ภาคผนวก

ภาคผนวก ก.

โปรแกรมจำลอง

ลำดับสัญลักษณ์ในโปรแกรม

สัญลักษณ์		ความหมาย	หน่วย
Tam	=	อุณหภูมิอากาศ	°C
Tam_K	=	อุณหภูมิอากาศ	K
TG	=	อุณหภูมิกระจก	K
G	=	ความเร่งเนื่องจากแรงโน้มถ่วงของโลก	m/s^2
N	=	จำนวนเทอร์โมไซฟ่อน	-
L_e	=	ความยาวส่วนทำระเหยของเทอร์โมไซฟ่อน	m
W	=	ความกว้างของแผงรับรังสีแสงอาทิตย์	m
A	=	พื้นที่รับแสงของแผงรับรังสีแสงอาทิตย์	m^2
K_air	=	สัมประสิทธิ์การนำความร้อนของอากาศ	W/m.K
Pr	=	เลขพรันด์เทิลของอากาศ	-
v_air	=	ปริมาตรจำเพาะของอากาศ	m^2/s
Emission_air_1	=	ค่าเปล่งรังสีของกระจก	-
Emission_air_2	=	ค่าเปล่งรังสีของแผ่นดูดซับรังสี	-
Botmann	=	เลขสเตฟาน-โบลมันน์	-
Bate	=	สัมประสิทธิ์การขยายตัวเนื่องจากความร้อนเชิงปริมาตร	-
Num	=	เลขนัสเซลท์ของอากาศ	-
h_conv	=	สัมประสิทธิ์การพาความร้อนของอากาศ	W/K
h_rad	=	สัมประสิทธิ์การแผ่รังสีความร้อนของอากาศ	W/K
z_conv	=	ความต้านทานความร้อนจากการพาความร้อน	K/W
z_rad	=	ความต้านทานความร้อนจากการแผ่รังสีความร้อน	K/W
Q_loss	=	อัตราความร้อนสูญเสียที่แผงรับรังสีแสงอาทิตย์	W
Tabs_K	=	อุณหภูมิแผ่นดูดซับรังสี	K
T_w	=	อุณหภูมิน้ำในถังเก็บ	°C
T_water	=	อุณหภูมิน้ำในถังเก็บ	K
T_cond	=	อุณหภูมิที่ส่วนควบแน่นของเทอร์โมไซฟ่อน	K
d_out	=	ขนาดเส้นผ่านศูนย์กลางภายนอกของเทอร์โมไซฟ่อน	m
d_in	=	ขนาดเส้นผ่านศูนย์กลางภายในของเทอร์โมไซฟ่อน	m

ลำดับสัญลักษณ์ในโปรแกรม (ต่อ)

สัญลักษณ์		ความหมาย	หน่วย
r_out	=	ขนาดรัศมีภายนอกของเทอร์โมไซฟอน	m
r_in	=	ขนาดรัศมีภายในของเทอร์โมไซฟอน	m
L_c	=	ความยาวส่วนควบแน่นของเทอร์โมไซฟอน	m
L_a	=	ความยาวส่วนที่ไม่มีการถ่ายเทความร้อน	m
k_cu	=	สัมประสิทธิ์การนำความร้อนของเทอร์โมไซฟอน	W/m.K
Specific_Volume	=	ปริมาตรจำเพาะของน้ำ	m^3/kg
Enthalpy_water	=	เอนทาลปีของน้ำ	kJ/kg
Thermal_water	=	สัมประสิทธิ์การนำความร้อนของน้ำ	W/m.K
Pr_water	=	เลขพรันด์เทิลของน้ำ	-
Specific_Heat	=	ความร้อนจำเพาะของน้ำ	kJ/(kg.K)
Bate_water	=	สัมประสิทธิ์การขยายตัวเนื่องจากความร้อนเชิงปริมาตร	-
Ray_water	=	เลขเรย์ลีของน้ำ	-
h_cond	=	สัมประสิทธิ์การนำความร้อนของน้ำ	W/K
S_co	=	พื้นที่ผิวรอบทรงกระบอกในส่วนควบแน่น	m^2
Z_9	=	ค่าความต้านทานความร้อนโดยการพาระหว่างผิวของส่วนควบแน่นกับแหล่งระบายความร้อน	K/W
Q_TS	=	อัตราการถ่ายเทความร้อนของเทอร์โมไซฟอน	W
Pressure	=	ค่าความดันของสารทำงาน	Pa
Volume_gas	=	ปริมาตรจำเพาะของสารทำงาน	m^3/kg
Enthalpy_134a	=	ค่าเอนทาลปีของสารทำงาน	kJ/kg
Thermal_134a	=	สัมประสิทธิ์การนำความร้อนของสารทำงาน	W/m.K
cp_134a	=	ความร้อนจำเพาะของสารทำงาน	kJ/(kg.K)
Rho_134a	=	ค่าความหนาแน่นของสารทำงาน	kg/m^3
Pa	=	ค่าความดันบรรยากาศ	Pa
Free2	=	merit number	$kg/(K^{0.75}s^{2.5})$
F	=	อัตราการเติมสารทำงาน	%

ลำดับสัญลักษณ์ในโปรแกรม (ต่อ)

สัญลักษณ์		ความหมาย	หน่วย
Z_2	=	ค่าความต้านทานความร้อนโดยการนำผ่านความหนาของผนังท่อเทอร์โมไซฟอนในส่วนทำระเหย	K/W
Z_8	=	ค่าความต้านทานความร้อนโดยการนำ ผ่านความหนาของผนังท่อเทอร์โมไซฟอนในส่วนควบแน่น	K/W
Z_3f	=	ค่าความต้านทานความร้อนฟิล์มของเหลว	K/W
Z_3p	=	ค่าความต้านทานความร้อนในแอ่งเดือด	K/W
Z_3	=	ค่าความต้านทานความร้อนภายในของของไหลที่กำลังเดือดในเทอร์โมไซฟอน	K/W
Re	=	เลขเรย์โนลของสารทำงาน	-
Z_7	=	ค่าความต้านทานความร้อนภายในของของไหลที่กำลังควบแน่นในท่อเทอร์โมไซฟอน	K/W
Z_8	=	ค่าความต้านทานความร้อนโดยการนำผ่านความหนาของผนังท่อเทอร์โมไซฟอนในส่วนควบแน่น	K/W
Z_10	=	ค่าความต้านทานความร้อนในแนวแกนตามผนังท่อ	K/W
Z_tot	=	ค่าความต้านทานความร้อนรวมภายในเทอร์โมไซฟอน	K/W
T_cond_new	=	อุณหภูมิที่ส่วนควบแน่นค่าใหม่	K
D_out	=	ขนาดเส้นผ่านศูนย์กลางภายนอกของถัง	m
D_in	=	ขนาดเส้นผ่านศูนย์กลางภายในของถัง	m
K_fiber	=	สัมประสิทธิ์การนำความร้อนของฉนวนกันความร้อน	W/m.K
r_tank_out	=	รัศมีภายนอกของถัง	m
r_tank_in	=	รัศมีภายในของถัง	m
h_air	=	สัมประสิทธิ์การพาความร้อนของอากาศ	W/m.K
Thermal_Al	=	สัมประสิทธิ์การนำความร้อนของถัง	W/m.K
Thiekness_tank	=	ความหนาของถัง	m
Thickness_insulate	=	ความหนาของฉนวน	m
Volume_tank	=	ปริมาตรในถัง	m^3
m_water	=	มวลของน้ำในถัง	kg

ลำดับสัญลักษณ์ในโปรแกรม (ต่อ)

สัญลักษณ์		ความหมาย	หน่วย
Q_loss	=	อัตราความร้อนสูญเสียที่ถัง	W
Q_st	=	ความร้อนสะสมของน้ำในถังเก็บ	W
T_water_new	=	อุณหภูมิของน้ำร้อนในถังเก็บล่าสุด	K

โปรแกรมจำลอง

```
Tam1  = 28.25;
Tam2  = 29.45;
Tam3  = 30.51;
Tam4  = 31.56;
Tam5  = 32.81;
Tam6  = 34.10;
Tam7  = 35.21;
Tam8 = 36.15;
Tam9 = 37.08;
Tam10 = 38.08;
Tam11 = 38.95;
Tam12 = 39.15;
Tam13 = 38.81;
Tam14 = 38.15;
Tam15 = 37.23;
Tam16 = 36.33;
Tam17 = 35.43;
Tam18 = 34.6;
Tam19 = 33.73;
Tam20 = 32.68;
Tam21 = 31.68;
Tam22 = 30.78;
Tamtot=
[Tam1,Tam2,Tam3,Tam4,Tam5,Tam6,Tam7,Tam8,Tam9,Tam10,Tam11,Tam12,Tam13,T
am14,Tam15,Tam16,Tam17,Tam18,Tam19,Tam20,Tam21,Tam22];

I1  = 116.8416;
I2  = 204.0354;
I3  = 291.0552;
I4  = 371.8354;
I5  = 466.5760;
I6  = 535.4864;
I7  = 589.2604;
I8 = 679.1093;
I9 = 761.5895;
I10 = 812.1489;
I11 = 840.8229;
I12 = 845.1770;
I13 = 817.9072;
I14 = 772.8010;
I15 = 721.5239;
I16 = 658.9125;
I17 = 593.3000;
I18 = 484.1343;
I19 = 348.8260;
I20 = 251.6479;
I21 = 161.4208;
I22 = 76.1000;
```

```
Itot=
[I1,I2,I3,I4,I5,I6,I7,I8,I9,I10,I11,I12,I13,I14,I15,I16,I17,I18,I19,I20
,I21,I22];
N=10;
N_pipe=5;
N = input('ระบุจำนวนท่อ:');
T_w = input('T_w:');
for num = 0:1:21
num = num + 1;
Itot=[ I1 I2 I3 I4 I5 I6 I7 I8 I9 I10 I11 I12 I13 I14 I15 I16 I17 I18
I19 I20 I21 I22];
Tamtot=[ Tam1 Tam2 Tam3 Tam4 Tam5 Tam6 Tam7 Tam8 Tam9 Tam10 Tam11 Tam12
Tam13 Tam14 Tam15 Tam16 Tam17 Tam18 Tam19 Tam20 Tam21 Tam22];
ro= [1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22];
I= interp1(ro, Itot, num);
Tam= interp1(ro, Tamtot, num);
aa34main
end
```

```
"air_1"
Tam_K=Tam+273;
TG=Tam_K+0.5;
G=9.81;
L_e=2;
W=1;
A=L_e*W;
"Interpolate air_1"
Tav_air_1=(TG-(0.25*(TG-Tam_K)));
T_air_1              = [ 100       150       200       250       300
350       400       450       500       550       600       650
700       750       800       850       900 ];
Pr_air_1             = [ 0.7860    0.7580    0.7370    0.7200    0.7070
0.7000    0.6900    0.6860    0.6840    0.6830    0.6850    0.6900
0.6950    0.7020    0.7090    0.7160    0.7200];
Thermal_cond_air_1 = [ 9.34      13.8      18.1      22.3      26.3
30        33.8      37.3      40.7      43.9      46.9      49.7
52.4      54.9      57.3      59.6      62.0 ];
Kinematic_air_1      = [ 2         4.4426    7.59      11.44     15.89
20.92     26.41     32.39     38.79     45.57     52.69     60.21
68.1      76.37     84.93     93.80     102.90];
K_air_1      = interp1 (T_air_1, Thermal_cond_air_1, Tav_air_1)*10^-3;
Pr_1         = interp1 (T_air_1, Pr_air_1, Tav_air_1);
v_air_1      = interp1 (T_air_1, Kinematic_air_1, Tav_air_1)*10^-6;
Emission_air_1=0.88;
Emission_air_2=0.044;
Botmann=5.67*10^-8;
Bate_1=1/(Tam_K+(0.25*(TG-Tam_K)));
GrcPr_1=exp(3.848+(29.146*cos((73.6*pi)/180)));
GrL_1=G* Bate_1*L_e^3*(TG-Tam_K)/( v_air_1^2);
Num_1=0.14*(((GrL_1*Pr_1)^(1/3))-
(GrcPr_1^(1/3)))+0.56*((GrcPr_1*cos((73.6*pi)/180))^(1/4));
h_conv_1=(( Num_1* K_air_1)/L_e);
h_rad_1= Emission_air_1* Botmann*(TG+Tam_K)*(TG^2+Tam_K^2);
z_conv_1=1/( h_conv_1*A);
z_rad_1=1/( h_rad_1*A);
Q_loss_1=( TG-Tam_K)/(((1/z_conv_1)+(1/z_rad_1))^-1);
"air_2"
Tabs_K=TG+1;
Tai_air_2=(Tam_K+TG)/2;
Tav_air_2=(Tabs_K-(0.25*( Tabs_K- Tai_air_2)));
T_air_2              = [ 100       150       200       250       300
350       400       450       500       550       600       650
700       750       800       850       900 ];
```

```
Pr_air_2           = [ 0.7860   0.7580   0.7370     0.7200     0.7070
0.7000    0.6900    0.6860     0.6840     0.6830    0.6850    0.6900
0.6950    0.7020    0.7090    0.7160    0.7200];
Thermal_cond_air_2 = [ 9.34     13.8     18.1       22.3       26.3
30        33.8      37.3       40.7       43.9      46.9      49.7
52.4      54.9      57.3      59.6       62.0 ];
Kinematic_air_2    = [ 2         4.4426   7.59       11.44      15.89
20.92     26.41     32.39      38.79      45.57     52.69     60.21
68.1      76.37     84.93     93.80      102.90];
K_air_2      = interp1 (T_air_2, Thermal_cond_air_2, Tav_air_2)*10^-3;
Pr_2         = interp1 (T_air_2, Pr_air_2, Tav_air_2);
v_air_2      = interp1 (T_air_2, Kinematic_air_2, Tav_air_2)*10^-6;
Bate_2=1/( Tai_air_2+(0.25*( Tabs_K - Tai_air_2)));
GrcPr_2=exp(3.848+(29.146*cos((73.6*pi)/180)));
GrL_2=G* Bate_2*L_e^3*( Tabs_K - Tai_air_2)/( v_air_2^2);
Num_2=0.14*(((GrL_2* Pr_2)^(1/3))-
(GrcPr_2^(1/3)))+0.56*((GrcPr_2*cos((73.6*3.142)/180))^(1/4));
h_conv_2=(( Num_2* K_air_2)/L_e);
h_rad_2= Emission_air_2* Botmann*( Tabs_K +TG)*( Tabs_K ^2+TG^2);
z_conv_2=1/( h_conv_2*A);
z_rad_2=1/( h_rad_2*A);
Q_loss_2=(Tabs_K -TG)/(((1/z_conv_2)+(1/z_rad_2))^-1);
pa1=abs(Q_loss_1-Q_loss_2);
while pa1 >= 0.05
    Tabs_K_new=Tabs_K+0.005;
    Tai_air_2=(Tam_K+TG)/2;
    Tav_air_2_new=(Tabs_K_new-(0.25*( Tabs_K_new- Tai_air_2)));
    T_air_2            = [ 100      150      200       250       300
350       400       450        500        550       600       650
700       750       800        850        900 ];
    Pr_air_2           = [ 0.7860   0.7580   0.7370     0.7200
0.7070    0.7000    0.6900     0.6860     0.6840     0.6830    0.6850
0.6900    0.6950    0.7020     0.7090    0.7160    0.7200];
    Thermal_cond_air_2 = [ 9.34     13.8     18.1       22.3       26.3
30        33.8      37.3       40.7       43.9      46.9      49.7
52.4      54.9      57.3      59.6       62.0 ];
    Kinematic_air_2    = [ 2         4.4426   7.59       11.44
15.89     20.92     26.41      32.39      38.79     45.57     52.69
60.21     68.1      76.37      84.93      93.80     102.90];
    K_air_2_new     = interp1 (T_air_2, Thermal_cond_air_2,
Tav_air_2_new)*10^-3;
    Pr_2_new        = interp1 (T_air_2, Pr_air_2, Tav_air_2_new);
    v_air_2_new     = interp1 (T_air_2, Kinematic_air_2,
Tav_air_2_new)*10^-6;
    Bate_2_new=1/( Tai_air_2+(0.25*( Tabs_K_new - Tai_air_2)));
    GrcPr_2_new=exp(3.848+(29.146*cos((73.6*pi)/180)));
    GrL_2_new=G* Bate_2_new*L_e^3*( Tabs_K_new -
Tai_air_2)/( v_air_2_new^2);
```

```
    Num_2_new=0.14*(((GrL_2_new* Pr_2_new)^(1/3))-
(GrcPr_2_new^(1/3)))+0.56*((GrcPr_2_new*cos((73.6*3.142)/180))^(1/4));
    h_conv_2_new=(( Num_2_new* K_air_2_new)/L_e);
    h_rad_2_new= Emission_air_2* Botmann*( Tabs_K_new +TG)*( Tabs_K_new
^2+TG^2);
    z_conv_2_new=1/( h_conv_2_new*A);
    z_rad_2_new=1/( h_rad_2_new*A);
    Q_loss_2_new=( Tabs_K_new -
TG)/(((1/z_conv_2_new)+(1/z_rad_2_new))^-1);
    pa1=abs(Q_loss_1-Q_loss_2_new);
    Tabs_K=Tabs_K_new;
end
T_w=input('T_w:');
T_water=T_w+273.15;
T_cond=T_water+1;
d_out  = 0.02222;
d_in   = 0.02108;
r_out  = d_out/2;
r_in   = d_in/2;
L_c    = 0.478726;
L_e    = 2;
L_a    = 0.055;
k_cu   = 398.4;
%Calculate Q_TS_1
Tav_tank=(T_cond+T_water)/2;
T_water_tank            = [ 273.15      275         280         285
290         295         300         305         310         315
320         325         330         335         340         345
350         355         360         365         370         373.15
375         380         385         390         400         410
420         430         440         450         460         470
480         490         500         510         520         530
540         550         560         570         580         590
600         610         620         625         630         635
640         645         647.3 ];
Specific_Volume_Liquid  = [ 1.000       1.000       1.000       1.000
1.001       1.002       1.003       1.005       1.007       1.009
1.011       1.013       1.016       1.018       1.021       1.024
1.027       1.030       1.034       1.038       1.041       1.044
1.045       1.049       1.053       1.058       1.067       1.077
1.088       1.099       1.110       1.123       1.137       1.152
1.167       1.184       1.203       1.222       1.244       1.268
1.294       1.323       1.355       1.392       1.433       1.482
1.541       1.612       1.705       1.778       1.856       1.935
2.075       2.351       3.170   ];
Specific_Volume_Gas     = [ 206.3       181.7       130.4       99.4
69.7        51.94       39.13       29.74       22.93       17.82
13.98       11.06       8.82        7.09        5.74        4.683
3.846       3.180       2.645       2.212       1.861       1.679
1.574       1.337       1.142       0.980       0.731       0.553
0.425       0.331       0.261       0.208       0.167       0.136
0.111       0.0922      0.0766      0.0631      0.0525      0.0445
0.0375      0.0317      0.0269      0.0228      0.0193      0.0163
```

```
0.0137      0.0115      0.0094      0.0085      0.0075      0.0066
0.0057      0.0045      0.0032  ];
Thermal_cond_water      = [ 569         574         582         590
598         606         613         620         628         634
640         645         650         656         660         668
668         671         674         677         679         680
681         683         685         686         688         688
688         685         682         678         673         667
660         651         642         631         621         608
594         580         563         548         528         513
497         467         444         430         412         392
367         331         238 ];
Viscosity_Liquid_water  = [ 1750        1652        1422        1225
1080        959         855         769         695         631
577         528         489         453         420         389
365         343         324         306         298         279
274         260         248         237         217         200
185         173         162         152         143         136
129         124         118         113         108         104
101         97          94          91          88          84
81          77          72          70          67          64
59          54          45  ];
Pr_Liquid_water         = [ 12.99       12.22       10.26       8.81
7.56        6.62        5.83        5.20        4.62        4.16
3.77        3.42        3.15        2.88        2.66        2.45
2.29        2.14        2.02        1.91        1.80        1.76
1.70        1.61        1.53        1.47        1.34        1.24
1.16        1.09        1.04        0.99        0.95        0.92
0.89        0.87        0.86        0.85        0.84        0.85
0.86        0.87        0.90        0.94        0.99        1.05
1.14        1.30        1.52        1.65        2.0         2.7
4.2         12          0   ];
Specific_Heat_Liquid    = [ 4.217       4.211       4.198       4.189
4.184       4.181       4.179       4.178       4.178       4.179
4.180       4.182       4.184       4.186       4.188       4.191
4.195       4.199       4.203       4.209       4.214       4.217
4.220       4.226       4.232       4.239       4.256       4.278
4.302       4.331       4.360       4.400       4.440       4.480
4.530       4.590       4.660       4.740       4.840       4.950
5.080       5.240       5.430       5.680       6.000       6.410
7.000       7.850       9.350       10.600      12.600      16.400
26.000      90.000      0.000 ];
Specific_Volume_L = interp1 (T_water_tank, Specific_Volume_Liquid,
Tav_tank)*10^-3;
Specific_Volume_G = interp1 (T_water_tank, Specific_Volume_Gas,
Tav_tank);
Thermal_water     = interp1 (T_water_tank, Thermal_cond_water,
Tav_tank)*10^-3;
Viscosity_water   = interp1 (T_water_tank, Viscosity_Liquid_water,
Tav_tank)*10^-6;
Pr_water          = interp1 (T_water_tank, Pr_Liquid_water, Tav_tank);
Specific_Heat     = interp1 (T_water_tank, Specific_Heat_Liquid,
Tav_tank)*10^3;
Rho_water         = (1 / Specific_Volume_L);
```

```
Kinematic_water   = (Viscosity_water / Rho_water);
Thermal_diffus_water =  Thermal_water / (Rho_water*Specific_Heat);
Bate_water        =  1 / ((T_cond+T_water)/2);
Ray_water         = abs(G*Bate_water*(d_out^3)*(T_cond -
T_water))/(Kinematic_water*Thermal_diffus_water);
h_cond            = (Thermal_water / d_out)*(0.6 +
((0.387)*(Ray_water^(1/6))) / (1 + (0.559 /
Pr_water)^(9/16))^(8/27))^2;
S_co  =   pi*d_out*L_c;
 S_co^2)
Z_9   =   1/(h_cond*S_co);
Q_TS_1=(T_cond-T_water)/Z_9;
'calculate Q_TS_2
Tav_syphon=(T_cond + Tabs_K)/2;
T_134a                = [ 273.15      275.15      277.15      279.15
281.15      283.15      285.15      287.15      289.15      291.15
293.15      295.15      297.15      299.15      301.15      303.15
305.15      307.15      309.15      311.15      313.15      315.15
317.15      319.15      321.15      323.15      325.15      327.15
329.15      331.15      333.15      335.15      337.15      339.15
341.15      343.15      345.15      347.15      349.15      351.15
353.15      358.15      363.15      368.15      373.15      374.18 ];
Rho_134a_Liquid       = [ 1293.7      1287.1      1280.5      1273.8
1267.0      1260.2      1253.3      1246.3      1239.3      1232.1
1224.9      1217.5      1210.1      1202.6      1194.9      1187.2
1179.3      1171.3      1163.2      1154.9      1146.5      1137.9
1129.2      1120.3      1111.3      1102.0      1092.6      1082.9
1073.0      1062.8      1052.4      1041.7      1030.7      1019.4
1007.7      995.6       983.1       970.0       956.5       942.3
927.4       886.2       836.9       771.6       646.7       513.3 ];
Pressure_134a         = [ 0.29269     0.31450     0.33755     0.36186
0.38749     0.41449     0.44289     0.47276     0.50413     0.53706
0.57159     0.60777     0.65466     0.68531     0.72676     0.77008
0.81530     0.86250     0.91172     0.96301     1.0165      1.0721
1.1300      1.1901      1.2527      1.3177      1.3852      1.4553
1.5280      1.6033      1.6815      1.7625      1.8464      1.9334
2.0234      2.1165      2.2130      2.3127      2.4159      2.5227
2.6331      2.9259      3.2445      3.5916      3.9721      4.0560 ];
Volume_134a_gas       = [ 0.06935     0.06470     0.06042     0.05648
0.05284     0.04948     0.04636     0.04348     0.04081     0.03833
0.03606     0.03388     0.03189     0.03003     0.02829     0.02667
0.02516     0.02374     0.02241     0.02116     0.01999     0.01890
0.01786     0.01689     0.01598     0.01511     0.01430     0.0353
0.01280     0.01212     0.01146     0.01085     0.01026     0.00970
0.00917     0.00867     0.00818     0.00772     0.00728     0.00686
0.00646     0.00550     0.00461     0.00374     0.00265     0.00195 ];
Enthalpy_134a_Liquid  = [ 200.00      202.68      205.37      208.08
210.80      213.53      216.27      219.03      221.80      224.59
227.40      230.21      233.05      235.90      238.77      241.65
244.55      247.47      250.41      253.37      256.35      259.35
262.38      265.42      268.49      271.59      274.71      277.86
281.04      284.25      287.49      290.77      294.08      297.44
300.84      304.29      307.79      311.34      314.96      318.65
322.41      332.27      343.01      355.43      347.02      389.78 ];
```

```
Enthalpy_134a_gas     = [ 398.68      399.84      401.00      402.14
403.27      404.40      405.51      406.61      407.70      408.78
409.84      410.89      411.93      412.95      413.95      414.94
415.90      416.85      417.78      418.69      419.85      420.35
421.28      422.09      422.88      423.63      424.35      425.03
425.68      426.29      426.86      427.37      427.84      428.25
428.61      428.89      429.10      429.23      429.27      429.20
429.02      427.91      425.48      420.60      407.08      389.78 ];
Thermal_cond_134a     = [ 93.4        92.5        91.6        90.7
89.7        88.8        87.9        87          86          85.1
84.2        83.3        82.4        81.4        80.5        79.6
78.7        77.7        76.8        75.9        75          74.1
73.1        72.2        71.3        70.4        69.5        68.5
67.6        66.7        65.8        64.9        63.9        63
62.1        61.2        60.3        59.3        58.4        57.5
56.6        54.3        0           0           0           0 ];
Viscosity_134a        = [ 287.4       280.4       273.6       267.0
260.6       254.3       248.3       242.5       236.8       231.2
225.8       220.5       215.4       210.4       205.5       200.7
196.0       191.4       186.9       182.5       178.2       174.0
169.8       165.7       161.7       157.7       153.8       149.9
146.1       142.3       138.6       134.9       131.2       127.5
123.9       120.3       116.7       113.1       109.4       105.8
102.1       92.7        82.6        70.9        53.0        0 ];
Specific_134a_Liquid  = [ 1.335       1.341       1.347       1.353
1.360       1.367       1.374       1.381       1.388       1.396
1.404       1.412       1.420       1.429       1.438       1.447
1.457       1.467       1.478       1.489       1.500       1.513
1.525       1.539       1.553       1.569       1.585       1.602
1.621       1.641       1.663       1.686       1.712       1.740
1.772       1.806       1.846       1.890       1.941       2.000
2.069       2.313       2.766       3.961       0           0 ];
Pr_134a               = [ 4.108       4.065       4.023       3.983
3.951       3.915       3.881       3.849       3.882       3.793
3.765       3.738       3.712       3.694       3.671       3.648
3.629       3.614       3.597       3.580       3.564       3.553
3.542       3.532       3.522       3.515       3.508       3.506
3.503       3.501       3.503       3.504       3.515       3.521
3.535       3.550       3.573       3.605       3.636       3.680
3.732       3.949       0           0           0           0 ];
Rho_134a_L      = interp1 (T_134a, Rho_134a_Liquid, Tav_syphon);
Pressure        = interp1 (T_134a, Pressure_134a, Tav_syphon)*10^6;
Volume_gas      = interp1 (T_134a, Volume_134a_gas, Tav_syphon);
Enthalpy_134a_g= interp1 (T_134a, Enthalpy_134a_gas, Tav_syphon)*10^3;
Enthalpy_134a_L= interp1 (T_134a, Enthalpy_134a_Liquid,
Tav_syphon)*10^3;
Thermal_134a    = interp1 (T_134a, Thermal_cond_134a, Tav_syphon)*10^-3;
Viscosity       = interp1 (T_134a, Viscosity_134a, Tav_syphon)*10^-6;
cp_134a         = interp1 (T_134a, Specific_134a_Liquid,
Tav_syphon)*10^3;
Pr              = interp1 (T_134a, Pr_134a, Tav_syphon);
Rho_134a_gas          =  ( 1 / Volume_gas);
Kinematic             =  (Viscosity / Rho_134a_L);
Volume_134a_Liquid    =  (1 / Rho_134a_L);
```

```
Enthalpy_Diff          =  Enthalpy_134a_g - Enthalpy_134a_L;
% Rho_134a_L(kg/m^3), Volume_gas(m^3/kg), Enthalpy_Diff(J/kg),
Pressure(Pa), Thermal_134a(W/m-K), Viscosity(Pa.s), Cp_134a(J/kg-K)
Pa      = 0.10132*10^6;
Free2=((Enthalpy_Diff*(Thermal_134a^3)*(Rho_134a_L^2))/Viscosity)^0.25;
Free3=28.079*((Pressure / Pa)^0.23);
F       = 0.7;
% ln(d_out/d_in)=ln_dia
% ln(0.03242/0.02126)=0.05266
ln_dia=0.05266;
Z_2=ln_dia/(2*pi*L_e*k_cu);
Z_8=ln_dia/(2*pi*L_c*k_cu);
Z_3f = (0.235*(Q_TS_1^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_e*(Free2^(4/3)));
Z_3p = 1/((Free3)*(G^0.2)*(Q_TS_1^0.4)*((pi*d_in*L_e)^0.6));
    if Z_3p < Z_3f
        Z_3 = Z_3p;
    else
        Z_3 = (Z_3p*F) + (Z_3f*(1 - F));
    end
    % Calculate Z_7
    Re = (4*Q_TS_1)/(Enthalpy_Diff*Viscosity*pi*d_in);
    if Re>1300
        Z_7 = (0.235*(Q_TS_1^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_c*(Free2^(4/3)))*(191*(Re^-0.733));
    else
        Z_7 =(0.235*(Q_TS_1^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_c*(Free2^(4/3)));
    end
    Z_8 = ln_dia /(2*pi*L_c*k_cu);
    % Calculate Z_10
    a_across = (pi*((d_out^2)-(d_in^2))) / 4;
    Z_10 = ((0.5*L_e) + L_a + (0.5*L_c)) / (a_across*k_cu) ;
    Z_p = Z_10 /(Z_2 + Z_3 + Z_7 + Z_8);
    if Z_p > 20
       Z_tot = Z_2 + Z_3 + Z_7 + Z_8;
    else
       Z_tot = ((Z_2 + Z_3 + Z_7 + Z_8)^-1 + (1/Z_10))^-1;
    end
Q_TS_2=(Tabs_K-T_cond)/Z_tot;
if Q_TS_2<=0
    Q_TS_1_new=Q_TS_1;
else
pa2=abs(Q_TS_1-Q_TS_2);
 if pa2 < 20
       Q_TS_1_new=Q_TS_1;
   end
while pa2 >20
    T_cond_new=T_cond+0.02;
    % calculate Q_TS_1_new
    Tav_tank=(T_cond_new+T_water)/2;
    T_water_tank              = [ 273.15      275         280         285
290         295         300         305         310         315
320         325         330         335         340         345
```

```
350         355         360         365         370         373.15
375         380         385         390         400         410
420         430         440         450         460         470
480         490         500         510         520         530
540         550         560         570         580         590
600         610         620         625         630         635
640         645         647.3 ];
    Specific_Volume_Liquid  = [ 1.000       1.000       1.000
1.000       1.001       1.002       1.003       1.005       1.007
1.009       1.011       1.013       1.016       1.018       1.021
1.024       1.027       1.030       1.034       1.038       1.041
1.044       1.045       1.049       1.053       1.058       1.067
1.077       1.088       1.099       1.110       1.123       1.137
1.152       1.167       1.184       1.203       1.222       1.244
1.268       1.294       1.323       1.355       1.392       1.433
1.482       1.541       1.612       1.705       1.778       1.856
1.935       2.075       2.351       3.170   ];
    Specific_Volume_Gas     = [ 206.3       181.7       130.4
99.4        69.7        51.94       39.13       29.74       22.93
17.82       13.98       11.06       8.82        7.09        5.74
4.683       3.846       3.180       2.645       2.212       1.861
1.679       1.574       1.337       1.142       0.980       0.731
0.553       0.425       0.331       0.261       0.208       0.167
0.136       0.111       0.0922      0.0766      0.0631      0.0525
0.0445      0.0375      0.0317      0.0269      0.0228      0.0193
0.0163      0.0137      0.0115      0.0094      0.0085      0.0075
0.0066      0.0057      0.0045      0.0032  ];
    Thermal_cond_water      = [ 569         574         582         590
598         606         613         620         628         634
640         645         650         656         660         668
668         671         674         677         679         680
681         683         685         686         688         688
688         685         682         678         673         667
660         651         642         631         621         608
594         580         563         548         528         513
497         467         444         430         412         392
367         331         238 ];
    Viscosity_Liquid_water  = [ 1750        1652        1422
1225        1080        959         855         769         695         631
577         528         489         453         420         389
365         343         324         306         298         279
274         260         248         237         217         200
185         173         162         152         143         136
129         124         118         113         108         104
101         97          94          91          88          84
81          77          72          70          67          64
59          54          45  ];
    Pr_Liquid_water         = [ 12.99       12.22       10.26
8.81        7.56        6.62        5.83        5.20        4.62
4.16        3.77        3.42        3.15        2.88        2.66
2.45        2.29        2.14        2.02        1.91        1.80
1.76        1.70        1.61        1.53        1.47        1.34
1.24        1.16        1.09        1.04        0.99        0.95
0.92        0.89        0.87        0.86        0.85        0.84
```

```
0.85        0.86        0.87        0.90        0.94        0.99
1.05        1.14        1.30        1.52        1.65        2.0
2.7         4.2         12          0   ];
    Specific_Heat_Liquid    = [ 4.217       4.211       4.198
4.189       4.184       4.181       4.179       4.178       4.178
4.179       4.180       4.182       4.184       4.186       4.188
4.191       4.195       4.199       4.203       4.209       4.214
4.217       4.220       4.226       4.232       4.239       4.256
4.278       4.302       4.331       4.360       4.400       4.440
4.480       4.530       4.590       4.660       4.740       4.840
4.950       5.080       5.240       5.430       5.680       6.000
6.410       7.000       7.850       9.350       10.600      12.600
16.400      26.000      90.000      0.000 ];
    Specific_Volume_L = interp1 (T_water_tank, Specific_Volume_Liquid,
Tav_tank)*10^-3;
    Specific_Volume_G = interp1 (T_water_tank, Specific_Volume_Gas,
Tav_tank);
    Thermal_water     = interp1 (T_water_tank, Thermal_cond_water,
Tav_tank)*10^-3;
    Viscosity_water   = interp1 (T_water_tank, Viscosity_Liquid_water,
Tav_tank)*10^-6;
    Pr_water          = interp1 (T_water_tank, Pr_Liquid_water,
Tav_tank);
    Specific_Heat     = interp1 (T_water_tank, Specific_Heat_Liquid,
Tav_tank)*10^3;
    Rho_water         = (1 / Specific_Volume_L);
    Kinematic_water   = (Viscosity_water / Rho_water);
    Thermal_diffus_water =  Thermal_water / (Rho_water*Specific_Heat);
    Bate_water        =  1 / ((T_cond_new+T_water)/2);
    Ray_water         = abs(G*Bate_water*(d_out^3)*(T_cond_new -
T_water))/(Kinematic_water*Thermal_diffus_water);
    h_cond            = (Thermal_water / d_out)*(0.6 +
((0.387)*(Ray_water^(1/6))) / (1 + (0.559 /
Pr_water)^(9/16))^(8/27))^2;
    S_co  =   pi*d_out*L_c;
    %S_co(m^2)
    Z_9   =   1/(h_cond*S_co);
    Q_TS_1_new=(T_cond_new-T_water)/Z_9;
    %calculate Q_TS_1_new
    Tav_syphon=(T_cond_new + Tabs_K)/2;
    T_134a              = [ 273.15      275.15      277.15
279.15      281.15      283.15      285.15      287.15      289.15
291.15      293.15      295.15      297.15      299.15      301.15
303.15      305.15      307.15      309.15      311.15      313.15
315.15      317.15      319.15      321.15      323.15      325.15
327.15      329.15      331.15      333.15      335.15      337.15
339.15      341.15      343.15      345.15      347.15      349.15
351.15      353.15      358.15      363.15      368.15      373.15
374.18 ];
    Rho_134a_Liquid       = [ 1293.7      1287.1      1280.5
1273.8      1267.0      1260.2      1253.3      1246.3      1239.3
1232.1      1224.9      1217.5      1210.1      1202.6      1194.9
1187.2      1179.3      1171.3      1163.2      1154.9      1146.5
1137.9      1129.2      1120.3      1111.3      1102.0      1092.6
```

```
1082.9      1073.0      1062.8      1052.4      1041.7      1030.7
1019.4      1007.7      995.6       983.1       970.0       956.5
942.3       927.4       886.2       836.9       771.6       646.7
513.3 ];
    Pressure_134a          = [ 0.29269     0.31450     0.33755
0.36186     0.38749     0.41449     0.44289     0.47276     0.50413
0.53706     0.57159     0.60777     0.65466     0.68531     0.72676
0.77008     0.81530     0.86250     0.91172     0.96301     1.0165
1.0721      1.1300      1.1901      1.2527      1.3177      1.3852
1.4553      1.5280      1.6033      1.6815      1.7625      1.8464
1.9334      2.0234      2.1165      2.2130      2.3127      2.4159
2.5227      2.6331      2.9259      3.2445      3.5916      3.9721
4.0560 ];
    Volume_134a_gas        = [ 0.06935     0.06470     0.06042
0.05648     0.05284     0.04948     0.04636     0.04348     0.04081
0.03833     0.03606     0.03388     0.03189     0.03003     0.02829
0.02667     0.02516     0.02374     0.02241     0.02116     0.01999
0.01890     0.01786     0.01689     0.01598     0.01511     0.01430
0.0353      0.01280     0.01212     0.01146     0.01085     0.01026
0.00970     0.00917     0.00867     0.00818     0.00772     0.00728
0.00686     0.00646     0.00550     0.00461     0.00374     0.00265
0.00195 ];
    Enthalpy_134a_Liquid   = [ 200.00      202.68      205.37
208.08      210.80      213.53      216.27      219.03      221.80
224.59      227.40      230.21      233.05      235.90      238.77
241.65      244.55      247.47      250.41      253.37      256.35
259.35      262.38      265.42      268.49      271.59      274.71
277.86      281.04      284.25      287.49      290.77      294.08
297.44      300.84      304.29      307.79      311.34      314.96
318.65      322.41      332.27      343.01      355.43      347.02
389.78 ];
    Enthalpy_134a_gas      = [ 398.68      399.84      401.00
402.14      403.27      404.40      405.51      406.61      407.70
408.78      409.84      410.89      411.93      412.95      413.95
414.94      415.90      416.85      417.78      418.69      419.85
420.35      421.28      422.09      422.88      423.63      424.35
425.03      425.68      426.29      426.86      427.37      427.84
428.25      428.61      428.89      429.10      429.23      429.27
429.20      429.02      427.91      425.48      420.60      407.08
389.78 ];
    Thermal_cond_134a      = [ 93.4        92.5        91.6        90.7
89.7        88.8        87.9        87          86          85.1
84.2        83.3        82.4        81.4        80.5        79.6
78.7        77.7        76.8        75.9        75          74.1
73.1        72.2        71.3        70.4        69.5        68.5
67.6        66.7        65.8        64.9        63.9        63
62.1        61.2        60.3        59.3        58.4        57.5
56.6        54.3        0           0           0           0 ];
    Viscosity_134a         = [ 287.4       280.4       273.6       267.0
260.6       254.3       248.3       242.5       236.8       231.2
225.8       220.5       215.4       210.4       205.5       200.7
196.0       191.4       186.9       182.5       178.2       174.0
169.8       165.7       161.7       157.7       153.8       149.9
146.1       142.3       138.6       134.9       131.2       127.5
```

```
123.9       120.3       116.7       113.1       109.4       105.8
102.1       92.7        82.6        70.9        53.0        0 ];
    Specific_134a_Liquid  = [ 1.335       1.341       1.347       1.353
1.360       1.367       1.374       1.381       1.388       1.396
1.404       1.412       1.420       1.429       1.438       1.447
1.457       1.467       1.478       1.489       1.500       1.513
1.525       1.539       1.553       1.569       1.585       1.602
1.621       1.641       1.663       1.686       1.712       1.740
1.772       1.806       1.846       1.890       1.941       2.000
2.069       2.313       2.766       3.961       0           0 ];
    Pr_134a               = [ 4.108       4.065       4.023       3.983
3.951       3.915       3.881       3.849       3.882       3.793
3.765       3.738       3.712       3.694       3.671       3.648
3.629       3.614       3.597       3.580       3.564       3.553
3.542       3.532       3.522       3.515       3.508       3.506
3.503       3.501       3.503       3.504       3.515       3.521
3.535       3.550       3.573       3.605       3.636       3.680
3.732       3.949       0           0           0           0 ];
    Rho_134a_L     = interp1 (T_134a, Rho_134a_Liquid, Tav_syphon);
    Pressure       = interp1 (T_134a, Pressure_134a, Tav_syphon)*10^6;
    Volume_gas     = interp1 (T_134a, Volume_134a_gas, Tav_syphon);
    Enthalpy_134a_g= interp1 (T_134a, Enthalpy_134a_gas,
Tav_syphon)*10^3;
    Enthalpy_134a_L= interp1 (T_134a, Enthalpy_134a_Liquid,
Tav_syphon)*10^3;
    Thermal_134a   = interp1 (T_134a, Thermal_cond_134a,
Tav_syphon)*10^-3;
    Viscosity      = interp1 (T_134a, Viscosity_134a, Tav_syphon)*10^-
6;
    cp_134a        = interp1 (T_134a, Specific_134a_Liquid,
Tav_syphon)*10^3;
    Pr             = interp1 (T_134a, Pr_134a, Tav_syphon);
    Rho_134a_gas          =  ( 1 / Volume_gas);
    Kinematic             =  (Viscosity / Rho_134a_L);
    Volume_134a_Liquid    =  (1 / Rho_134a_L);
    Enthalpy_Diff         =  Enthalpy_134a_g - Enthalpy_134a_L;
    Pa     = 0.10132*10^6;

Free2=((Enthalpy_Diff*(Thermal_134a^3)*(Rho_134a_L^2))/Viscosity)^0.25;
    Free3=28.079*((Pressure / Pa)^0.23);
    F      = 0.7;
    ln_dia
    n_dia=0.05266;
    Z_2=ln_dia/(2*pi*L_e*k_cu);
    Z_8=ln_dia/(2*pi*L_c*k_cu);
    Z_3f = (0.235*(Q_TS_1_new^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_e*(Free2^(4/3)));
    Z_3p = 1/((Free3)*(G^0.2)*(Q_TS_1_new^0.4)*((pi*d_in*L_e)^0.6));
        if Z_3p < Z_3f
            Z_3 = Z_3p;
        else
```

```
            Z_3 = (Z_3p*F) + (Z_3f*(1 - F));
        end
        Re = (4*Q_TS_1_new)/(Enthalpy_Diff*Viscosity*pi*d_in);
        if Re>1300
            Z_7 = (0.235*(Q_TS_1_new^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_c*(Free2^(4/3)))*(191*(Re^-0.733));
        else
            Z_7 =(0.235*(Q_TS_1_new^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_c*(Free2^(4/3)));
        end
        a_across = (pi*((d_out^2)-(d_in^2))) / 4;
        Z_10 = ((0.5*L_e) + L_a + (0.5*L_c)) / (a_across*k_cu) ;
        Z_p = Z_10 /(Z_2 + Z_3 + Z_7 + Z_8);
        if Z_p > 20
           Z_tot = Z_2 + Z_3 + Z_7 + Z_8;
        else
           Z_tot = ((Z_2 + Z_3 + Z_7 + Z_8)^-1 + (1/Z_10))^-1;
        end
    Q_TS_2_new=(Tabs_K-T_cond_new)/Z_tot;
    if Q_TS_2_new <= 0
        pa2 = 9;
        Q_TS_1_new = Q_TS_1;
    else
         pa2=abs(Q_TS_1_new-Q_TS_2_new);
         T_cond=T_cond_new;
    end
end
end
transmissivity=0.79;
absorbtivity=0.97;
QG_1=transmissivity*absorbtivity*I*A;
QG_2=(Q_TS_1_new*N)+Q_loss_1;
pa4=abs(QG_1-QG_2);


while pa4>= 160
TG_new=TG+0.01;
TG=TG_new;
G=9.81;
N=input('Number');
L_e=2;
W=1;
A=L_e*W;
```

```
Tav_air_1=(TG-(0.25*(TG-Tam_K)));
T_air_1            = [ 100       150       200       250       300
350       400       450       500       550       600       650
700       750       800       850       900 ];
Pr_air_1           = [ 0.7860    0.7580    0.7370    0.7200    0.7070
0.7000    0.6900    0.6860    0.6840    0.6830    0.6850    0.6900
0.6950    0.7020    0.7090    0.7160    0.7200];
Thermal_cond_air_1 = [ 9.34      13.8      18.1      22.3      26.3
30        33.8      37.3      40.7      43.9      46.9      49.7
52.4      54.9      57.3      59.6      62.0 ];
Kinematic_air_1    = [ 2         4.4426    7.59      11.44     15.89
20.92     26.41     32.39     38.79     45.57     52.69     60.21
68.1      76.37     84.93     93.80     102.90];
T_air(K), Rho_air(kg/m^3), Thermal_cond(W/m-K),
Kinematic_air(m^2/s), Alpha_air(m^2/s), Viscosity_air(Ns/m^2)
K_air_1     = interp1 (T_air_1, Thermal_cond_air_1, Tav_air_1)*10^-3;
Pr_1        = interp1 (T_air_1, Pr_air_1, Tav_air_1);
v_air_1     = interp1 (T_air_1, Kinematic_air_1, Tav_air_1)*10^-6;
Emission_air_1=0.88;
0.60-0.96 อลูมิเนียม
Emission_air_2=0.044;
Botmann=5.67*10^-8;
Bate_1=1/(Tam_K+(0.25*(TG-Tam_K)));
GrcPr_1=exp(3.848+(29.146*cos((73.6*pi)/180)));
GrL_1=G* Bate_1*L_e^3*(TG-Tam_K)/( v_air_1^2);
Num_1=0.14*(((GrL_1*Pr_1)^(1/3))-
(GrcPr_1^(1/3)))+0.56*((GrcPr_1*cos((73.6*pi)/180))^(1/4));
h_conv_1=(( Num_1* K_air_1)/L_e);
h_rad_1= Emission_air_1* Botmann*(TG+Tam_K)*(TG^2+Tam_K^2);
z_conv_1=1/( h_conv_1*A);
z_rad_1=1/( h_rad_1*A);
Q_loss_1=( TG-Tam_K)/(((1/z_conv_1)+(1/z_rad_1))^-1);
Tabs=input(' Tabs: ');
Tabs_K=TG+1;
Tai_air="Input Tabs"
Tabs_K=Tabs+1;
Tai_air_2=(Tam_K+TG)/2;
Tav_air_2=(Tabs_K-(0.25*( Tabs_K- Tai_air_2)));
T_air_2            = [ 100       150       200       250       300
350       400       450       500       550       600       650
700       750       800       850       900 ];
Pr_air_2           = [ 0.7860    0.7580    0.7370    0.7200    0.7070
0.7000    0.6900    0.6860    0.6840    0.6830    0.6850    0.6900
0.6950    0.7020    0.7090    0.7160    0.7200];
Thermal_cond_air_2 = [ 9.34      13.8      18.1      22.3      26.3
30        33.8      37.3      40.7      43.9      46.9      49.7
52.4      54.9      57.3      59.6      62.0 ];
Kinematic_air_2    = [ 2         4.4426    7.59      11.44     15.89
20.92     26.41     32.39     38.79     45.57     52.69     60.21
68.1      76.37     84.93     93.80     102.90];
T_air(K), Rho_air(kg/m^3), Thermal_cond(W/m-K),
Kinematic_air(m^2/s),Alpha_air(Thermal diffusivity,m^2/s),
Viscosity_air(Ns/m^2),
```

```
K_air_2     = interp1 (T_air_2, Thermal_cond_air_2, Tav_air_2)*10^-3;
Pr_2        = interp1 (T_air_2, Pr_air_2, Tav_air_2);
v_air_2     = interp1 (T_air_2, Kinematic_air_2, Tav_air_2)*10^-6;
Bate_2=1/( Tai_air_2+(0.25*( Tabs_K - Tai_air_2)));
GrcPr_2=exp(3.848+(29.146*cos((73.6*pi)/180)));
GrL_2=G* Bate_2*L_e^3*( Tabs_K - Tai_air_2)/( v_air_2^2);
Num_2=0.14*(((GrL_2* Pr_2)^(1/3))-
(GrcPr_2^(1/3)))+0.56*((GrcPr_2*cos((73.6*3.142)/180))^(1/4));
h_conv_2=(( Num_2* K_air_2)/L_e);
h_rad_2= Emission_air_2* Botmann*( Tabs_K +TG)*( Tabs_K ^2+TG^2);
z_conv_2=1/( h_conv_2*A);
z_rad_2=1/( h_rad_2*A);
Q_loss_2=(Tabs_K -TG)/(((1/z_conv_2)+(1/z_rad_2))^-1);
pa1=abs(Q_loss_1-Q_loss_2);
while pa1 >= 0.05
    Tabs_K_new=Tabs_K+0.005;
    Tai_air_2=(Tam_K+TG)/2;
    Tav_air_2_new=(Tabs_K_new-(0.25*( Tabs_K_new- Tai_air_2)));
    T_air_2            = [ 100      150      200       250       300
350       400       450       500       550       600       650
700       750       800       850       900 ];
    Pr_air_2           = [ 0.7860   0.7580   0.7370    0.7200
0.7070    0.7000    0.6900    0.6860    0.6840    0.6830    0.6850
0.6900    0.6950    0.7020    0.7090    0.7160    0.7200];
    Thermal_cond_air_2 = [ 9.34     13.8     18.1      22.3      26.3
30        33.8      37.3      40.7      43.9      46.9      49.7
52.4      54.9      57.3      59.6      62.0 ];
    Kinematic_air_2    = [ 2        4.4426   7.59      11.44
15.89     20.92     26.41     32.39     38.79     45.57     52.69
60.21     68.1      76.37     84.93     93.80     102.90];
    K_air_2_new     = interp1 (T_air_2, Thermal_cond_air_2,
Tav_air_2_new)*10^-3;
    Pr_2_new        = interp1 (T_air_2, Pr_air_2, Tav_air_2_new);
    v_air_2_new     = interp1 (T_air_2, Kinematic_air_2,
Tav_air_2_new)*10^-6;
    Bate_2_new=1/( Tai_air_2+(0.25*( Tabs_K_new - Tai_air_2)));
    GrcPr_2_new=exp(3.848+(29.146*cos((73.6*pi)/180)));
    GrL_2_new=G* Bate_2_new*L_e^3*( Tabs_K_new -
Tai_air_2)/( v_air_2_new^2);
    Num_2_new=0.14*(((GrL_2_new* Pr_2_new)^(1/3))-
(GrcPr_2_new^(1/3)))+0.56*((GrcPr_2_new*cos((73.6*3.142)/180))^(1/4));
    h_conv_2_new=(( Num_2_new* K_air_2_new)/L_e);
    h_rad_2_new= Emission_air_2* Botmann*( Tabs_K_new +TG)*( Tabs_K_new
^2+TG^2);
    z_conv_2_new=1/( h_conv_2_new*A);
    z_rad_2_new=1/( h_rad_2_new*A);
    Q_loss_2_new=( Tabs_K_new -
TG)/(((1/z_conv_2_new)+(1/z_rad_2_new))^-1);
    pa1=abs(Q_loss_1-Q_loss_2_new);
    Tabs_K=Tabs_K_new;
end
```

```
T_w=input('T_water:');
T_water=T_w+273.15;
T_cond=T_water+1;
Tav_tank=(T_cond+T_water)/2;
T_water_tank            = [ 273.15      275          280          285
290         295         300         305         310          315
320          325          330          335          340          345
350          355          360          365          370          373.15
375          380          385          390          400          410
420          430          440          450          460          470
480          490          500          510          520          530
540          550          560          570          580          590
600          610          620          625          630          635
640          645          647.3 ];
Specific_Volume_Liquid  = [ 1.000       1.000        1.000        1.000
1.001       1.002       1.003       1.005       1.007       1.009
1.011        1.013        1.016        1.018        1.021        1.024
1.027        1.030        1.034        1.038        1.041        1.044
1.045        1.049        1.053        1.058        1.067        1.077
1.088        1.099        1.110        1.123        1.137        1.152
1.167        1.184        1.203        1.222        1.244        1.268
1.294        1.323        1.355        1.392        1.433        1.482
1.541        1.612        1.705        1.778        1.856        1.935
2.075        2.351        3.170    ];
Specific_Volume_Gas     = [ 206.3       181.7        130.4        99.4
69.7        51.94       39.13       29.74       22.93       17.82
13.98        11.06        8.82         7.09         5.74         4.683
3.846        3.180        2.645        2.212        1.861        1.679
1.574        1.337        1.142        0.980        0.731        0.553
0.425        0.331        0.261        0.208        0.167        0.136
0.111        0.0922       0.0766       0.0631       0.0525       0.0445
0.0375       0.0317       0.0269       0.0228       0.0193       0.0163
0.0137       0.0115       0.0094       0.0085       0.0075       0.0066
0.0057       0.0045       0.0032   ];
Thermal_cond_water      = [ 569         574          582          590
598         606         613         620         628          634
640          645          650          656          660          668
668          671          674          677          679          680
681          683          685          686          688          688
688          685          682          678          673          667
660          651          642          631          621          608
594          580          563          548          528          513
497          467          444          430          412          392
367          331          238 ];
Viscosity_Liquid_water  = [ 1750        1652         1422         1225
1080        959         855         769         695          631
577          528          489          453          420          389
365          343          324          306          298          279
274          260          248          237          217          200
185          173          162          152          143          136
129          124          118          113          108          104
```

```
101         97          94          91          88          84
81          77          72          70          67          64
59          54          45  ];
Pr_Liquid_water         = [ 12.99       12.22       10.26       8.81
7.56        6.62        5.83        5.20        4.62        4.16
3.77        3.42        3.15        2.88        2.66        2.45
2.29        2.14        2.02        1.91        1.80        1.76
1.70        1.61        1.53        1.47        1.34        1.24
1.16        1.09        1.04        0.99        0.95        0.92
0.89        0.87        0.86        0.85        0.84        0.85
0.86        0.87        0.90        0.94        0.99        1.05
1.14        1.30        1.52        1.65        2.0         2.7
4.2         12          0   ];
Specific_Heat_Liquid    = [ 4.217       4.211       4.198       4.189
4.184       4.181       4.179       4.178       4.178       4.179
4.180       4.182       4.184       4.186       4.188       4.191
4.195       4.199       4.203       4.209       4.214       4.217
4.220       4.226       4.232       4.239       4.256       4.278
4.302       4.331       4.360       4.400       4.440       4.480
4.530       4.590       4.660       4.740       4.840       4.950
5.080       5.240       5.430       5.680       6.000       6.410
7.000       7.850       9.350       10.600      12.600      16.400
26.000      90.000      0.000 ];
Specific_Volume_L = interp1 (T_water_tank, Specific_Volume_Liquid,
Tav_tank)*10^-3;
Specific_Volume_G = interp1 (T_water_tank, Specific_Volume_Gas,
Tav_tank);
Thermal_water     = interp1 (T_water_tank, Thermal_cond_water,
Tav_tank)*10^-3;
Viscosity_water   = interp1 (T_water_tank, Viscosity_Liquid_water,
Tav_tank)*10^=6;
Pr_water          = interp1 (T_water_tank, Pr_Liquid_water, Tav_tank);
Specific_Heat     = interp1 (T_water_tank, Specific_Heat_Liquid,
Tav_tank)*10^3;
Rho_water         = (1 / Specific_Volume_L);
Kinematic_water   = (Viscosity_water / Rho_water);
Thermal_diffus_water =  Thermal_water / (Rho_water*Specific_Heat);
Bate_water        =  1 / ((T_cond+T_water)/2);
Ray_water         = abs(G*Bate_water*(d_out^3)*(T_cond -
T_water))/(Kinematic_water*Thermal_diffus_water);
h_cond            = (Thermal_water / d_out)*(0.6 +
((0.387)*(Ray_water^(1/6))) / (1 + (0.559 /
Pr_water)^(9/16))^(8/27))^2;
S_co    =   pi*d_out*L_c;
'S_co(m^2)
Z_9    =   1/(h_cond*S_co);
Q_TS_1=(T_cond-T_water)/Z_9;
 calculate Q_TS_2
Tav_syphon=(T_cond + Tabs_K)/2;
T_134a                  = [ 273.15      275.15      277.15      279.15
281.15      283.15      285.15      287.15      289.15      291.15
293.15      295.15      297.15      299.15      301.15      303.15
305.15      307.15      309.15      311.15      313.15      315.15
317.15      319.15      321.15      323.15      325.15      327.15
```

```
329.15      331.15      333.15      335.15      337.15      339.15
341.15      343.15      345.15      347.15      349.15      351.15
353.15      358.15      363.15      368.15      373.15      374.18 ];
Rho_134a_Liquid       = [ 1293.7      1287.1      1280.5      1273.8
1267.0      1260.2      1253.3      1246.3      1239.3      1232.1
1224.9      1217.5      1210.1      1202.6      1194.9      1187.2
1179.3      1171.3      1163.2      1154.9      1146.5      1137.9
1129.2      1120.3      1111.3      1102.0      1092.6      1082.9
1073.0      1062.8      1052.4      1041.7      1030.7      1019.4
1007.7      995.6       983.1       970.0       956.5       942.3
927.4       886.2       836.9       771.6       646.7       513.3 ];
Pressure_134a         = [ 0.29269     0.31450     0.33755     0.36186
0.38749     0.41449     0.44289     0.47276     0.50413     0.53706
0.57159     0.60777     0.65466     0.68531     0.72676     0.77008
0.81530     0.86250     0.91172     0.96301     1.0165      1.0721
1.1300      1.1901      1.2527      1.3177      1.3852      1.4553
1.5280      1.6033      1.6815      1.7625      1.8464      1.9334
2.0234      2.1165      2.2130      2.3127      2.4159      2.5227
2.6331      2.9259      3.2445      3.5916      3.9721      4.0560 ];
Volume_134a_gas       = [ 0.06935     0.06470     0.06042     0.05648
0.05284     0.04948     0.04636     0.04348     0.04081     0.03833
0.03606     0.03388     0.03189     0.03003     0.02829     0.02667
0.02516     0.02374     0.02241     0.02116     0.01999     0.01890
0.01786     0.01689     0.01598     0.01511     0.01430     0.0353
0.01280     0.01212     0.01146     0.01085     0.01026     0.00970
0.00917     0.00867     0.00818     0.00772     0.00728     0.00686
0.00646     0.00550     0.00461     0.00374     0.00265     0.00195 ];
Enthalpy_134a_Liquid  = [ 200.00      202.68      205.37      208.08
210.80      213.53      216.27      219.03      221.80      224.59
227.40      230.21      233.05      235.90      238.77      241.65
244.55      247.47      250.41      253.37      256.35      259.35
262.38      265.42      268.49      271.59      274.71      277.86
281.04      284.25      287.49      290.77      294.08      297.44
300.84      304.29      307.79      311.34      314.96      318.65
322.41      332.27      343.01      355.43      347.02      389.78 ];
Enthalpy_134a_gas     = [ 398.68      399.84      401.00      402.14
403.27      404.40      405.51      406.61      407.70      408.78
409.84      410.89      411.93      412.95      413.95      414.94
415.90      416.85      417.78      418.69      419.85      420.35
421.28      422.09      422.88      423.63      424.35      425.03
425.68      426.29      426.86      427.37      427.84      428.25
428.61      428.89      429.10      429.23      429.27      429.20
429.02      427.91      425.48      420.60      407.08      389.78 ];
Thermal_cond_134a     = [ 93.4        92.5        91.6        90.7
89.7        88.8        87.9        87          86          85.1
84.2        83.3        82.4        81.4        80.5        79.6
78.7        77.7        76.8        75.9        75          74.1
73.1        72.2        71.3        70.4        69.5        68.5
67.6        66.7        65.8        64.9        63.9        63
62.1        61.2        60.3        59.3        58.4        57.5
56.6        54.3        0           0           0           0 ];
Viscosity_134a        = [ 287.4       280.4       273.6       267.0
260.6       254.3       248.3       242.5       236.8       231.2
225.8       220.5       215.4       210.4       205.5       200.7
```

```
196.0       191.4       186.9       182.5       178.2       174.0
169.8       165.7       161.7       157.7       153.8       149.9
146.1       142.3       138.6      134.9       131.2      127.5
123.9       120.3       116.7       113.1       109.4       105.8
102.1       92.7        82.6        70.9        53.0        0 ];
Specific_134a_Liquid  = [ 1.335       1.341       1.347       1.353
1.360       1.367       1.374       1.381       1.388       1.396
1.404       1.412       1.420       1.429       1.438       1.447
1.457       1.467       1.478       1.489       1.500       1.513
1.525       1.539       1.553       1.569       1.585       1.602
1.621       1.641       1.663      1.686       1.712      1.740
1.772       1.806       1.846       1.890       1.941       2.000
2.069       2.313       2.766       3.961       0           0 ];
Pr_134a               = [ 4.108       4.065       4.023       3.983
3.951       3.915       3.881       3.849       3.882       3.793
3.765       3.738       3.712       3.694       3.671       3.648
3.629       3.614       3.597       3.580       3.564       3.553
3.542       3.532       3.522       3.515       3.508       3.506
3.503       3.501       3.503      3.504       3.515      3.521
3.535       3.550       3.573       3.605       3.636       3.680
3.732       3.949       0           0           0           0 ];
Rho_134a_L      = interp1 (T_134a, Rho_134a_Liquid, Tav_syphon);
Pressure        = interp1 (T_134a, Pressure_134a, Tav_syphon)*10^6;
Volume_gas      = interp1 (T_134a, Volume_134a_gas, Tav_syphon);
Enthalpy_134a_g= interp1 (T_134a, Enthalpy_134a_gas, Tav_syphon)*10^3;
Enthalpy_134a_L= interp1 (T_134a, Enthalpy_134a_Liquid,
Tav_syphon)*10^3;
Thermal_134a    = interp1 (T_134a, Thermal_cond_134a, Tav_syphon)*10^-3;
Viscosity       = interp1 (T_134a, Viscosity_134a, Tav_syphon)*10^-6;
cp_134a         = interp1 (T_134a, Specific_134a_Liquid,
Tav_syphon)*10^3;
Pr              = interp1 (T_134a, Pr_134a, Tav_syphon);
Rho_134a_gas          =  ( 1 / Volume_gas);
Kinematic             =  (Viscosity / Rho_134a_L);
Volume_134a_Liquid    =  (1 / Rho_134a_L);
Enthalpy_Diff         =  Enthalpy_134a_g - Enthalpy_134a_L;
Pa      = 0.10132*10^6;
Free2=((Enthalpy_Diff*(Thermal_134a^3)*(Rho_134a_L^2))/Viscosity)^0.25;
Free3=28.079*((Pressure / Pa)^0.23);
F       = 0.7;
ln_dia
ln_dia=0.05266;
Z_2=ln_dia/(2*pi*L_e*k_cu);
Z_8=ln_dia/(2*pi*L_c*k_cu);
Z_3f = (0.235*(Q_TS_1^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_e*(Free2^(4/3)));
Z_3p = 1/((Free3)*(G^0.2)*(Q_TS_1^0.4)*((pi*d_in*L_e)^0.6));
    if Z_3p < Z_3f
        Z_3 = Z_3p;
    else
        Z_3 = (Z_3p*F) + (Z_3f*(1 - F));
```

```
    end
    % Calculate Z_7
    Re = (4*Q_TS_1)/(Enthalpy_Diff*Viscosity*pi*d_in);
    if Re>1300
        Z_7 = (0.235*(Q_TS_1^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_c*(Free2^(4/3)))*(191*(Re^-0.733));
    else
        Z_7 =(0.235*(Q_TS_1^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_c*(Free2^(4/3)));
    end
    % Calculate Z_10
    a_across = (pi*((d_out^2)-(d_in^2))) / 4;
    Z_10 = ((0.5*L_e) + L_a + (0.5*L_c)) / (a_across*k_cu) ;
    Z_p = Z_10 /(Z_2 + Z_3 + Z_7 + Z_8);
    if Z_p > 20
       Z_tot = Z_2 + Z_3 + Z_7 + Z_8;
    else
       Z_tot = ((Z_2 + Z_3 + Z_7 + Z_8)^-1 + (1/Z_10))^-1;
    end
Q_TS_2=(Tabs_K-T_cond)/Z_tot;
if Q_TS_2<= 0
    Q_TS_1_new = Q_TS_1;
else
pa2=abs(Q_TS_1-Q_TS_2);
 if pa2 < 20
       Q_TS_1_new=Q_TS_1;
   end
while pa2 >= 20
    T_cond_new=T_cond+0.1;
    %Calculate Q_TS_1_new
    Tav_tank=(T_cond_new+T_water)/2;
    T_water_tank            = [ 273.15      275         280         285
290         295         300         305         310         315
320         325         330         335         340         345
350         355         360         365         370         373.15
375         380         385         390         400         410
420         430         440         450         460         470
480         490         500         510         520         530
540         550         560         570         580         590
600         610         620         625         630         635
640         645         647.3 ];
    Specific_Volume_Liquid  = [ 1.000       1.000       1.000
1.000       1.001       1.002       1.003       1.005       1.007
1.009       1.011       1.013       1.016       1.018       1.021
1.024       1.027       1.030       1.034       1.038       1.041
1.044       1.045       1.049       1.053       1.058       1.067
1.077       1.088       1.099       1.110       1.123       1.137
1.152       1.167       1.184       1.203       1.222       1.244
1.268       1.294       1.323       1.355       1.392       1.433
1.482       1.541       1.612       1.705       1.778       1.856
1.935       2.075       2.351       3.170   ];
    Specific_Volume_Gas     = [ 206.3       181.7       130.4
99.4        69.7        51.94       39.13       29.74       22.93
17.82       13.98       11.06       8.82        7.09        5.74
```

```
4.683       3.846       3.180       2.645       2.212       1.861
1.679       1.574       1.337       1.142       0.980       0.731
0.553       0.425       0.331       0.261       0.208       0.167
0.136       0.111       0.0922      0.0766      0.0631      0.0525
0.0445      0.0375      0.0317      0.0269      0.0228      0.0193
0.0163      0.0137      0.0115      0.0094      0.0085      0.0075
0.0066      0.0057      0.0045      0.0032  ];
    Thermal_cond_water      = [ 569         574         582         590
598         606         613         620         628         634
640         645         650         656         660         668
668         671         674         677         679         680
681         683         685         686         688         688
688         685         682         678         673         667
660         651         642         631         621         608
594         580         563         548         528         513
497         467         444         430         412         392
367         331         238 ];
    Viscosity_Liquid_water  = [ 1750        1652        1422
1225        1080        959         855         769         695         631
577         528         489         453         420         389
365         343         324         306         298         279
274         260         248         237         217         200
185         173         162         152         143         136
129         124         118         113         108         104
101         97          94          91          88          84
81          77          72          70          67          64
59          54          45  ];
    Pr_Liquid_water         = [ 12.99       12.22       10.26
8.81        7.56        6.62        5.83        5.20        4.62
4.16        3.77        3.42        3.15        2.88        2.66
2.45        2.29        2.14        2.02        1.91        1.80
1.76        1.70        1.61        1.53        1.47        1.34
1.24        1.16        1.09        1.04        0.99        0.95
0.92        0.89        0.87        0.86        0.85        0.84
0.85        0.86        0.87        0.90        0.94        0.99
1.05        1.14        1.30        1.52        1.65        2.0
2.7         4.2         12          0   ];
    Specific_Heat_Liquid    = [ 4.217       4.211       4.198
4.189       4.184       4.181       4.179       4.178       4.178
4.179       4.180       4.182       4.184       4.186       4.188
4.191       4.195       4.199       4.203       4.209       4.214
4.217       4.220       4.226       4.232       4.239       4.256
4.278       4.302       4.331       4.360       4.400       4.440
4.480       4.530       4.590       4.660       4.740       4.840
4.950       5.080       5.240       5.430       5.680       6.000
6.410       7.000       7.850       9.350       10.600      12.600
16.400      26.000      90.000      0.000 ];
    Specific_Volume_L = interp1 (T_water_tank, Specific_Volume_Liquid,
Tav_tank)*10^-3;
    Specific_Volume_G = interp1 (T_water_tank, Specific_Volume_Gas,
Tav_tank);
    Thermal_water     = interp1 (T_water_tank, Thermal_cond_water,
Tav_tank)*10^-3;
```

```
    Viscosity_water   = interp1 (T_water_tank, Viscosity_Liquid_water,
Tav_tank)*10^-6;
    Pr_water          = interp1 (T_water_tank, Pr_Liquid_water,
Tav_tank);
    Specific_Heat     = interp1 (T_water_tank, Specific_Heat_Liquid,
Tav_tank)*10^3;
    Rho_water         = (1 / Specific_Volume_L);
    Kinematic_water   = (Viscosity_water / Rho_water);
    Thermal_diffus_water =  Thermal_water / (Rho_water*Specific_Heat);
    Bate_water        =  1 / ((T_cond_new+T_water)/2);
    Ray_water         = abs(G*Bate_water*(d_out^3)*(T_cond_new -
T_water))/(Kinematic_water*Thermal_diffus_water);
    h_cond            = (Thermal_water / d_out)*(0.6 +
((0.387)*(Ray_water^(1/6))) / (1 + (0.559 /
Pr_water)^(9/16))^(8/27))^2;
    S_co  =   pi*d_out*L_c;
    S_co,m^2
    Z_9   =   1/(h_cond*S_co);
    Q_TS_1_new=(T_cond_new-T_water)/Z_9;
    Calculate Q_TS_2_new
    Tav_syphon=(T_cond_new + Tabs_K)/2;
    T_134a                = [ 273.15      275.15      277.15
279.15      281.15      283.15      285.15      287.15      289.15
291.15      293.15      295.15      297.15      299.15      301.15
303.15      305.15      307.15      309.15      311.15      313.15
315.15      317.15      319.15      321.15      323.15      325.15
327.15      329.15      331.15      333.15      335.15      337.15
339.15      341.15      343.15      345.15      347.15      349.15
351.15      353.15      358.15      363.15      368.15      373.15
374.18 ];
    Rho_134a_Liquid       = [ 1293.7      1287.1      1280.5
1273.8      1267.0      1260.2      1253.3      1246.3      1239.3
1232.1      1224.9      1217.5      1210.1      1202.6      1194.9
1187.2      1179.3      1171.3      1163.2      1154.9      1146.5
1137.9      1129.2      1120.3      1111.3      1102.0      1092.6
1082.9      1073.0      1062.8      1052.4      1041.7      1030.7
1019.4      1007.7      995.6       983.1       970.0       956.5
942.3       927.4       886.2       836.9       771.6       646.7
513.3 ];
    Pressure_134a         = [ 0.29269     0.31450     0.33755
0.36186     0.38749     0.41449     0.44289     0.47276     0.50413
0.53706     0.57159     0.60777     0.65466     0.68531     0.72676
0.77008     0.81530     0.86250     0.91172     0.96301     1.0165
1.0721      1.1300      1.1901      1.2527      1.3177      1.3852
1.4553      1.5280      1.6033      1.6815      1.7625      1.8464
1.9334      2.0234      2.1165      2.2130      2.3127      2.4159
2.5227      2.6331      2.9259      3.2445      3.5916      3.9721
4.0560 ];
    Volume_134a_gas       = [ 0.06935     0.06470     0.06042
0.05648     0.05284     0.04948     0.04636     0.04348     0.04081
0.03833     0.03606     0.03388     0.03189     0.03003     0.02829
0.02667     0.02516     0.02374     0.02241     0.02116     0.01999
0.01890     0.01786     0.01689     0.01598     0.01511     0.01430
0.0353      0.01280     0.01212     0.01146     0.01085     0.01026
```

```
0.00970    0.00917    0.00867    0.00818    0.00772    0.00728
0.00686    0.00646    0.00550    0.00461    0.00374    0.00265
0.00195 ];
    Enthalpy_134a_Liquid  = [ 200.00      202.68      205.37
208.08      210.80      213.53      216.27      219.03      221.80
224.59      227.40      230.21      233.05      235.90      238.77
241.65      244.55      247.47      250.41      253.37      256.35
259.35      262.38      265.42      268.49      271.59      274.71
277.86     281.04      284.25      287.49      290.77      294.08
297.44     300.84      304.29      307.79      311.34     314.96
318.65     322.41      332.27      343.01      355.43      347.02
389.78 ];
    Enthalpy_134a_gas     = [ 398.68      399.84      401.00
402.14      403.27      404.40      405.51      406.61      407.70
408.78      409.84      410.89      411.93      412.95      413.95
414.94      415.90      416.85      417.78      418.69      419.85
420.35      421.28      422.09      422.88      423.63      424.35
425.03     425.68      426.29      426.86      427.37      427.84
428.25     428.61      428.89      429.10      429.23     429.27
429.20     429.02      427.91      425.48      420.60      407.08
389.78 ];
    Thermal_cond_134a     = [ 93.4        92.5        91.6        90.7
89.7        88.8        87.9        87          86          85.1
84.2        83.3        82.4        81.4        80.5        79.6
78.7        77.7        76.8        75.9        75          74.1
73.1        72.2        71.3        70.4        69.5        68.5
67.6        66.7        65.8        64.9        63.9        63
62.1        61.2        60.3        59.3        58.4        57.5
56.6        54.3        0           0           0           0 ];
    Viscosity_134a        = [ 287.4       280.4       273.6       267.0
260.6       254.3       248.3       242.5       236.8       231.2
225.8       220.5       215.4       210.4       205.5       200.7
196.0       191.4       186.9       182.5       178.2       174.0
169.8       165.7       161.7       157.7       153.8       149.9
146.1       142.3       138.6      134.9       131.2      127.5
123.9       120.3       116.7       113.1       109.4       105.8
102.1       92.7        82.6        70.9        53.0        0 ];
    Specific_134a_Liquid  = [ 1.335       1.341       1.347       1.353
1.360       1.367       1.374       1.381       1.388       1.396
1.404       1.412       1.420       1.429       1.438       1.447
1.457       1.467       1.478       1.489       1.500       1.513
1.525       1.539       1.553       1.569       1.585       1.602
1.621       1.641       1.663      1.686      1.712      1.740
1.772       1.806       1.846       1.890      1.941       2.000
2.069       2.313       2.766       3.961       0           0 ];
    Pr_134a               = [ 4.108       4.065       4.023       3.983
3.951       3.915       3.881       3.849       3.882       3.793
3.765       3.738       3.712       3.694       3.671       3.648
3.629       3.614       3.597       3.580       3.564       3.553
3.542       3.532       3.522       3.515       3.508       3.506
3.503       3.501       3.503      3.504      3.515      3.521
3.535       3.550       3.573       3.605      3.636       3.680
3.732       3.949       0           0           0           0 ];
    Rho_134a_L     = interp1 (T_134a, Rho_134a_Liquid, Tav_syphon);
```

```
    Pressure       = interp1 (T_134a, Pressure_134a, Tav_syphon)*10^6;
    Volume_gas     = interp1 (T_134a, Volume_134a_gas, Tav_syphon);
    Enthalpy_134a_g= interp1 (T_134a, Enthalpy_134a_gas,
Tav_syphon)*10^3;
    Enthalpy_134a_L= interp1 (T_134a, Enthalpy_134a_Liquid,
Tav_syphon)*10^3;
    Thermal_134a   = interp1 (T_134a, Thermal_cond_134a,
Tav_syphon)*10^-3;
    Viscosity      = interp1 (T_134a, Viscosity_134a, Tav_syphon)*10^-
6;
    cp_134a        = interp1 (T_134a, Specific_134a_Liquid,
Tav_syphon)*10^3;
    Pr             = interp1 (T_134a, Pr_134a, Tav_syphon);
    Rho_134a_gas          =  ( 1 / Volume_gas);
    Kinematic             =  (Viscosity / Rho_134a_L);
    Volume_134a_Liquid    =  (1 / Rho_134a_L);
    Enthalpy_Diff         =  Enthalpy_134a_g - Enthalpy_134a_L;
    % Rho_134a(kg/m^3), Volume gas(m^3/kg), Enthalpy_Diff(J/kg),
Pressure(Pa), Thermal_134a W/m-K, Viscosity-134a, cp_134a(J/kg-K)
    Pa     = 0.10132*10^6;

Free2=((Enthalpy_Diff*(Thermal_134a^3)*(Rho_134a_L^2))/Viscosity)^0.25;
    Free3=28.079*((Pressure / Pa)^0.23);
    F      = 0.7;
    %ln(d_out/d_in)=ln_dia
    %0.05266=ln(1.12d_in/d_in)
    ln_dia=0.05266;
    Z_2=ln_dia/(2*pi*L_e*k_cu);
    Z_8=ln_dia/(2*pi*L_c*k_cu);
    Z_3f = (0.235*(Q_TS_1_new^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_e*(Free2^(4/3)));
    Z_3p = 1/((Free3)*(G^0.2)*(Q_TS_1_new^0.4)*((pi*d_in*L_e)^0.6));
        if Z_3p < Z_3f
            Z_3 = Z_3p;
        else
            Z_3 = (Z_3p*F) + (Z_3f*(1 - F));
        end
        % Calculate Z_7
        Re = (4*Q_TS_1_new)/(Enthalpy_Diff*Viscosity*pi*d_in);
        if Re>1300
            Z_7 = (0.235*(Q_TS_1_new^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_c*(Free2^(4/3)))*(191*(Re^-0.733));
        else
            Z_7 =(0.235*(Q_TS_1_new^(1/3))) /
((d_in^(4/3))*(G^(1/3))*L_c*(Free2^(4/3)));
        end
        % Calculate Z_10
        a_across = (pi*((d_out^2)-(d_in^2))) / 4;
        Z_10 = ((0.5*L_e) + L_a + (0.5*L_c)) / (a_across*k_cu) ;
        Z_p = Z_10 /(Z_2 + Z_3 + Z_7 + Z_8);
        if Z_p > 20
           Z_tot = Z_2 + Z_3 + Z_7 + Z_8;
        else
           Z_tot = ((Z_2 + Z_3 + Z_7 + Z_8)^-1 + (1/Z_10))^-1;
```

```
        end
    Q_TS_2_new=(Tabs_K-T_cond_new)/Z_tot;
    if Q_TS_2_new <= 0
        pa2=9;
        Q_TS_1_new = Q_TS_1;
    else
         pa2=abs(Q_TS_1_new-Q_TS_2_new);
         T_cond=T_cond_new;
    end
end
end
%calculate QG_1
%Using 10% Global Radiation
transmissivity=0.79;
absorbtivity=0.97;
QG_1=transmissivity*absorbtivity*I*A;
%calculate QG_2
QG_2=(Q_TS_1_new*N)+Q_loss_1;
pa4=abs(QG_1-QG_2);
TG_new=TG;
end

%Water
D_out=0.483726;
D_in=0.478726;
L_c= 0.478726;
K_fiber=0.036;
h_air=25;
r_tank_out=D_out/2;
r_tank_in=D_in/2;
Thermal_Al=237;
Thickness_tank=0.0015;
Thickness_insulate=0.05;
r_insulate=(L_c/2)+Thickness_tank+Thickness_insulate;
% Water in tank is 100 liter
A_insulate=2*pi*r_insulate*W;
Tav_tank=(T_cond+T_water)/2;
T_water_tank              = [ 273.15      275         280          285
290         295         300         305         310          315
320         325         330         335         340          345
350         355         360         365         370          373.15
375         380         385         390         400          410
420         430         440         450         460          470
480         490         500         510         520          530
540         550         560         570         580          590
600         610         620         625         630          635
640         645         647.3 ];
Specific_Volume_Liquid  = [ 1.000       1.000       1.000        1.000
1.001       1.002       1.003       1.005       1.007        1.009
1.011       1.013       1.016       1.018       1.021        1.024
1.027       1.030       1.034       1.038       1.041        1.044
1.045       1.049       1.053       1.058       1.067        1.077
1.088       1.099       1.110       1.123       1.137        1.152
```

```
1.167       1.184       1.203       1.222       1.244       1.268
1.294       1.323       1.355       1.392       1.433       1.482
1.541       1.612       1.705       1.778       1.856       1.935
2.075       2.351       3.170   ];
Specific_Heat_Liquid    = [ 4.217       4.211       4.198       4.189
4.184       4.181       4.179       4.178       4.178       4.179
4.180       4.182       4.184       4.186       4.188       4.191
4.195       4.199       4.203       4.209       4.214       4.217
4.220       4.226       4.232       4.239       4.256       4.278
4.302       4.331       4.360       4.400       4.440       4.480
4.530       4.590       4.660       4.740       4.840       4.950
5.080       5.240       5.430       5.680       6.000       6.410
7.000       7.850       9.350       10.600      12.600      16.400
26.000      90.000      0.000 ];
Specific_Volume_L = interp1 (T_water_tank, Specific_Volume_Liquid,
Tav_tank)*10^-3;
Specific_Heat     = interp1 (T_water_tank, Specific_Heat_Liquid,
Tav_tank)*10^3;
Rho_water         = (1 / Specific_Volume_L);
Kinematic_water   = (Viscosity_water / Rho_water);
m_water=(0.18*Rho_water);
ln=0.177581;
Z_loss=(1/(h_air*A_insulate)+(ln/(2*pi*W*K_fiber)));
Q_loss=(Tam_K-T_water)/Z_loss;
Q_st=(Q_TS_1_new*N)-Q_loss;
T_water_new=((Q_st*1800)/(Specific_Heat*m_water))+T_water;

T_w=T_water_new-273.15;
Tabs=Tabs_K-273.15;
T_c=T_cond-273.15;

fprintf('T_cond = %.3f\n',T_cond);
fprintf('T_water= %.3f\n',T_water);
fprintf('Tam= %.3f\n',Tam);
fprintf('Tam_K = %.3f\n',Tam_K);
fprintf('TG = %.3f\n',TG);
fprintf('Tabs_K = %.3f\n',Tabs_K);
fprintf('Q_loss_1 = %.3f\n',Q_loss_1);
fprintf('Q_loss_2 = %.3f\n',Q_loss_2_new);
fprintf('Q_TS_1_new = %.3f\n',Q_TS_1_new);
fprintf('Q_TS_2_new = %.3f\n',Q_TS_2_new);
fprintf('QG_1  = %.3f\n',QG_1);
fprintf('QG_2 = %.3f\n',QG_2);
fprintf('TG_new = %.3f\n',TG);
fprintf('T_cond = %.3f\n',T_cond);
fprintf('T_water_new = %.3f\n',T_water_new);
fprintf('Q_st = %.3f\n',Q_st);
fprintf('Tabs = %.3f\n',Tabs);
fprintf('T_c = %.3f\n',T_c);
fprintf('T_w = %.3f\n',T_w);
fprintf('num = %.3f\n',num);
```

ภาคผนวก ข.

ตารางสมบัติของสาร

ตารางที่ ข.1 แสดงค่าคุณสมบัติของอากาศ [12]

TABLE A.4 Thermophysieal Properties of Gases at Atmospheric Pressure[a]

T (K)	ρ (kg/m^3)	c_p (kJ/kg · K)	$\mu \cdot 10^7$ (N · s/m^2)	$\nu \cdot 10^6$ (m^2/s)	$k \cdot 10^3$ (W/m · K)	$\alpha \cdot 10^6$ (m^2/s)	Pr
Air							
100	3.5562	1.032	71.1	2.00	9.34	2.54	0.786
150	2.3364	1.012	103.4	4.426	13.8	5.84	0.758
200	1.7458	1.007	132.5	7.590	18.1	10.3	0.737
250	1.3947	1.006	159.6	11.44	22.3	15.9	0.720
300	1.1614	1.007	184.6	15.89	26.3	22.5	0.707
350	0.9950	1.009	208.2	20.92	30.0	29.9	0.700
400	0.8711	1.014	230.1	26.41	33.8	38.3	0.690
450	0.7740	1.021	250.7	32.39	37.3	47.2	0.686
500	0.6964	1.030	270.1	38.79	40.7	56.7	0.684
550	0.6329	1.040	288.4	45.57	43.9	66.7	0.683
600	0.5804	1.051	305.8	52.69	46.9	76.9	0.685
650	0.5356	1.063	322.5	60.21	49.7	87.3	0.690
700	0.4975	1.075	338.8	68.10	52.4	98.0	0.695
750	0.4643	1.087	354.6	76.37	54.9	109	0.702
800	0.4354	1.099	369.8	84.93	57.3	120	0.709
850	0.4097	1.110	384.3	93.80	59.6	131	0.716
900	0.3868	1.121	398.1	102.9	62.0	143	0.720
950	0.3666	1.131	411.3	112.2	64.3	155	0.723
1000	0.3482	1.141	424.4	121.9	66.7	168	0.726
1100	0.3166	1.159	449.0	141.8	71.5	195	0.728
1200	0.2902	1.175	473.0	162.9	76.3	224	0.728
1300	0.2679	1.189	496.0	185.1	82	238	0.719
1400	0.2488	1.207	530	213	91	303	0.703
1500	0.2322	1.230	557	240	100	350	0.685
1600	0.2177	1.248	584	268	106	390	0.688
1700	0.2049	1.267	611	298	113	435	0.685
1800	0.1935	1.286	637	329	120	482	0.683
1900	0.1833	1.307	663	362	128	534	0.677
2000	0.1741	1.337	689	396	137	589	0.672
2100	0.1658	1.372	715	431	147	646	0.667
2200	0.1582	1.417	740	468	160	714	0.655
2300	0.1513	1.478	766	506	175	783	0.647
2400	0.1448	1.558	792	547	196	869	0.630
2500	**0.1389**	**1.665**	**818**	**589**	**222**	**960**	**0.613**
3000	**0.1135**	**2.726**	**955**	**841**	**486**	**1570**	**0.536**

ตารางที่ ข.2 แสดงคุณสมบัติ น้ำอิ่มตัว – ตารางอุณหภูมิ [12]

TABLE A–4

Saturated water—Temperature table

		Specific volume, m^3/kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg · K		
Temp., T °C	Sat. press., P_{sat} kPa	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
0.01	0.6117	0.001000	206.00	0.000	2374.9	2374.9	0.001	2500.9	2500.9	0.0000	9.1556	9.1556
5	0.8725	0.001000	147.03	21.019	2360.8	2381.8	21.020	2489.1	2510.1	0.0763	8.9487	9.0249
10	1.2281	0.001000	106.32	42.020	2346.6	2388.7	42.022	2477.2	2519.2	0.1511	8.7488	8.8999
15	1.7057	0.001001	77.885	62.980	2332.5	2395.5	62.982	2465.4	2528.3	0.2245	8.5559	8.7803
20	2.3392	0.001002	57.762	83.913	2318.4	2402.3	83.915	2453.5	2537.4	0.2965	8.3696	8.6661
25	3.1698	0.001003	43.340	104.83	2304.3	2409.1	104.83	2441.7	2546.5	0.3672	8.1895	8.5567
30	4.2469	0.001004	32.879	125.73	2290.2	2415.9	125.74	2429.8	2555.6	0.4368	8.0152	8.4520
35	5.6291	0.001006	25.205	146.63	2276.0	2422.7	146.64	2417.9	2564.6	0.5051	7.8466	8.3517
40	7.3851	0.001008	19.515	167.53	2261.9	2429.4	167.53	2406.0	2573.5	0.5724	7.6832	8.2556
45	9.5953	0.001010	15.251	188.43	2247.7	2436.1	188.44	2394.0	2582.4	0.6386	7.5247	8.1633
50	12.352	0.001012	12.026	209.33	2233.4	2442.7	209.34	2382.0	2591.3	0.7038	7.3710	8.0748
55	15.763	0.001015	9.5639	230.24	2219.1	2449.3	230.26	2369.8	2600.1	0.7680	7.2218	7.9898
60	19.947	0.001017	7.6670	251.16	2204.7	2455.9	251.18	2357.7	2608.8	0.8313	7.0769	7.9082
65	25.043	0.001020	6.1935	272.09	2190.3	2462.4	272.12	2345.4	2617.5	0.8937	6.9360	7.8296
70	31.202	0.001023	5.0396	293.04	2175.8	2468.9	293.07	2333.0	2626.1	0.9551	6.7989	7.7540
75	38.597	0.001026	4.1291	313.99	2161.3	2475.3	314.03	2320.6	2634.6	1.0158	6.6655	7.6812
80	47.416	0.001029	3.4053	334.97	2146.6	2481.6	335.02	2308.0	2643.0	1.0756	6.5355	7.6111
85	57.868	0.001032	2.8261	355.96	2131.9	2487.8	356.02	2295.3	2651.4	1.1346	6.4089	7.5435
90	70.183	0.001036	2.3593	376.97	2117.0	2494.0	377.04	2282.5	2659.6	1.1929	6.2853	7.4782
95	84.609	0.001040	1.9808	398.00	2102.0	2500.1	398.09	2269.6	2667.6	1.2504	6.1647	7.4151
100	101.42	0.001043	1.6720	419.06	2087.0	2506.0	419.17	2256.4	2675.6	1.3072	6.0470	7.3542
105	120.90	0.001047	1.4186	440.15	2071.8	2511.9	440.28	2243.1	2683.4	1.3634	5.9319	7.2952
110	143.38	0.001052	1.2094	461.27	2056.4	2517.7	461.42	2229.7	2691.1	1.4188	5.8193	7.2382
115	169.18	0.001056	1.0360	482.42	2040.9	2523.3	482.59	2216.0	2698.6	1.4737	5.7092	7.1829
120	198.67	0.001060	0.89133	503.60	2025.3	2528.9	503.81	2202.1	2706.0	1.5279	5.6013	7.1292
125	232.23	0.001065	0.77012	524.83	2009.5	2534.3	525.07	2188.1	2713.1	1.5816	5.4956	7.0771
130	270.28	0.001070	0.66808	546.10	1993.4	2539.5	546.38	2173.7	2720.1	1.6346	5.3919	7.0265
135	313.22	0.001075	0.58179	567.41	1977.3	2544.7	567.75	2159.1	2726.9	1.6872	5.2901	6.9773
140	361.53	0.001080	0.50850	588.77	1960.9	2549.6	589.16	2144.3	2733.5	1.7392	5.1901	6.9294
145	415.68	0.001085	0.44600	610.19	1944.2	2554.4	610.64	2129.2	2739.8	1.7908	5.0919	6.8827
150	476.16	0.001091	0.39248	631.66	1927.4	2559.1	632.18	2113.8	2745.9	1.8418	4.9953	6.8371
155	543.49	0.001096	0.34648	653.19	1910.3	2563.5	653.79	2098.0	2751.8	1.8924	4.9002	6.7927
160	618.23	0.001102	0.30680	674.79	1893.0	2567.8	675.47	2082.0	2757.5	1.9426	4.8066	6.7492
165	700.93	0.001108	0.27244	696.46	1875.4	2571.9	697.24	2065.6	2762.8	1.9923	4.7143	6.7067
170	792.18	0.001114	0.24260	718.20	1857.5	2575.7	719.08	2048.8	2767.9	2.0417	4.6233	6.6650
175	892.60	0.001121	0.21659	740.02	1839.4	2579.4	741.02	2031.7	2772.7	2.0906	4.5335	6.6242
180	1002.8	0.001127	0.19384	761.92	1820.9	2582.8	763.05	2014.2	2777.2	2.1392	4.4448	6.5841
185	1123.5	0.001134	0.17390	783.91	1802.1	2586.0	785.19	1996.2	2781.4	2.1875	4.3572	6.5447
190	1255.2	0.001141	0.15636	806.00	1783.0	2589.0	807.43	1977.9	2785.3	2.2355	4.2705	6.5059
195	1398.8	0.001149	0.14089	828.18	1763.6	2591.7	829.78	1959.0	2788.8	2.2831	4.1847	6.4678
200	1554.9	0.001157	0.12721	850.46	1743.7	2594.2	852.26	1939.8	2792.0	2.3305	4.0997	6.4302

ตารางที่ ข.2 แสดงคุณสมบัติ น้ำอิ่มตัว – ตารางอุณหภูมิ (ต่อ)

TABLE A–4

Saturated water—Temperature table (*Continued*)

		Specific volume, m³/kg		*Internal energy,* kJ/kg			*Enthalpy,* kJ/kg			*Entropy,* kJ/kg · K		
Temp., T °C	Sat. press., P_{sat} kPa	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
205	1724.3	0.001164	0.11508	872.86	1723.5	2596.4	874.87	1920.0	2794.8	2.3776	4.0154	6.3930
210	1907.7	0.001173	0.10429	895.38	1702.9	2598.3	897.61	1899.7	2797.3	2.4245	3.9318	6.3563
215	2105.9	0.001181	0.094680	918.02	1681.9	2599.9	920.50	1878.8	2799.3	2.4712	3.8489	6.3200
220	2319.6	0.001190	0.086094	940.79	1660.5	2601.3	943.55	1857.4	2801.0	2.5176	3.7664	6.2840
225	2549.7	0.001199	0.078405	963.70	1638.6	2602.3	966.76	1835.4	2802.2	2.5639	3.6844	6.2483
230	2797.1	0.001209	0.071505	986.76	1616.1	2602.9	990.14	1812.8	2802.9	2.6100	3.6028	6.2128
235	3062.6	0.001219	0.065300	1010.0	1593.2	2603.2	1013.7	1789.5	2803.2	2.6560	3.5216	6.1776
240	3347.0	0.001229	0.059707	1033.4	1569.8	2603.1	1037.5	1765.5	2803.0	2.7018	3.4405	6.1424
245	3651.2	0.001240	0.054656	1056.9	1545.7	2602.7	1061.5	1740.8	2802.2	2.7476	3.3596	6.1072
250	3976.2	0.001252	0.050085	1080.7	1521.1	2601.8	1085.7	1715.3	2801.0	2.7933	3.2788	6.0721
255	4322.9	0.001263	0.045941	1104.7	1495.8	2600.5	1110.1	1689.0	2799.1	2.8390	3.1979	6.0369
260	4692.3	0.001276	0.042175	1128.8	1469.9	2598.7	1134.8	1661.8	2796.6	2.8847	3.1169	6.0017
265	5085.3	0.001289	0.038748	1153.3	1443.2	2596.5	1159.8	1633.7	2793.5	2.9304	3.0358	5.9662
270	5503.0	0.001303	0.035622	1177.9	1415.7	2593.7	1185.1	1604.6	2789.7	2.9762	2.9542	5.9305
275	5946.4	0.001317	0.032767	1202.9	1387.4	2590.3	1210.7	1574.5	2785.2	3.0221	2.8723	5.8944
280	6416.6	0.001333	0.030153	1228.2	1358.2	2586.4	1236.7	1543.2	2779.9	3.0681	2.7898	5.8579
285	6914.6	0.001349	0.027756	1263.7	1328.1	2581.8	1263.1	1510.7	2773.7	3.1144	2.7066	5.8210
290	7441.8	0.001366	0.025554	1279.7	1296.9	2576.5	1289.8	1476.9	2766.7	3.1608	2.6225	5.7834
295	7999.0	0.001384	0.023528	1306.0	1264.5	2570.5	1317.1	1441.6	2758.7	3.2076	2.5374	5.7450
300	8587.9	0.001404	0.021659	1332.7	1230.9	2563.6	1344.8	1404.8	2749.6	3.2548	2.4511	5.7059
305	9209.4	0.001425	0.019932	1360.0	1195.9	2555.8	1373.1	1366.3	2739.4	3.3024	2.3633	5.6657
310	9865.0	0.001447	0.018333	1387.7	1159.3	2547.1	1402.0	1325.9	2727.9	3.3506	2.2737	5.6243
315	10,556	0.001472	0.016849	1416.1	1121.1	2537.2	1431.6	1283.4	2715.0	3.3994	2.1821	5.5816
320	11,284	0.001499	0.015470	1445.1	1080.9	2526.0	1462.0	1238.5	2700.6	3.4491	2.0881	5.5372
325	12,051	0.001528	0.014183	1475.0	1038.5	2513.4	1493.4	1191.0	2684.3	3.4998	1.9911	5.4908
330	12,858	0.001560	0.012979	1505.7	993.5	2499.2	1525.8	1140.3	2666.0	3.5516	1.8906	5.4422
335	13,707	0.001597	0.011848	1537.5	945.5	2483.0	1559.4	1086.0	2645.4	3.6050	1.7857	5.3907
340	14,601	0.001638	0.010783	1570.7	893.8	2464.5	1594.6	1027.4	2622.0	3.6602	1.6756	5.3358
345	15,541	0.001685	0.009772	1605.5	837.7	2443.2	1631.7	963.4	2595.1	3.7179	1.5585	5.2765
350	16,529	0.001741	0.008806	1642.4	775.9	2418.3	1671.2	892.7	2563.9	3.7788	1.4326	5.2114
355	17,570	0.001808	0.007872	1682.2	706.4	2388.6	1714.0	812.9	2526.9	3.8442	1.2942	5.1384
360	18,666	0.001895	0.006950	1726.2	625.7	2351.9	1761.5	720.1	2481.6	3.9165	1.1373	5.0537
365	19,822	0.002015	0.006009	1777.2	526.4	2303.6	1817.2	605.5	2422.7	4.0004	0.9489	4.9493
370	21,044	0.002217	0.004953	1844.5	385.6	2230.1	1891.2	443.1	2334.3	4.1119	0.6890	4.8009
373.95	22,064	0.003106	0.003106	2015.7	0	2015.7	2084.3	0	2084.3	4.4070	0	4.4070

TABLE A.6 Thermophysical Properties of Saturated Water[a]

Temperature, T (K)	Pressure, P (bars)[b]	Specific Volume (m^3/kg)		Heat of Vaporization, h_{fg} (kJ/kg)	Specific Heat (kJ/kg · K)		Viscosity (N · s/m^2)		Thermal Conductivity (W/m · K)		Prandtl Number		Surface Tension, $\sigma_f \cdot 10^3$ (N/m)	Expansion Coefficient, $\beta_f \cdot 10^6$ (K^{-1})	Temperature, T (K)
		$v_f \cdot 10^3$	v_g		c_{pf}	c_{pg}	$\mu_f \cdot 10^6$	$\mu_g \cdot 10^6$	$k_f \cdot 10^3$	$k_g \cdot 10^3$	Pr_f	Pr_g			
273.15	0.00611	1.000	206.3	2502	4.217	1.854	1750	8.02	569	18.2	12.99	0.815	75.5	−68.05	273.15
275	0.00697	1.000	181.7	2497	4.211	1.855	1652	8.09	574	18.3	12.22	0.817	75.3	−32.74	275
280	0.00990	1.000	130.4	2485	4.198	1.858	1422	8.29	582	18.6	10.26	0.825	74.8	46.04	280
285	0.01387	1.000	99.4	2473	4.189	1.861	1225	8.49	590	18.9	8.81	0.833	74.3	114.1	285
290	0.01917	1.001	69.7	2461	4.184	1.864	1080	8.69	598	19.3	7.56	0.841	73.7	174.0	290
295	0.02617	1.002	51.94	2449	4.181	1.868	959	8.89	606	19.5	6.62	0.849	72.7	227.5	295
300	0.03531	1.003	39.13	2438	4.179	1.872	855	9.09	613	19.6	5.83	0.857	71.7	276.1	300
305	0.04712	1.005	29.74	2426	4.178	1.877	769	9.29	620	20.1	5.20	0.865	70.9	320.6	305
310	0.06221	1.007	22.93	2414	4.178	1.882	695	9.49	628	20.4	4.62	0.873	70.0	361.9	310
315	0.08132	1.009	17.82	2402	4.179	1.888	631	9.69	634	20.7	4.16	0.883	69.2	400.4	315
320	0.1053	1.011	13.98	2390	4.180	1.895	577	9.89	640	21.0	3.77	0.894	68.3	436.7	320
325	0.1351	1.013	11.06	2378	4.182	1.903	528	10.09	645	21.3	3.42	0.901	67.5	471.2	325
330	0.1719	1.016	8.82	2366	4.184	1.911	489	10.29	650	21.7	3.15	0.908	66.6	504.0	330
335	0.2167	1.018	7.09	2354	4.186	1.920	453	10.49	656	22.0	2.88	0.916	65.8	535.5	335
340	0.2713	1.021	5.74	2342	4.188	1.930	420	10.69	660	22.3	2.66	0.925	64.9	566.0	340
345	0.3372	1.024	4.683	2329	4.191	1.941	389	10.89	668	22.6	2.45	0.933	64.1	595.4	345
350	0.4163	1.027	3.846	2317	4.195	1.954	365	11.09	668	23.0	2.29	0.942	63.2	624.2	350
355	0.5100	1.030	3.180	2304	4.199	1.968	343	11.29	671	23.3	2.14	0.951	62.3	652.3	355
360	0.6209	1.034	2.645	2291	4.203	1.983	324	11.49	674	23.7	2.02	0.960	61.4	697.9	360
365	0.7514	1.038	2.212	2278	4.209	1.999	306	11.69	677	24.1	1.91	0.969	60.5	707.1	365
370	0.9040	1.041	1.861	2265	4.214	2.017	289	11.89	679	24.5	1.80	0.978	59.5	728.7	370
373.15	1.0133	1.044	1.679	2257	4.217	2.029	279	12.02	680	24.8	1.76	0.984	58.9	750.1	373.15
375	1.0815	1.045	1.574	2252	4.220	2.036	274	12.09	681	24.9	1.70	0.987	58.6	761	375
380	1.2869	1.049	1.337	2239	4.226	2.057	260	12.29	683	25.4	1.61	0.999	57.6	788	380
385	1.5233	1.053	1.142	2225	4.232	2.080	248	12.49	685	25.8	1.53	1.004	56.6	814	385

ตารางที่ ก.3 แสดงคุณสมบัติทางความร้อนของน้ำ [12]

ตารางที่ ข.4 แสดงคุณสมบัติของสารทำงาน R-134a [12]

Refrigerant 134a Properties of Saturated Liquid and Saturated Vapor

Temp	Pressure	Density kg/m^3	Volume m^3/kg	Enthalpy kJ/kg		Entropy kJ/(kg.K)		Speciffic Heat kJ/(kg.K)		Viscosity μ Pa.s		Thermal Cond mW/(m.K)		Surface Tension
°C	MPa	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	mN/m
-26.07b	0.10132	1374.3	0.19016	166.07	382.90	0.8701	1.7476	1.268	0.784	406.4	9.79	105.4	9.52	15.54
10.00	0.41449	1260.2	0.04948	213.53	404.40	1.0483	1.7224	1.367	0.930	254.3	11.42	88.8	12.66	10.30
12.00	0.44289	1253.3	0.04636	216.27	405.51	1.0579	1.7215	1.374	0.939	248.3	11.52	87.9	12.84	10.02
14.00	0.47276	1246.3	0.04348	219.03	406.61	1.0674	1.7207	1.381	0.950	242.5	11.62	87.0	13.02	9.74
16.00	0.50413	1239.3	0.04081	221.80	407.70	1.0770	1.7199	1.388	0.960	236.8	11.72	86.0	13.20	9.47
18.00	0.53706	1232.1	0.03833	224.59	408.78	1.0865	1.7191	1.396	0.971	231.2	11.82	85.1	13.39	9.19
20.00	0.57159	1224.9	0.03603	227.40	409.84	1.0960	1.7183	1.404	0.982	225.8	11.92	84.2	13.57	8.92
22.00	0.60777	1217.5	0.03388	230.21	410.89	1.1055	1.7176	1.412	0.994	220.5	12.03	83.3	13.76	8.65
24.00	0.64566	1210.1	0.03189	233.05	411.93	1.1149	1.7169	1.420	1.006	215.4	12.14	82.4	13.96	8.38
26.00	0.68531	1202.6	0.03003	235.90	412.95	1.1244	1.7162	1.429	1.018	210.4	12.25	81.4	14.15	8.11
28.00	0.72676	1194.9	0.02829	238.77	413.95	1.1338	1.7155	1.438	1.031	205.5	12.36	80.5	14.35	7.84
30.00	0.77008	1187.2	0.02667	241.65	414.94	1.1432	1.7149	1.447	1.044	200.7	12.48	79.6	14.56	7.57
32.00	0.81530	1179.3	0.02516	244.55	415.90	1.1527	1.7142	1.457	1.058	196.0	12.60	78.7	14.76	7.31
34.00	0.86250	1171.3	0.02374	247.47	416.85	1.1621	1.7135	1.467	1.073	191.4	12.72	77.7	14.97	7.05

Refrigerant 134a Properties of Saturated Liquid and Saturated Vapor (Continued)

Temp	Pressure	Density kg/m^3	Volume m^3/kg	Enthalpy kJ/kg		Entropy kJ/(kg.K)		Speciffic Heat kJ/(kg.K)		Viscosity μ Pa.s		Thermal Cond mW/(m.K)		Surface Tension
°C	MPa	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	mN/m
36.00	0.91172	1163.2	0.02241	250.41	417.78	1.1715	1.7129	1.478	1.088	186.9	12.84	72.9	15.19	6.78
38.00	0.96301	1154.9	0.02116	253.37	418.69	1.1809	1.7122	1.489	1.104	182.5	12.97	75.9	15.41	6.52
40.00	1.0165	1146.5	0.01999	256.35	419.58	1.1903	1.7115	1.500	1.120	178.2	13.10	75.0	15.64	6.27
42.00	1.0721	1137.9	0.01890	259.35	420.44	1.1997	1.7108	1.513	1.138	174.0	13.24	74.1	15.86	6.01
44.00	1.1300	1129.2	0.01786	262.38	421.28	1.2091	1.7101	1.525	1.156	169.8	13.38	73.1	16.10	5.76
46.00	1.1901	1120.3	0.01689	265.42	422.09	1.2185	1.7094	1.539	1.175	165.7	13.52	72.2	16.34	5.51
48.00	1.2527	1111.3	0.0159	268.49	422.88	1.2279	1.7086	1.553	1.196	161.7	13.67	71.3	16.59	5.26
50.00	1.3177	1102.0	0.01511	271.59	423.63	1.2373	1.7078	1.569	1.218	157.7	13.83	70.4	16.84	5.01
52.00	1.3852	1092.6	0.01430	274.71	424.35	1.2468	1.7070	1.585	1.241	153.8	13.99	69.5	17.10	4.76
54.00	1.4553	1082.9	0.01353	277.86	425.03	1.2562	1.7061	1.602	1.266	149.9	14.16	68.5	17.36	4.52
56.00	1.5280	1073.0	0.01280	281.04	425.68	1.2657	1.7051	1.621	1.293	146.1	14.33	67.6	17.63	4.28
58.00	1.6033	1062.8	0.01212	284.25	426.29	1.2752	1.7041	1.641	1.322	142.3	14.51	66.7	17.91	4.04
60.00	1.6815	1052.4	0.01146	287.49	426.86	1.2847	1.7031	1.663	1.354	138.6	14.71	65.8	18.19	3.81
62.00	1.7625	1041.7	0.01085	290.77	427.37	1.2943	1.7019	1.686	1.388	134.9	14.91	64.9	18.48	3.57

ตารางที่ ข.4 แสดงค่าคุณสมบัติของสารทำงาน R-134a (ต่อ)

Refrigerant 134a Properties of Saturated Liquid and Saturated Vapor (Continued)

Temp	Pressure	Density kg/m^3	Volume m^3/ kg	Enthalpy kJ/kg		Entropy kJ/(kg.K)		Speciffic Heat kJ/(kg.K)		Viscosity μ Pa.s		Thermal Cond mW/(m.K)		Surface Tension
°C	MPa	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	mN/m
64.00	1.8464	1030.7	0.01026	294.08	427.84	1.3039	1.7007	1.712	1.426	131.2	15.12	63.9	18.78	3.34
66.00	1.9334	1019.4	0.00970	297.44	428.25	1.3136	1.6993	1.740	1.468	127.5	15.35	63.0	19.09	3.12
68.00	2.0234	1007.7	0.00917	300.84	428.61	1.3234	1.6979	1.772	1.515	123.9	15.59	62.1	19.40	2.89
70.00	2.1165	995.6	0.00867	304.29	428.89	1.3332	1.6963	1.806	1.567	120.3	15.85	61.2	19.72	2.67
72.00	2.2130	983.1	0.00818	307.79	429.10	1.3430	1.6945	1.846	1.642	116.7	16.12	60.3	20.05	2.46
74.00	2.3127	970.0	0.00772	311.34	429.23	1.3530	1.6926	1.890	1.693	113.1	16.41	59.3	20.39	2.24
76.00	2.4159	956.5	0.00728	314.96	429.27	1.3631	1.6905	1.941	1.770	109.4	16.73	58.4	20.74	2.03
78.00	2.5277	942.3	0.00686	318.65	429.20	1.3733	1.6881	2.000	1.861	105.8	17.08	57.5	21.09	1.83
80.00	2.6331	927.4	0.00646	322.41	429.02	1.3837	1.6855	2.069	1.967	102.1	17.46	56.6	21.46	1.63
85.00	2.9259	886.2	0.00550	332.27	427.91	1.4105	1.6775	2.313	2.348	92.7	18.59	54.3	22.41	1.15
90.00	3.2445	836.9	0.00461	343.01	425.48	1.4392	1.6663	2.766	3.064	82.6	20.15	-	-	0.72
95.00	3.5916	771.6	0.00374	355.434	420.60	1.4720	1.6490	3.961	4.942	70.9	22.59	-	-	0.33
100.00	3.9721	646.7	0.00265	374.02	407.08	1.5207	1.6093	-	-	53.0	28.86	-	-	0.03

b= boiling point

ตารางที่ ข.4 แสดงค่าคุณสมบัติของสารทำงาน R-134a (ต่อ)

ภาคผนวก ค.
อื่นๆ

ตารางที่ ค.1 ค่าพลังงานแสงอาทิตย์และอุณหภูมิอากาศของจังหวัดพิษณุโลก จากกรมอุตุนิยมวิทยา

วัน/เดือน/ปี	เวลา	Global Radiation (W/m^2)	Ambient Temperature ($^{\circ}C$)
2/4/2008	6:00:00	8.2905	25.75
2/4/2008	6:30:00	46.0010	27.03
2/4/2008	7:00:00	116.8416	28.25
2/4/2008	7:30:00	204.0354	29.45
2/4/2008	8:00:00	291.0552	30.51
2/4/2008	8:30:00	371.8354	31.56
2/4/2008	9:00:00	466.5760	32.10
2/4/2008	9:30:00	535.4864	34.10
2/4/2008	10:00:00	589.2604	35.21
2/4/2008	10:30:00	679.1093	36.15
2/4/2008	11:00:00	761.5895	37.08
2/4/2008	11:30:00	812.1489	38.08
2/4/2008	12:00:00	840.8229	38.95
2/4/2008	12:30:00	845.1770	39.15
2/4/2008	13:00:00	817.9072	38.81
2/4/2008	13:30:00	772.8010	38.15
2/4/2008	14:00:00	721.5239	37.23
2/4/2008	14:30:00	658.9125	36.33
2/4/2008	15:00:00	593.3000	35.43
2/4/2008	15:30:00	484.1343	34.60
2/4/2008	16:00:00	348.8260	33.73
2/4/2008	16:30:00	251.6479	32.68
2/4/2008	17:00:00	161.4208	31.68
2/4/2008	17:30:00	76.1000	30.78
2/4/2008	18:00:00	24.5	29.58
2/4/2008	18:30:00	0	28.78

ตารางที่ ค.2 แสดงราคาท่อทองแดงชนิดเส้นตรง [11]

TYPE M (ASTM-B88) ความยาว 6 เมตร

SIZE (OD)	WALL THICKNESS	LIST PRICE
3/8"	0.022"	400
1/2"	0.025"	570
5/8"	0.028"	830
3/4"	0.030"	1,085
7/8"	0.032"	1,315
1-1/8"	0.035"	1,885
1-3/8"	0.042"	3,485
1-5/8"	0.050"	4,800
2-1/8"	0.060"	7,485
2-5/8"	0.070"	10,920
3-1/8"	0.080"	14,400

TYPE L (ASTM-B88) ความยาว 6 เมตร

SIZE(OD)	WALL THICKNESS	LIST PRICE
3/8"	0.030"	630
1/2"	0.035"	1,000
5/8"	0.040"	1,435
3/4"	0.042"	1,770
7/8"	0.045"	2,315
1-1/8"	0.050"	3,200
1-3/8"	0.055"	4,515
1-5/8"	0.060"	5,770
2-1/8"	0.070"	8,630
2-5/8"	0.080"	13,080
3-1/8"	0.090"	17,160

ตารางที่ ค.2 แสดงราคาท่อทองแดงชนิดเส้นตรง (ต่อ)

TYPE K (ASTM-B88) ความยาว 6 เมตร

SIZE(OD)	WALL THICKNESS	LIST PRICE
3/8"	0.035"	920
1/2"	0.049"	1,560
5/8"	0.049"	1,910
3/4"	0.049"	2,830
7/8"	0.065"	3,530
1-1/8"	0.065"	4,670
1-3/8"	0.065"	6,355
1-5/8"	0.072"	8,150
2-1/8"	0.083"	12,240
2-5/8"	0.095"	20,085
3-1/8"	0.109"	29,460