ((FLAG1==1)&&(FLAG3==1))
    THW_out(S)=T_w_bed_out2; THW_inn(S)=THW_in;
elseif ((FLAG1==1)&&(FLAG3==0))
    THW_out(S)=THW_in; THW_inn(S)=THW_in;
elseif ((FLAG1==0)&&(FLAG3==1))
    THW_out(S)=THW_in; THW_inn(S)=THW_in;
end
%-----------------Chilled Water Stream Temp--------------------------------
T_w_evap_in=TCHW_in; m_dot_water_evap=m_dot_CHW;
TCHW_inn(S)=TCHW_in; TCHW_out(S)=EvapTwo(TE,T_w_evap_in,m_dot_water_evap);
Chilled_out=TCHW_out(S)-273;
%==========================================================================
% Adsorption / Desorption Switching
```

```
if
((M==1)||(M==3)||(M==5)||(M==7)||(M==9)||(M==11)||(M==13)||(M==15)||(M==17)
||(M==19))
T_des(S)=T_bed2(S); W_des(S)=W_bed2(S); T_ads(S)=T_bed(S);
W_ads(S)=W_bed(S);
elseif
((M==2)||(M==4)||(M==6)||(M==8)||(M==10)||(M==12)||(M==14)||(M==16)||(M==18
)||(M==20))
T_des(S)=T_bed(S); W_des(S)=W_bed(S); T_ads(S)=T_bed2(S);
W_ads(S)=W_bed2(S);
end;
%===========================================================================
m_water_ads(S)=W_bed(S)*M_bed_ads;
m_water_des(S)=W_bed2(S)*M_bed_ads;
m_water_tot(S)=m_water_ads(S)+m_water_des(S);
%===========================================================================
% Instant Performance Indicators
dq_in=(m_dot_HW*4.18*Dtime/t_cycle)*(THW_inn(S)-THW_out(S));
Q_in=Q_in+dq_in;
dq_evap=(m_dot_water_evap*4.18*Dtime/t_cycle)*(TCHW_inn(S)-TCHW_out(S));
Q_evap=Q_evap+dq_evap;
%------------------------------Data Plot-----------------------------------
subplot(3,2,1); PLT1=plot(Time,THW_inn,'k--',Time,TCW_inn,'k--
',Time,TCHW_inn,...
    'k--',Time,T_des,'b-',Time,T_ads,'c-',Time,T_evap,'m-',Time,T_cond,'r-
');
set(PLT1,'linewidth',2); set(gca,'fontsize',10); xlabel('Time [Sec]',
'fontsize',...
    12); ylabel('Temperature [C]','fontsize',12); title('Heat Exchangers
Temperature Profile','fontsize',14);

subplot(3,2,2); PLT2=plot(Time,THW_inn,'r-',Time,THW_out,'m-
',Time,TCW_inn,...
    'k-',Time,TCW_out,'g-',Time,TCHW_inn,'b-',Time,TCHW_out,'c-');
set(PLT2,'linewidth',2); set(gca,'fontsize',10); xlabel('Time [Sec]',
'fontsize',...
    12); ylabel('Temperatures [C]','fontsize',12); title('Heat Exchangers
Outlet Temperature','fontsize',14);

subplot(3,2,3); PLT3=plot(Time,M_ref_L_evap,'k-');
set(PLT3,'linewidth',2); set(gca,'fontsize',10); xlabel('Time [Sec]',
'fontsize',...
    12); ylabel('Evaporator Refrigerant [kg]','fontsize',12);
title('Evaporator Refrigerant mass','fontsize',14);

subplot(3,2,4); PLT3=plot(Time,m_water_tot,'k-');
set(PLT3,'linewidth',2); set(gca,'fontsize',10); xlabel('Time [Sec]',
'fontsize',...
    12); ylabel('Ads & Des Refrigerant [kg]','fontsize',12); title('Ads &
Des Refrigerant mass','fontsize',14);

subplot(3,2,5); PLT3=plot(Time,m_water_ads,'k-');
set(PLT3,'linewidth',2); set(gca,'fontsize',10); xlabel('Time [Sec]',
'fontsize',...
    12); ylabel('Adsorber Refrigerant [kg]','fontsize',12); title('Adsorber
Refrigerant mass','fontsize',14);

subplot(3,2,6); PLT3=plot(Time,m_water_des,'k-');
```

```
set(PLT3,'linewidth',2); set(gca,'fontsize',10); xlabel('Time [Sec]',
'fontsize',...
    12); ylabel('Desorber Refrigerant [kg]','fontsize',12); title('Desorber
Refrigerant mass','fontsize',14);
drawnow;
%===========================================================================
Time_i=t;
W_bed2_i=Y2_t(1);
T_bed2_i=Y2_t(2);
T_cond_i=Y2_t(3);
%---------------------------------------------------------------------------
W_bed_i=Y2_t(4);
T_bed_i=Y2_t(5);
T_evap_i=Y2_t(6);
%---------------------------------------------------------------------------
M_ref_L_evap_i=Y2_t(7);
end
% Cyclic Performance Indicators
Q_Cooling(M)=Q_evap;
Q_Heating(M)=Q_in;
COP(M)=Q_evap/Q_in;
SCP(M)=Q_evap/(M_bed_ads);
%---------------------------------------------------------------------------
W_bed2_i=Y2_t(4);
T_bed2_i=Y2_t(5);
%---------------------------------------------------------------------------
W_bed_i=Y2_t(1);
T_bed_i=Y2_t(2);
End
%---------------------------------------------------------------------------
% Complete Run Performance Indicators
[MC_bedi(i),MC_SBedi(i),MC_Adi(i),M_bed_adsi(i)]=
MCs(fin_pitch_bed,Metal,Pge);
MCSM(i)=MC_SBedi(i)/(MC_bedi(i)+MC_Adi(i));
P(i)=fin_pitch_bed_mm;
Q_Coolingi(i)=Q_Cooling(N_cyc);
Q_Heatingi(i)=Q_Heating(N_cyc);
COPi(i)=COP(N_cyc);
SCPi(i)=SCP(N_cyc);
end
```

A.3 Bed / Heat exchanger interaction flow chart



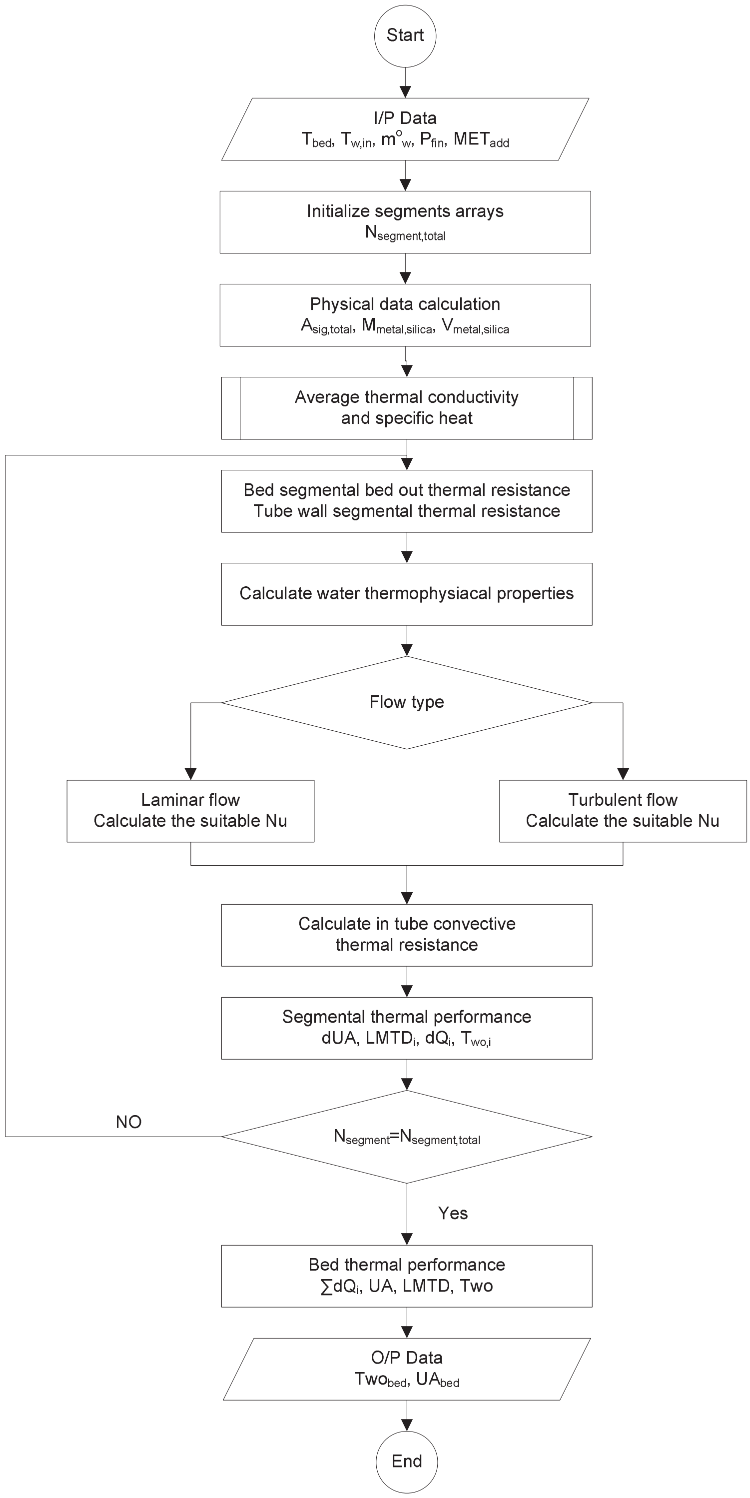
A.4 Bed / Heat exchanger interaction code

```
function dy=ddydwdt(t,y,M_ref_L_cond,m_dot_HW,m_dot_CW,m_dot_CHW,THW_in,...

TCW_in,TCHW_in,FLAG1,FLAG3,Dtime,FLAG4,FLAG5,fin_pitch_bed_mm,Metal,Pge)
%===========================================================================
% This sub-program for solving energy balance equations for different heat
% exchangers (adsorbent bed, evaporator and condenser)
%Initial vector
dy=zeros(7,1);
T_bed2=y(2); T_cond=y(3); T_bed=y(5); T_evap=y(6); M_ref_L_evap=y(7);
%===========================================================================
FLAG2=1; Cv=1.9; fin_pitch_bed=fin_pitch_bed_mm/1000;
[MC_bed, MC_SBed, MC_Ad, M_bed_ads]=MCs(fin_pitch_bed, Metal, Pge);
MCp_bed_met=MC_Ad+MC_bed+(616.816*3.83-616.816);
MCp_bed_ads=MC_SBed; MCp_bed_w=407.8*4.18;
MCp_cond_met=191.3277*1.25; MCp_evap_met=185.3718;
D_so=2.54E-4; Rp=0.15E-3; Ea=4.2E4; R=8.3145; H_ads=2.51E3;
%===========================================================================
          %Desorber temperature constant
%===========================================================================
if ((FLAG1==1)&(FLAG3==1))
    T_w_bed_in2=THW_in; m_dot_water_bed2=m_dot_HW;
elseif ((FLAG1==1)&(FLAG3==0))
    T_w_bed_in2=THW_in; m_dot_water_bed2=m_dot_HW;
elseif ((FLAG1==0)&(FLAG3==1))
    T_w_bed_in2=TCW_in; m_dot_water_bed2=m_dot_CW;
end
%---------------------------------------------------------------------------
    %Bed heating water stream
[T_w_bed_out2, UA_bed2]=
BedTwo(T_bed2,T_w_bed_in2,m_dot_water_bed2,fin_pitch_bed,Metal,Pge)
%---------------------------------------------------------------------------
P_sat_ref_cond=refpropm('P','T',T_cond,'Q',0,'water');      %P_sat_ref
P_sat_bed2=refpropm('P','T',T_bed2,'Q',0,'water');          %P_sat_ads
%---------------------------------------------------------------------------
if ((FLAG1==1)&(FLAG3==0))
    w_star_bed2=Uptake_sat(T_bed,T_bed2);
    W_bed_const1=15*D_so/Rp^2;
elseif ((FLAG1==0)&(FLAG3==1))
    w_star_bed2=Uptake_sat(T_bed2,T_bed2);
    W_bed_const1=0;
else
    w_star_bed2=Uptake_sat(T_cond,T_bed2);
    W_bed_const1=15*D_so/Rp^2;
end
%---------------------------------------------------------------------------
Cp_w_T_bed2=refpropm('C','T',T_bed2,'Q',1,'water')*1E-3;    %Cp_w_T_bed
%---------------------------------------------------------------------------
T_bed_const1=FLAG1*M_bed_ads*H_ads*(15*D_so/Rp^2);
T_bed_const2=(1-FLAG4)*m_dot_water_bed2*4.18*(T_w_bed_in2-T_w_bed_out2);
T_bed_const3=MCp_bed_ads+MCp_bed_met+(FLAG4*MCp_bed_w);
T_bed_const4=M_bed_ads*Cp_w_T_bed2;
%===========================================================================
         %Adsorber temperature constant
%===========================================================================
if ((FLAG1==1)&(FLAG3==1))
    T_w_bed_in=TCW_in; m_dot_water_bed=m_dot_CW;
```

```
elseif ((FLAG1==1)&(FLAG3==0))
    T_w_bed_in=TCW_in; m_dot_water_bed=m_dot_CW;
elseif ((FLAG1==0)&(FLAG3==1))
    T_w_bed_in=T_w_bed_out2; m_dot_water_bed=m_dot_CW;
end
%---------------------------------------------------------------------------
    %Bed cooling water stream
[T_w_bed_out,
UA_bed]=BedTwo(T_bed,T_w_bed_in,m_dot_water_bed,fin_pitch_bed,Metal,Pge)
%---------------------------------------------------------------------------
P_sat_ref_evap=refpropm('P','T',T_evap,'Q',0,'water');
P_sat_bed=refpropm('P','T',T_bed,'Q',0,'water');
%---------------------------------------------------------------------------
h_ref_g_T_hex=refpropm('H','T',T_evap,'Q',1,'water')*1E-3;
h_ref_P_hex_T_bed=refpropm('H','T',T_bed,'P',P_sat_bed,'water')*1E-3;
Cp_w_T_bed=refpropm('C','T',T_bed,'Q',1,'water')*1E-3;
%---------------------------------------------------------------------------
if ((FLAG1==1)&(FLAG3==0))
    w_star_bed=Uptake_sat(T_evap,T_bed);
    W_bed_const2=0;
elseif ((FLAG1==0)&(FLAG3==1))
    w_star_bed=Uptake_sat(T_bed,T_bed);
    W_bed_const2=0;
else
    w_star_bed=Uptake_sat(T_evap,T_bed);
    W_bed_const2=15*D_so/Rp^2;
end
%---------------------------------------------------------------------------
T_bed_const5=FLAG1*M_bed_ads*H_ads*(15*D_so/Rp^2);
T_bed_const6=FLAG1*M_bed_ads*((FLAG3*(h_ref_g_T_hex-h_ref_P_hex_T_bed))...
    +((1-FLAG3)*Cv*(T_bed2-T_bed)))*(15*D_so/Rp^2);
T_bed_const7=(1-FLAG4)*m_dot_water_bed*4.18*(T_w_bed_in-T_w_bed_out);
T_bed_const8=MCp_bed_ads+MCp_bed_met+(FLAG4*MCp_bed_w);
T_bed_const9=M_bed_ads*Cp_w_T_bed;
%===========================================================================
        %Condenser constants
%===========================================================================
if ((FLAG1==1)&(FLAG3==1))
    T_w_cond_in=T_w_bed_out; m_dot_water_cond=m_dot_CW;
elseif ((FLAG1==1)&(FLAG3==0))
    T_w_cond_in=TCW_in; m_dot_water_cond=m_dot_CW;
elseif ((FLAG1==0)&(FLAG3==1))
    T_w_cond_in=T_w_bed_out; m_dot_water_cond=m_dot_CW;
end
%---------------------------------------------------------------------------
   %Condenser water outlet temperature
[T_w_cond_out]=CondTwo(T_cond,T_w_cond_in,m_dot_water_cond,Dtime);
%---------------------------------------------------------------------------
h_ref_cond_out=refpropm('H','T',T_cond,'Q',0,'water')*1E-3;
h_ref_bed2_out=refpropm('H','T',T_bed2,'P',P_sat_bed2,'water')*1E-3;
Cp_ref_L_cond=refpropm('C','T',T_cond,'Q',0,'water')*1E-3;
h_ref_cond_in=refpropm('H','T',T_cond,'Q',1,'water')*1E-3;
C_ref_bed2_out=refpropm('C','T',T_bed2,'Q',1,'water')*1E-3;
%---------------------------------------------------------------------------
T_cond_const1=-FLAG5*M_bed_ads*(h_ref_cond_in-
h_ref_cond_out)*(15*D_so/Rp^2);
T_cond_const2=m_dot_water_cond*4.18*(T_w_cond_in-T_w_cond_out);
T_cond_const3=(M_ref_L_cond*Cp_ref_L_cond)+MCp_cond_met;
```

```
T_cond_const4=-FLAG5*M_bed_ads*C_ref_bed2_out*(T_bed2-
T_cond)*(15*D_so/Rp^2);
%==========================================================================
        %Evaporator constants
%==========================================================================
T_w_evap_in=TCHW_in;
m_dot_water_evap=m_dot_CHW;
%--------------------------------------------------------------------------
     %Evaporator cooling water stream
[T_w_evap_out]=EvapTwo(T_evap,T_w_evap_in,m_dot_water_evap);
%--------------------------------------------------------------------------
h_ref_evap_in=refpropm('H','T',T_evap,'Q',0,'water')*1E-3;
h_ref_evap_out=refpropm('H','T',T_evap,'Q',1,'water')*1E-3;
Cp_ref_L_evap=refpropm('C','T',T_evap,'Q',0,'water')*1E-3;
%--------------------------------------------------------------------------
T_evap_const1=FLAG5*M_bed_ads*(h_ref_evap_in-
h_ref_evap_out)*(15*D_so/Rp^2);
T_evap_const2=m_dot_water_evap*4.18*(T_w_evap_in-T_w_evap_out);
T_evap_const3=(M_ref_L_evap*Cp_ref_L_evap)+MCp_evap_met;
%==========================================================================
dy(1)=W_bed_const1*(w_star_bed2-y(1))*exp(-Ea/(R*y(2)));
dy(2)=(T_bed_const1*exp(-Ea/(R*y(2)))*(w_star_bed2-
y(1))+T_bed_const2)/(T_bed_const3+(y(1)*T_bed_const4));
dy(3)=((T_cond_const1+T_cond_const4)*exp(-Ea/(R*y(2)))*(w_star_bed2-
y(1))+T_cond_const2)/T_cond_const3;
%==========================================================================
dy(4)=(FLAG3*W_bed_const2*exp(-Ea/(R*y(5)))*(w_star_bed-y(4)))-((1-
FLAG3)*W_bed_const1*(w_star_bed2-y(1))*exp(-Ea/(R*y(2))));
dy(5)=((T_bed_const5+T_bed_const6)*exp(-Ea/(R*y(5)))*(w_star_bed-
y(4))+T_bed_const7)/(T_bed_const8+(T_bed_const9*y(4)));
dy(6)=(T_evap_const1*exp(-Ea/(R*y(5)))*(w_star_bed-
y(4))+T_evap_const2+(0.04*(h_ref_evap_in-h_ref_evap_out)))/T_evap_const3;
%==========================================================================
dy(7)=-M_bed_ads*FLAG5*((W_bed_const1*(w_star_bed2-y(1))*exp(-
Ea/(R*y(2))))+(W_bed_const2*exp(-Ea/(R*y(5)))*(w_star_bed-y(4))));
```

A.5 Adsorbent bed model flow chart



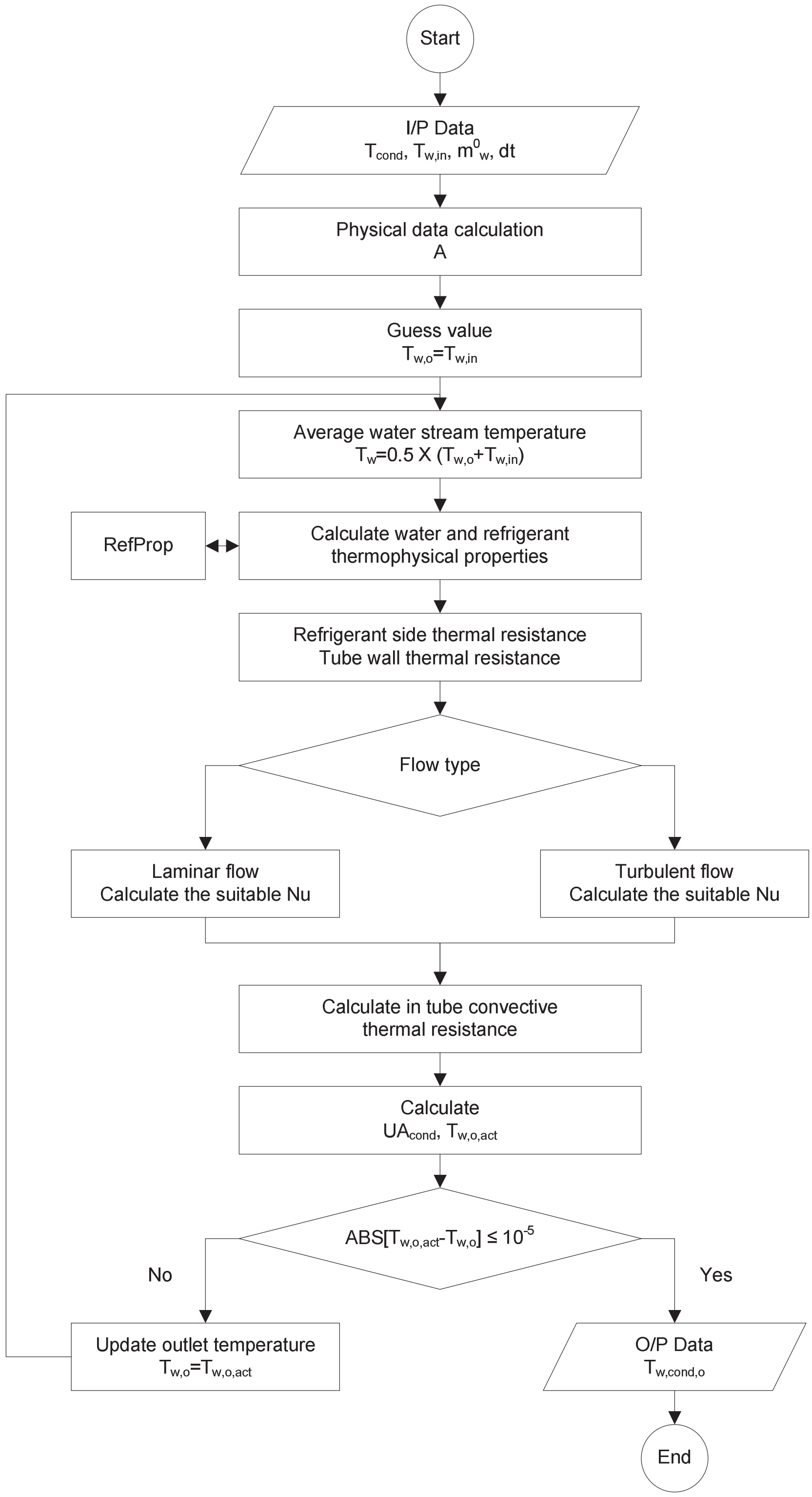
A.6 Adsorbent bed model code

```
function [T_w_bed_out,UA]=
BedTwo(T_bed,T_w_bed_in,m_dot_water_bed,fin_pitch_bed,Metal,Pge)
Ref='water'; SecFld='water';
%==========================================================================
% Input geometrical characteristics
L_fin_bed=340E-3; H_fin_bed=0.0285;             %fin_pitch_bed=1.5E-3;
Dp=0.31; L_module=3400E-3; N_t_module=12; N_pass_bed=2;
N_module=7*2*4; D_bed_o=(5/8)*0.0254; t_bed=0.8E-3; D_bed_i=D_bed_o-
(2*t_bed);
W_fin_bed=0.105E-3; epslon_bed=0.0015E-3;
N_fin_module=round(L_module/fin_pitch_bed);
%==========================================================================
% Array booking
N_inc=N_fin_module*2;
site=zeros(1,N_inc);Segma_R=zeros(1,N_inc);UA_bed=zeros(1,N_inc);T_w_out=ze
ros(1,N_inc);
DT_b=zeros(1,N_inc);DT_s=zeros(1,N_inc);LMTD=zeros(1,N_inc);dq=zeros(1,N_in
c);
T_w_in=zeros(1,N_inc);T_w_out=zeros(1,N_inc);htc_w_bedi=zeros(1,N_inc);
%==========================================================================
% Geometrical calculation
a=L_fin_bed/N_t_module; b=H_fin_bed; r_fin_bed=sqrt(a*b/pi);
D_fin_bed=r_fin_bed*2;
fin_space_bed=fin_pitch_bed-W_fin_bed; A_w_bed=pi*D_bed_i^2/4;
N_t_bed=N_module*N_t_module; N_t_bed_pass=N_t_bed/N_pass_bed;
T_bed_C=T_bed-273; R_cont_TSG=Rc(T_bed_C,Dp); R_cont_FSG=Rc(T_bed_C,Dp);
%==========================================================================
% Area calculation
L_FT=W_fin_bed*N_fin_module; L_UFT=L_module-L_FT; A_UFT=pi*D_bed_o*L_UFT;
A_UFTM=A_UFT*N_t_module;
A_FS=(L_fin_bed*H_fin_bed)-(0.25*pi*D_bed_o^2*N_t_module);
A_FTP=(2*L_fin_bed*W_fin_bed)+(2*H_fin_bed*W_fin_bed);
A_F=A_FS+A_FTP; A_FM=A_F*N_fin_module;
A_M=A_FM+A_UFTM; A_bed=A_M*N_module;
%==========================================================================
% Mass calculation
Roh_F=3661.85; C_F=0.896; Roh_T=8954; C_T=0.3831; Roh_S=690.987; C_S=0.921;
%Roh_S=708.299;
M_TM=0.25*pi*(D_bed_o^2-D_bed_i^2)*L_module*N_t_module*Roh_T;
M_FM=A_FS*W_fin_bed*Roh_F*N_fin_module;
MC_M=M_TM*C_T+M_FM*C_F;
%==========================================================================
V_TM=0.25*pi*L_module*N_t_module*D_bed_o^2;
V_FM=A_FS*W_fin_bed*N_fin_module;
V_M=L_module*L_fin_bed*H_fin_bed;
V_SM=V_M-V_FM-V_TM; M_SM=V_SM*Roh_S; M_SBed=(M_SM*N_module);
%==========================================================================
[K_SG, C_Ad]=KC_mix(Metal, Pge);
M_bed_ads=M_SBed*(1-Pge/100); MC_SBed=M_SBed*C_S;
MC_Ad=(M_SBed*Pge/100)*C_Ad; MC_bed=MC_M*N_module;
%==========================================================================
% Outside surface heat transfer resistance
A_s_fin_bed=(a*b)-(pi*D_bed_o^2/4);
d_SG=fin_space_bed/2;
RA1=R_cont_FSG/(2*A_s_fin_bed);% Axial contact thermal resistance (Per
increament)
```

```
RA2=d_SG/(2*A_s_fin_bed*K_SG);% Axial thermal resistance (Per increament)
RA=RA1+RA2; % Total axial thermal resistance (Per increament)
RB1=R_cont_TSG/(2*pi*D_bed_o*d_SG); % Radial Contact thermal resistance
(Per increment)
RB2=(log(D_fin_bed/D_bed_o))/(4*pi*K_SG*d_SG); % Radial thermal resistance
(Per increment)
RB=RB1+RB2; % Total radial thermal resistance (Per increment)
R_bed=RA*RB/(RA+RB); % Bed side thermal resistance for one increment
%==========================================================================
% Tube wall heat heat transfer resistance
K_t_bed=310*1E-3; %kW/m.K
R_t_bed=(log(D_bed_o/D_bed_i))/(2*pi*K_t_bed*fin_pitch_bed);
%==========================================================================
% Start of calculation loop
T_w_in(1)=T_w_bed_in;
for i=1:N_inc
site(i)=i;
%==========================================================================
% Water side heat transfer resistance
% Thermo-physical properties
T_w_bed=T_w_in(i);
P_atm=refpropm('P','T',373.15,'Q',0,SecFld);
Roh_w_bed=refpropm('D','T',T_w_bed,'P',P_atm,SecFld); %Kg/m3
Meu_w_bed=refpropm('V','T',T_w_bed,'P',P_atm,SecFld); %Pa s
Cp_w_bed=refpropm('C','T',T_w_bed,'P',P_atm,SecFld)*1E-3; %kJ/kg.K
K_w_bed=refpropm('L','T',T_w_bed,'P',P_atm,SecFld)*1E-3; %kW/m.K
Pr_w_bed=Cp_w_bed*Meu_w_bed/K_w_bed;
% Calculations
VeL_t_bed=m_dot_water_bed/(Roh_w_bed*A_w_bed*N_t_bed_pass);
Re_w_bed=Roh_w_bed*VeL_t_bed*D_bed_i/Meu_w_bed;
if (Re_w_bed<3000)
    f_bed_i=64/Re_w_bed;
    Nus_w_bed=4.36;
elseif (Re_w_bed>=3000)
    f_bed_i=(-1.8*log10((6.9/Re_w_bed)+(epslon_bed/(3.7*D_bed_i))^1.11))^-
2;
    Num5=(Pr_w_bed*f_bed_i/8)*(Re_w_bed-1000);
    Den5=1+(12.7*((f_bed_i/8)^0.5)*((Pr_w_bed^(2/3))-1));
    Nus_w_bed=Num5/Den5;
end
htc_w_bed=Nus_w_bed*K_w_bed/D_bed_i;
R_w_bed=1/(htc_w_bed*pi*D_bed_i*fin_pitch_bed);
%==========================================================================
% Thermal balance and outlet temperature calculation
Segma_R(i)=(R_w_bed+R_t_bed+R_bed);
UA_bed(i)=1/Segma_R(i);
T_w_out(i)=T_bed+(T_w_in(i)-T_bed)*(exp(-
UA_bed(i)/(m_dot_water_bed*4.18/N_t_bed_pass)));
if (T_w_bed_in>T_bed)
    DT_b(i)=T_w_in(i)-T_bed; DT_s(i)=T_w_out(i)-T_bed;
else
    DT_b(i)=T_bed-T_w_in(i); DT_s(i)=T_bed-T_w_out(i);
end
LMTD(i)=(DT_b(i)-DT_s(i))/(log(DT_b(i)/DT_s(i)));
dq(i)=UA_bed(i)*LMTD(i)*(12*7*4);
%==========================================================================
htc_w_bedi(i)=htc_w_bed;
%==========================================================================
if (i==N_inc)
```

```
    break
else
    T_w_in(i+1)=T_w_out(i);
end
end
T_w_bed_out=T_w_out(N_inc);
%==========================================================================
% Chick the tolerance in calculations
Q_bed1=sum(dq);
Q_bed2=m_dot_water_bed*4.18*(abs(T_w_bed_in-T_w_bed_out));
Tolerance=abs(Q_bed1-Q_bed2);
%==========================================================================
if (T_w_bed_in>T_bed)
    DT_b_bed=T_w_bed_in-T_bed; DT_s_bed=T_w_bed_out-T_bed;
else
    DT_b_bed=T_bed-T_w_bed_in; DT_s_bed=T_bed-T_w_bed_out;
end
LMTD_bed=(DT_b_bed-DT_s_bed)/(log(DT_b_bed/DT_s_bed));
UA=Q_bed1/(LMTD_bed);
U_bed=Q_bed1/(A_bed*LMTD_bed);
```

A.7 Condenser model flow chart

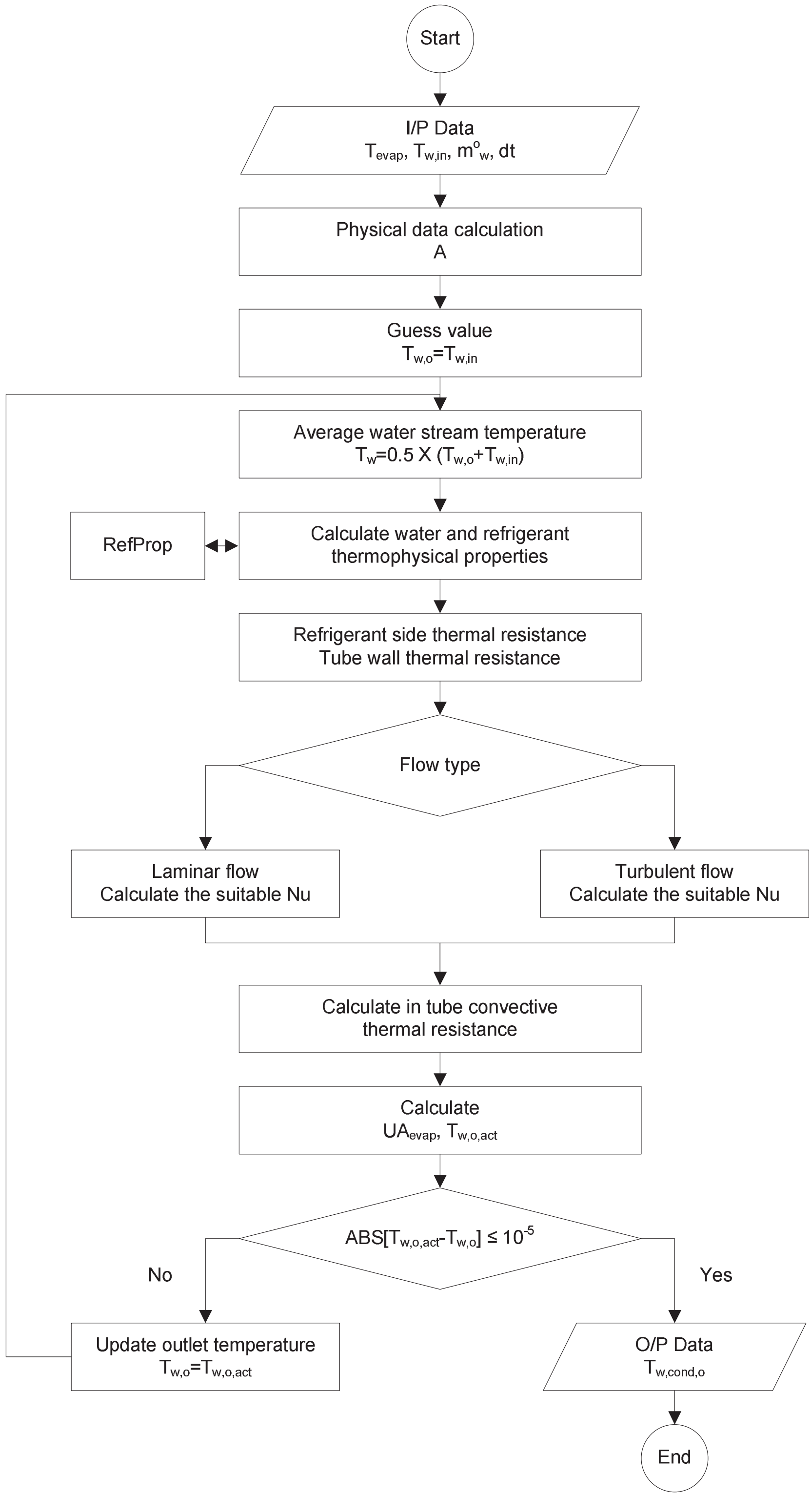


A.8 Condenser model code

```
function [T_w_cond_out]=CondTwo(T_cond,T_w_cond_in,m_dot_w_cond,Dtime)
Ref='water'; SecFld='water';
% Input geometrical characteristics
D_cond_o=0.75*0.0254;
t_cond_f=0.8E-3;
D_cond_i=D_cond_o-(2*t_cond_f);
N_t_cond=457;
L_t_cond=2654E-3;
N_pass_cond=3;
N_row_cond=11;
epslon_cond=0.0015E-3;
% Geometrical characteristics calculations
A_cond=pi*D_cond_o*L_t_cond*N_t_cond;
%============================================================================
ItrC=0;
T_w_cond_out=T_w_cond_in;
for n=1:10
ItrC=ItrC+1;
% A- refrigerant side convective resistance
% A-1 Thermo-physical properties
T_ref_cond_sat=T_cond;
T_w_cond=(T_w_cond_in+T_w_cond_out)/2;
T_ref_cond_surf=T_w_cond;
T_ref_cond_v=(T_ref_cond_surf+T_ref_cond_sat)/2;
Roh_ref_cond_L=refpropm('D','T',T_ref_cond_sat,'Q',0,Ref); %kg/m3
Roh_ref_cond_v=refpropm('D','T',T_ref_cond_v,'Q',1,Ref); %kg/m3
K_ref_cond_L=refpropm('L','T',T_ref_cond_sat,'Q',0,Ref)*1E-3; %kW/m K
h_ref_cond_L=refpropm('H','T',T_ref_cond_sat,'Q',0,Ref)*1E-3; %kJ/kg
h_ref_cond_v=refpropm('H','T',T_ref_cond_v,'Q',1,Ref)*1E-3; %kJ/kg
h_ref_cond_fg=abs(h_ref_cond_v-h_ref_cond_L);
Cp_ref_cond_v=refpropm('C','T',T_ref_cond_v,'Q',1,Ref)*1E-3; %kJ/kg K
Meu_ref_cond_L=refpropm('V','T',T_ref_cond_sat,'Q',0,Ref); %Pa s
% A-2 Calculations
gr=9.81; C1_ref_cond=0.729;
DeltaT_surf_sat=abs(T_ref_cond_sat-T_ref_cond_surf);
h_ref_cond_fg_bar=h_ref_cond_fg+0.68*Cp_ref_cond_v*abs(T_ref_cond_surf-
T_ref_cond_sat);
Num3=gr*Roh_ref_cond_L*(Roh_ref_cond_L-
Roh_ref_cond_v)*K_ref_cond_L^3*h_ref_cond_fg_bar;
Den3=N_row_cond*Meu_ref_cond_L*DeltaT_surf_sat*D_cond_o;
htc_ref_cond=C1_ref_cond*((Num3/Den3)^(1/4));
R_ref_cond=1/(htc_ref_cond*A_cond);
%----------------------------------------------------------------------------
% A-3 Mass balance
m_dot_ref_cond=htc_ref_cond*pi*D_cond_o*DeltaT_surf_sat/h_ref_cond_fg_bar;
m_dot_ref_cond_tot=m_dot_ref_cond*L_t_cond*N_t_cond;
m_ref_cond_tot_out=m_dot_ref_cond_tot*Dtime;
%============================================================================
% B- Water side convective resistance
% B-1 Thermo-physical properties
P_atm=refpropm('P','T',373.15,'Q',0,'water');
Roh_w_cond=refpropm('D','T',T_w_cond,'P',P_atm,SecFld);      %Kg/m3
Meu_w_cond=refpropm('V','T',T_w_cond,'P',P_atm,SecFld);      %Pa s
Cp_w_cond=refpropm('C','T',T_w_cond,'P',P_atm,SecFld)*1E-3; %kJ/kg.K
K_w_cond=refpropm('L','T',T_w_cond,'P',P_atm,SecFld)*1E-3;  %kW/m.K
Pr_w_cond=Cp_w_cond*Meu_w_cond/K_w_cond;
```

```
% B-2 Calculations
A_w_cond=pi*D_cond_i^2/4;
N_t_cond_pass=N_t_cond/N_pass_cond;
VeL_t_cond=m_dot_w_cond/(Roh_w_cond*A_w_cond*N_t_cond_pass);
Re_w_cond=Roh_w_cond*VeL_t_cond*D_cond_i/Meu_w_cond;
if (Re_w_cond<3000)
    f_cond_i=64/Re_w_cond
    Nus_w_cond=4.36
elseif (Re_w_cond>=3000)
    f_cond_i=(-
1.8*log10((6.9/Re_w_cond)+(epslon_cond/(3.7*D_cond_i))^1.11))^-2;
    Num4=(Pr_w_cond*f_cond_i/8)*(Re_w_cond-1000);
    Den4=1+(12.7*((f_cond_i/8)^0.5)*((Pr_w_cond^(2/3))-1));
    Nus_w_cond=Num4/Den4;
end
htc_w_cond=Nus_w_cond*K_w_cond/D_cond_i;
R_w_cond=1/(htc_w_cond*pi*D_cond_i*L_t_cond*N_t_cond);
%===========================================================================
% C- Tube wall conductance resistance
K_t_cond=310*1E-3; %kW/m.K
R_t_cond=(log(D_cond_o/D_cond_i))/(2*pi*K_t_cond*L_t_cond*N_t_cond);
%===========================================================================
% D- Overall thermal conductance
UA_cond=1/(R_w_cond+R_t_cond+R_ref_cond);
Twco=T_cond-((T_cond-T_w_cond_in)*exp(-UA_cond/(m_dot_w_cond*Cp_w_cond)));
Tol_cond_w_out=abs(Twco-T_w_cond_out);
if (Tol_cond_w_out<=1E-5)
    break
else
    T_w_cond_out=Twco;
end
end
```

A.9 Evaporator flow chart



Evaporator model code

```
function [T_w_evap_out]=EvapTwo(T_evap,T_w_evap_in,m_dot_w_evap)
Ref='water'; SecFld='water';
% Input geometrical characteristics
D_evap_i=16.33E-3;
D_evap_f=18.85E-3;
D_evap_r=17.75E-3;
t_evap_f=0.20E-3;
Pt_evap=0.45E-3;
L_t_evap=3894e-3;
N_t_evap=224;
N_pass_evap=3;
Eta_evap_f=0.98;
epslon_evap=0.0015E-3;
%==========================================================================
% Geometrical characteristics calculations
r1_evap=D_evap_r/2;
r2_evap=D_evap_f/2;
r2_c_evap=r2_evap+(t_evap_f/2);
A_f_evap=2*pi*(r2_c_evap^2-r1_evap^2);
A_uf_evap=pi*D_evap_r*(Pt_evap-t_evap_f);
A_fs_evap=2*(pi/4)*(D_evap_f^2-D_evap_r^2);
A_ft_evap=pi*D_evap_f*t_evap_f;
A_evap_seg=A_f_evap+A_uf_evap;
Term1_evap=1.3*Eta_evap_f;
Term2_evap=A_fs_evap/(A_evap_seg*(0.25*pi*(D_evap_f^2-
D_evap_r^2)/D_evap_f)^0.25);
Term3_evap=A_ft_evap/(A_evap_seg*D_evap_f^0.25);
Term4_evap=A_uf_evap/(A_evap_seg*D_evap_r^0.25);
D_evap=(Term1_evap*(Term2_evap+Term3_evap+Term4_evap))^-4;
N_evap_seg=L_t_evap/Pt_evap;
A_evap=A_evap_seg*N_evap_seg*N_t_evap;
%==========================================================================
itrE=0;
T_w_evap_out=T_w_evap_in;
for n=1:10
    itrE=itrE+1;
% A- Refrigerant side convective Resistance
% A-1 Thermo-physical properties calculations
T_w_evap=(T_w_evap_out+T_w_evap_in)/2;
T_ref_evap_surf=T_w_evap;
T_ref_evap_sat=T_evap;
T_ref_evap_v=(T_ref_evap_surf+T_ref_evap_sat)/2;
Roh_ref_evap_L=refpropm('D','T',T_ref_evap_sat,'Q',0,Ref); %Kg/m3
Roh_ref_evap_v=refpropm('D','T',T_ref_evap_v,'Q',1,Ref); %Kg/m3
h_ref_evap_L=refpropm('H','T',T_ref_evap_sat,'Q',0,Ref)*1E-3; %kJ/kg
h_ref_evap_v=refpropm('H','T',T_ref_evap_v,'Q',1,Ref)*1E-3; %kJ/kg
h_ref_evap_fg=abs(h_ref_evap_v-h_ref_evap_L); %kJ/kg
Cp_ref_evap_v=refpropm('C','T',T_ref_evap_v,'Q',1,Ref)*1E-3; %kJ/kg.K
Cp_ref_evap_L=refpropm('C','T',T_ref_evap_sat,'Q',0,Ref)*1E-3; %kJ/kg.K
Meu_ref_evap_v=refpropm('V','T',T_ref_evap_v,'Q',1,Ref); %Pa.s
Meu_ref_evap_L=refpropm('V','T',T_ref_evap_sat,'Q',0,Ref); %Pa.s
Neu_ref_evap_v=Meu_ref_evap_v/Roh_ref_evap_v;
K_ref_evap_v=refpropm('L','T',T_ref_evap_v,'Q',1,Ref)*1E-3; %kW/m.K
K_ref_evap_L=refpropm('L','T',T_ref_evap_sat,'Q',0,Ref)*1E-3; %kW/m.K
%--------------------------------------------------------------------------
% A-2-1 Calculations 'Film Boiling'
```

```
gr=9.81; C1_ref_evap=0.62;
DeltaT_surf_sat=abs(T_ref_evap_surf-T_ref_evap_sat);
h_ref_evap_fg_bar=h_ref_evap_fg+0.8*Cp_ref_evap_v*(T_ref_evap_surf-
T_ref_evap_sat);
Num1=gr*(Roh_ref_evap_L-Roh_ref_evap_v)*h_ref_evap_fg_bar*D_evap^3;
Den1=Neu_ref_evap_v*K_ref_evap_v*DeltaT_surf_sat;
Nus_ref_evap=C1_ref_evap*((Num1/Den1)^0.25);
htc_ref_evap1=Nus_ref_evap*K_ref_evap_v/D_evap;
%-----------------------------------------------------------------------------
% A-2-2 Calculations 'Nuclate Boiling'
C_s_f_evap=0.0068; n=1;
Ja_ref_evap=Cp_ref_evap_L*DeltaT_surf_sat/h_ref_evap_fg;
Pr_ref_evap_L=Cp_ref_evap_L*Meu_ref_evap_L/Meu_ref_evap_L;
TERM_A=Meu_ref_evap_L*h_ref_evap_fg/DeltaT_surf_sat;
TERM_B=gr*(Roh_ref_evap_L-Roh_ref_evap_v)/72.81E-3;
TERM_C=Ja_ref_evap/(C_s_f_evap*Pr_ref_evap_L^n);
htc_ref_evap=TERM_A*(TERM_B^0.5)*(TERM_C^3);
R_ref_evap=1/(htc_ref_evap*A_evap);
%=============================================================================
% B- Water side convective resistance
% B-1 Thermo-physical properties
P_atm=refpropm('P','T',373.15,'Q',0,'water');
Roh_w_evap=refpropm('D','T',T_w_evap,'P',P_atm,SecFld); %Kg/m3
Meu_w_evap=refpropm('V','T',T_w_evap,'P',P_atm,SecFld); %Pa s
Cp_w_evap=refpropm('C','T',T_w_evap,'P',P_atm,SecFld)*1E-3; %kJ/kg.K
K_w_evap=refpropm('L','T',T_w_evap,'P',P_atm,SecFld)*1E-3; %kW/m.K
Pr_w_evap=Cp_w_evap*Meu_w_evap/K_w_evap;
% B-2 Calculations
A_w_evap=pi*D_evap_i^2/4;
N_t_evap_pass=N_t_evap/N_pass_evap;
VeL_t_evap=m_dot_w_evap/(Roh_w_evap*A_w_evap*N_t_evap_pass);
Re_w_evap=Roh_w_evap*VeL_t_evap*D_evap_i/Meu_w_evap;
if (Re_w_evap<3000)
    f_evap_i=64/Re_w_evap;
    Nus_w_evap=4.36;
elseif (Re_w_evap>=3000)
    f_evap_i=(-
1.8*log10((6.9/Re_w_evap)+(epslon_evap/(3.7*D_evap_i))^1.11))^-2;
    %f_evap_i=((0.790*log(Re_w_evap))-1.64)^-2
    Num2=(Pr_w_evap*f_evap_i/8)*(Re_w_evap-1000);
    Den2=1+(12.7*((f_evap_i/8)^0.5)*((Pr_w_evap^(2/3))-1));
    Nus_w_evap=Num2/Den2;
end
htc_w_evap=Nus_w_evap*K_w_evap/D_evap_i;
R_w_evap=1/(htc_w_evap*pi*D_evap_i*L_t_evap*N_t_evap);
%=============================================================================
% C- Tube wall conductance resistance
K_t_evap=310*1E-3; %kW/m.K
D_evap_1=A_evap_seg/(pi*Pt_evap);
R_t_evap=(log(D_evap_1/D_evap_i))/(2*pi*K_t_evap*L_t_evap*N_t_evap);
%=============================================================================
% D- Overall thermal conductance
UA_evap=1/(R_w_evap+R_t_evap+R_ref_evap);
Tweo=T_evap+(T_w_evap_in-T_evap)*exp(-UA_evap/(m_dot_w_evap*Cp_w_evap));
Tol_evap_w_out=abs(Tweo-T_w_evap_out);
if (Tol_evap_w_out<=1E-5)
    break
else
    T_w_evap_out=Tweo;
```

```
end
end
T_w_evap_out=Tweo;
```

A.10 Mixture specific heat and thermal conductivity

```
function [K_SG, C_Ad]=KC_mix(Metal, Pge)
switch (Metal)
   case 'Al'
            C_Ad=0.896; %kJ/kg.K
       switch Pge
           case 0
               K_SG=0.198E-3; %kW/m.K
           case 5
               K_SG=0.218E-3; %kW/m.K
           case 10
               K_SG=0.314E-3; %kW/m.K
           case 15
               K_SG=0.363E-3; %kW/m.K
       end

   case 'Cu'
            C_Ad=0.385; %kJ/kg.K
       switch Pge
           case 0
               K_SG=0.198E-3; %kW/m.K
           case 5
               K_SG=0.187E-3; %kW/m.K
           case 10
               K_SG=0.246E-3; %kW/m.K
           case 15
               K_SG=0.324E-3; %kW/m.K
       end

   case 'Brass'
            C_Ad=0.380; %kJ/kg.K
       switch Pge
           case 0
               K_SG=0.198E-3; %kW/m.K
           case 5
               K_SG=0.176E-3; %kW/m.K
           case 10
               K_SG=0.211E-3; %kW/m.K
           case 15
               K_SG=0.327E-3; %kW/m.K
       end

    case 'Steel'
             C_Ad=0.460; %kJ/kg.K
        switch Pge
            case 0
                K_SG=0.198E-3; %kW/m.K
            case 5
                K_SG=0.141E-3; %kW/m.K
            case 10
                K_SG=0.169E-3; %kW/m.K
            case 15
                K_SG=0.254E-3; %kW/m.K
        end
    case 'None'
             C_Ad=0.0; %kJ/kg.K
```

```
                K_SG=0.198E-3; %kW/m.K
end
```