LAMPIRAN

Lampiran 1 *Coding* untuk simulasi

```
"! Inputs dan parameters :"

fluid$='r134a'
 M_dot = 0.5
 T_0=25
 T_ev = 60

  $ifnot parametrictable
T_cd = 25
  $endif

//p_ex_cd=1E5
//p_su_ev=8E5

pinch_ev = 6
pinch_cd = 6
hf$='air_ha'
//T_hf_su_ev = 85
p_hf_ev = 4E5
M_dot_hf = 2.57

//DELTAT_hf_ev = 15

cf$='water'
//T_cf_su_cd = 0
p_cf_cd = 2E5
M_dot_cf = 5
//DELTAT_cf_cd = 15

"Pressure drops di HE :"
DELTAp_ev = 0E3
DELTAp_cd = 0E3

"Overheating and subcooling :"
DELTAT_ex_ev = 0
DELTAT_ex_cd = 5

"Efisiensi :"
epsilon_exp = 0.8
epsilon_pp = 0.8
epsilon_rec = 0

r_p = p_su_exp/p_ex_exp
r_v = rho_su_exp/rho_ex_exp
```

"!First processing : "

"Tekanan saturasi :"
p_su_ev=P_sat(fluid$,T=T_ev)
//T_ev = T_sat(fluid$,p=p_su_ev)
//T_cd = T_sat(fluid$,p=p_ex_cd)
p_ex_cd=P_sat(fluid$,T=T_cd)

DELTAp_ev = p_su_ev - p_su_exp
DELTAp_cd = p_ex_exp - p_ex_cd
p_bar_ev = (p_su_ev + p_su_exp)/2
p_bar_cd = (p_ex_exp + p_ex_cd)/2
DELTAT_ex_ev = T_su_exp - t_sat(fluid$,p=p_su_exp)
DELTAT_ex_cd = T_sat(fluid$,p=p_ex_cd) - T_ex_cd

"!Turbin :"
h_su_exp = enthalpy(fluid$,t=t_su_exp,x=1)
s_su_exp = entropy(fluid$,t=t_su_exp,x=xs)
epsilon_exp = (h_su_exp - h_ex_exp)/(h_su_exp - h_ex_exp_s)
h_ex_exp_s = enthalpy(fluid$,p=p_ex_exp,s=s_su_exp)
t_ex_exp = temperature(fluid$,p=p_ex_exp,h=h_ex_exp)
rho_ex_exp = density(fluid$,p=p_ex_exp,X=1)
rho_su_exp = density(fluid$,p=p_su_exp,x=xs)

"!Kondensor : "
"Asumsi pressure drop terdistribusi merata pada HE terhadap perubahan entalpi :"

h_su_cd = h_ex_vap_rec
T_su_cd = T_ex_vap_rec
h_ex_cd = enthalpy(fluid$,p=p_ex_cd,t=t_ex_cd)
h_cd_v = enthalpy(fluid$,p=p_cd_v,x=1)
h_cd_l = enthalpy(fluid$,p=p_cd_l,x=0)
p_cd_v = p_ex_exp - DELTAp_cd * (h_ex_exp - h_cd_v)/(h_ex_exp - h_ex_cd)
p_cd_l = p_ex_exp - DELTAp_cd * (h_ex_exp - h_cd_l)/(h_ex_exp - h_ex_cd)
T_cd_v = temperature(fluid$,p=p_cd_v,x=1)
T_cd_l = temperature(fluid$,p=p_cd_l,x=0)

h_cf_su_cd = enthalpy(cf$,t=t_cf_su_cd,p=p_cf_cd)
M_dot_cf * (h_cf_ex_cd - h_cf_su_cd) = M_dot * (h_su_cd - h_ex_cd)
M_dot_cf * (h_cf_su_tp - h_cf_su_cd) =M_dot * (h_cd_l - h_ex_cd)
M_dot_cf * (h_cf_ex_tp - h_cf_su_cd) = M_dot * (min(h_cd_v,h_su_cd) - h_ex_cd)

T_cf_ex_cd = temperature(cf$,h=h_cf_ex_cd,p=p_cf_cd)

```
T_cf_su_tp = temperature(cf$,h=h_cf_su_tp,p=p_cf_cd)
T_cf_ex_tp = temperature(cf$,h=h_cf_ex_tp,p=p_cf_cd)

DELTAT_cf_cd = T_cf_ex_cd - T_cf_su_cd
pinch_cd = min(T_ex_cd - T_cf_su_cd,T_cd_v - T_cf_ex_tp,T_su_cd - T_cf_ex_cd)

"! Pump :"
h_su_pp = h_ex_cd
v_su_pp = volume(fluid$,p=p_ex_cd,h=h_ex_cd)
T_su_pp = Temperature(fluid$,p=p_ex_cd,h=h_ex_cd)
s_su_pp = entropy(fluid$,p=p_ex_cd,h=h_ex_cd)
h_ex_pp = h_su_pp + v_su_pp*(p_su_ev-p_ex_cd)/epsilon_pp

"Second method:"
h_ex_pp_s = enthalpy(fluid$,s=s_su_pp,p=p_su_ev)
epsilon_pp = (h_ex_pp_s- h_su_pp)/(h_ex_pp_bis - h_su_pp)

t_ex_pp = temperature(fluid$,h=h_ex_pp,p=p_su_ev)
s_ex_pp=entropy(fluid$,p=p_su_ev, t=t_su_ev)

"! Recuperator :"
"Pressure drop :"
DELTAp_vap_rec = DELTAp_cd * (h_ex_exp - h_ex_vap_rec)/(h_ex_exp - h_ex_cd)
p_ex_vap_rec = p_su_vap_rec - DELTAp_vap_rec

p_su_vap_rec = p_ex_exp

h_su_liq_rec = h_ex_pp
T_su_liq_rec = T_ex_pp
p_liq_rec = p_su_ev

H_su_vap_rec = h_ex_exp
T_su_vap_rec = T_ex_exp
p_vap_rec = (p_su_vap_rec + p_ex_vap_rec)/2

cp_liq_rec = cp(fluid$,t=t_su_liq_rec,p=p_liq_rec)
cp_vap_rec = cp(fluid$,t=t_su_vap_rec,X=1)

C_dot_liq_rec = M_dot * cp_liq_rec
C_dot_vap_rec = M_dot * cp_vap_rec

C_dot_min_rec = min(C_dot_liq_rec,C_dot_vap_rec)
C_dot_max_rec=max(C_dot_liq_rec,C_dot_vap_rec)
Q_dot_rec = epsilon_rec * C_dot_min_rec * (T_su_vap_rec - T_su_liq_rec)

Q_dot_rec = M_dot * (h_su_vap_rec - h_ex_vap_rec)
```

```
Q_dot_rec = m_dot * (h_ex_liq_rec - h_su_liq_rec)

T_ex_vap_rec = temperature(fluid$,h=h_ex_vap_rec,p=p_vap_rec)
T_ex_liq_rec = temperature(fluid$,h=h_ex_liq_rec,p=p_liq_rec)


"! Evaporator :"
h_su_ev = h_ex_liq_rec
T_su_ev = T_ex_liq_rec
h_ex_ev  = h_su_exp
h_ev_l = enthalpy(fluid$,p=p_ev_l,x=0)
h_ev_v = enthalpy(fluid$,p=p_ev_v,x=1)
p_ev_l = p_su_exp + DELTAp_ev * (h_ex_ev - h_ev_l)/(h_ex_ev - h_su_ev)
p_ev_v = p_su_exp + DELTAp_ev * (h_ex_ev - h_ev_v)/(h_ex_ev - h_su_ev)
T_ev_l = temperature(fluid$,x=0,p=p_ev_l)
T_ev_v = temperature(fluid$,x=1,p=p_ev_v)

"secondary fluid :"
h_hf_su_ev = enthalpy(hf$,t=t_hf_su_ev,p=p_hf_ev)
M_dot_hf * (h_hf_su_ev - h_hf_ex_ev) = M_dot * (h_ex_ev - h_su_ev)
M_dot_hf * (h_hf_su_ev - h_hf_ex_tp) = M_dot * (h_ex_ev - h_ev_l)
M_dot_hf * (h_hf_su_ev - h_hf_su_tp) = M_dot * (h_ex_ev - h_ev_v)

T_hf_ex_ev = temperature(hf$,h=h_hf_ex_ev,p=p_hf_ev)
T_hf_ex_tp = temperature(hf$,h=h_hf_ex_tp,p=p_hf_ev)
T_hf_su_tp = temperature(hf$,h=h_hf_su_tp,p=p_hf_ev)
DELTAT_hf_ev = T_hf_su_ev - T_hf_ex_ev

pinch_ev = min(T_hf_ex_ev - T_su_ev,T_hf_ex_tp - T_ev_l,T_hf_su_tp - T_su_exp)

"!T-s diagram :"
s[1] = entropy(fluid$,t=t_ex_pp,p=p_su_ev)
t[1] = t_ex_pp
p[1] = p_su_ev
h[1] = h_ex_pp

s[2] = entropy(fluid$,t=t_ex_liq_rec,p=p_su_ev)
t[2] = t_ex_liq_rec
p[2] = p_su_ev
h[2] = h_ex_liq_rec

s[3] = entropy(fluid$,p=p_ev_l,x=0)
t[3] = t_ev_l
p[3] = p_ev_l
h[3] = h_ev_l
```

```
s[4] = entropy(fluid$,p=p_ev_v,x=1)
t[4] = t_ev_v
h[4] = h_ev_v
p[4] = p_ev_v

s[5] = s_su_exp
t[5] = t_su_exp
h[5] = h_su_exp
p[5] = p_su_exp
mu[5] = viscosity(fluid$,t=t_su_exp,x=xs)
k[5] = conductivity(fluid$,t=t_su_exp,x=xs)

s[6] = entropy(fluid$,h=h_ex_exp,p=p_ex_exp)
t[6] = T_ex_exp
h[6] = h_ex_exp
p[6]= p_ex_exp
mu[6] = viscosity(fluid$,t=t_ex_exp,X=XQ)
k[6] = conductivity(fluid$,t=t_ex_exp,X=XQ)
rho[6] = density(fluid$,t=t_ex_exp,X=1)

s[7] = entropy(fluid$,h=h_ex_vap_rec,p=p_ex_vap_rec)
t[7] = T_ex_vap_rec
h[7] = h_ex_vap_rec
p[7]= p_ex_vap_rec

s[8] = min(s[5],entropy(fluid$,p=p_cd_v,x=1))
t[8] = t_cd_v
h[8] = min(h_ex_exp,h_cd_v)
p[8] = min(p_ex_exp,p_cd_v)

s[9] = entropy(fluid$,p=p_cd_l,x=0)
t[9] = t_cd_l
h[9] = h_cd_l
p[9] = p_cd_l

s[10] = entropy(fluid$,h=h_ex_cd,p=p_ex_cd)
t[10] = t_ex_cd
h[10] = h_ex_cd
p[10] = p_ex_cd

s[11] = s[1]
t[11] = t[1]
h[11] = h[1]
p[11] = p[1]

"T profile pada HE :"
T_hf[2] = T_hf_ex_ev
T_hf[3] = T_hf_ex_tp
```

```
T_hf[4] = T_hf_su_tp
T_hf[5] = T_hf_su_ev

T_cf[7] = T_cf_ex_cd
T_cf[8] = T_cf_ex_tp
T_cf[9] = T_cf_su_tp
T_cf[10] = T_cf_su_cd

"! Efisiensi : "
w_exp = h_su_exp - h_ex_exp
w_pp = h_ex_pp - h_su_pp
w_net = w_exp - w_pp
q_ev = h_ex_ev - h_su_ev
eta_cycle = (w_exp - w_pp)*100/q_ev

W_dot_net = w_net * M_dot
W_dot_exp = w_exp * M_dot
W_dot_pp = w_pp * M_dot
Q_dot_ev=q_ev*M_dot
Q_dot_cond=M_dot*(h_ex_exp-h_su_pp)

"! Second law efficiency:"
E_dot_hf = M_dot_hf *( (h_hf_su_ev - h_hf_0) - T_0 * (s_hf_su_ev - s_hf_0))
s_hf_su_ev = entropy(hf$,h=h_hf_su_ev,p=p_hf_ev)
h_hf_0 = enthalpy(hf$,T=T_0,p=p_hf_ev)
s_hf_0 = entropy(hf$,t=t_0,p=p_hf_ev)


"Exergy destruction di evaporator"
Exd_ev = T_0 * (m_dot*(s_su_exp-s_su_ev) - m_dot_hf * (s_hf_ex_ev-s_hf_su_ev))
s_su_ev = entropy(fluid$, T=T_su_ev, P=P_su_ev)
s_hf_ex_ev = entropy(hf$, T=T_hf_ex_ev, P=P_hf_ev)

"Exergy destruction di expander"
Exd_exp=T_0*m_dot*(s_ex_exp-s_su_exp)
s_ex_exp=entropy(fluid$, T=T_ex_exp, X=1)

"Exergy destruction di kondensor"
Exd_cd = T_0 * (m_dot*(s_ex_exp-s_su_pp) - m_dot_hf * (s_cf_ex_cd-s_cf_su_cd))
s_cf_su_cd = entropy(cf$, T=T_cf_su_cd, P=P_cf_cd)
s_cf_ex_cd= entropy(cf$, T=T_cf_ex_cd, P=P_cf_cd)

"Exergy destruction di pompa"
Exd_pp= T_0*m_dot*(s_ex_pp-s_su_pp)
```

"Exergy destruction total"
Ed_total=Exd_ev+Exd_exp+Exd_cd+Exd_pp
eta_II = W_dot_net*100/E_dot_hf

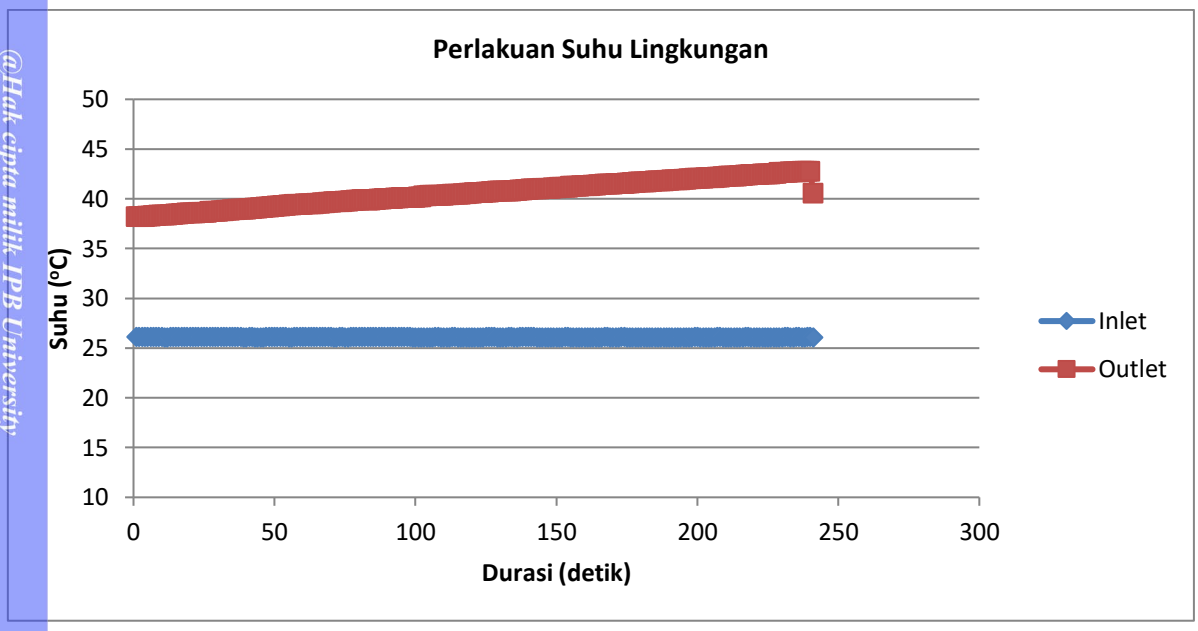
"! Fluid quality at the end of the expansion :"

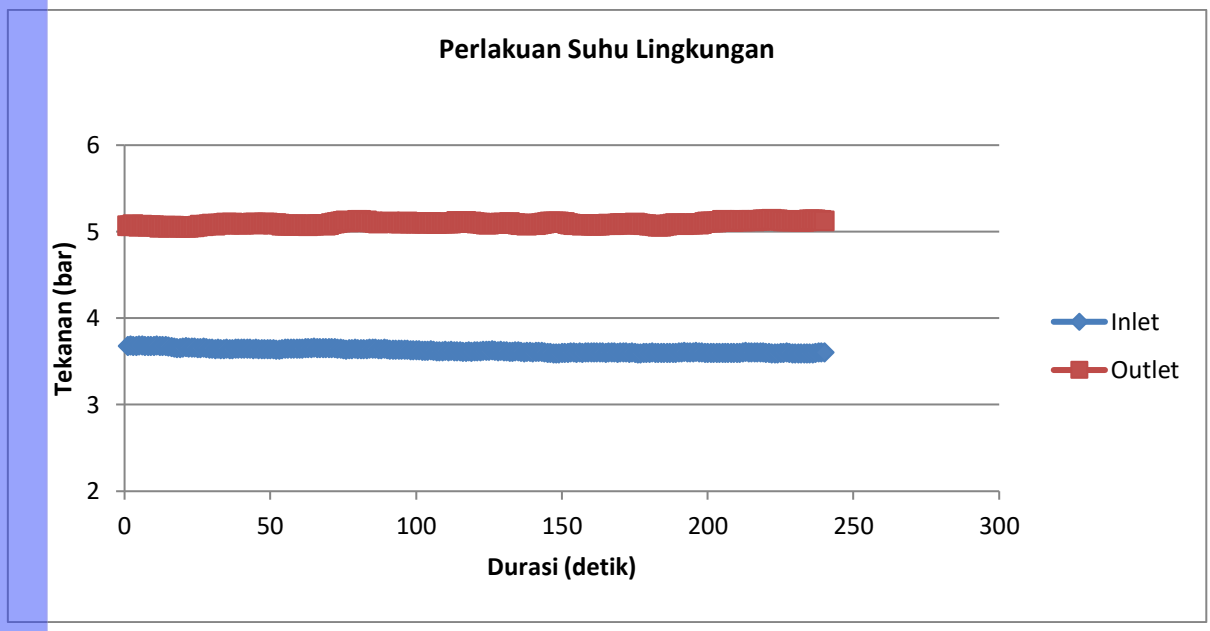
xs = quality(fluid$,h=h_su_exp,p=p_su_exp)
xQ = quality(fluid$,h=h_ex_exp,p=p_ex_exp)

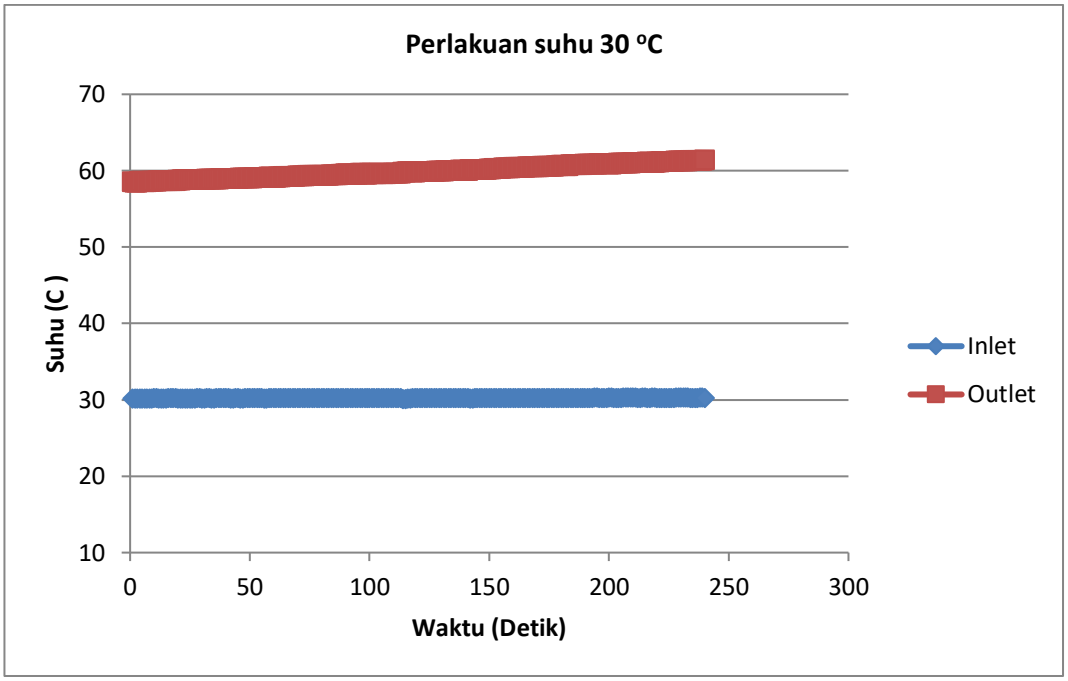
TC=T_crit(fluid$)
PC=P_crit(fluid$)*convert(Pa,Bar)
Hfg=Enthalpy_vaporization(fluid$,T=T_ev)
Qhfg= m_dot*Hfg
Qsen= m_dot*(h_ev_l-h_su_ev)

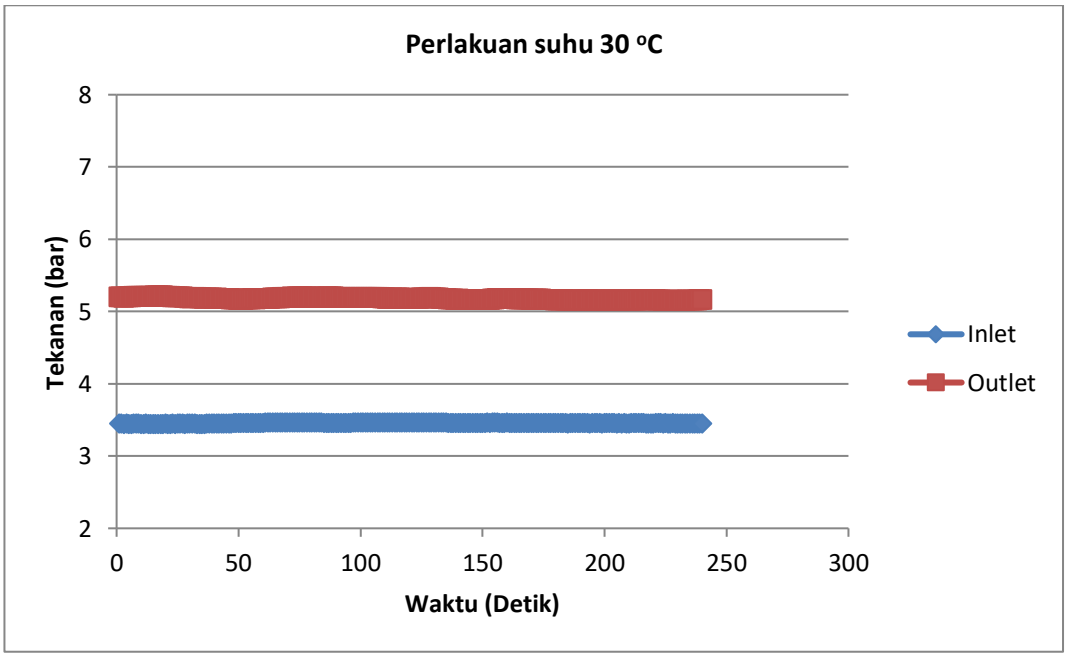
T_nb=NormalBoilingPt(fluid$)
cp=Cp(fluid$,T=25,P=100000)
cv=Cv(fluid$,T=25,P=100000)
Vs=Volume(fluid$,t=t_su_exp,x=1)
s2=Entropy(fluid$,T=T_cd,x=1)
Jenis = (s_su_exp - s2)/(T_ev - T_cd)

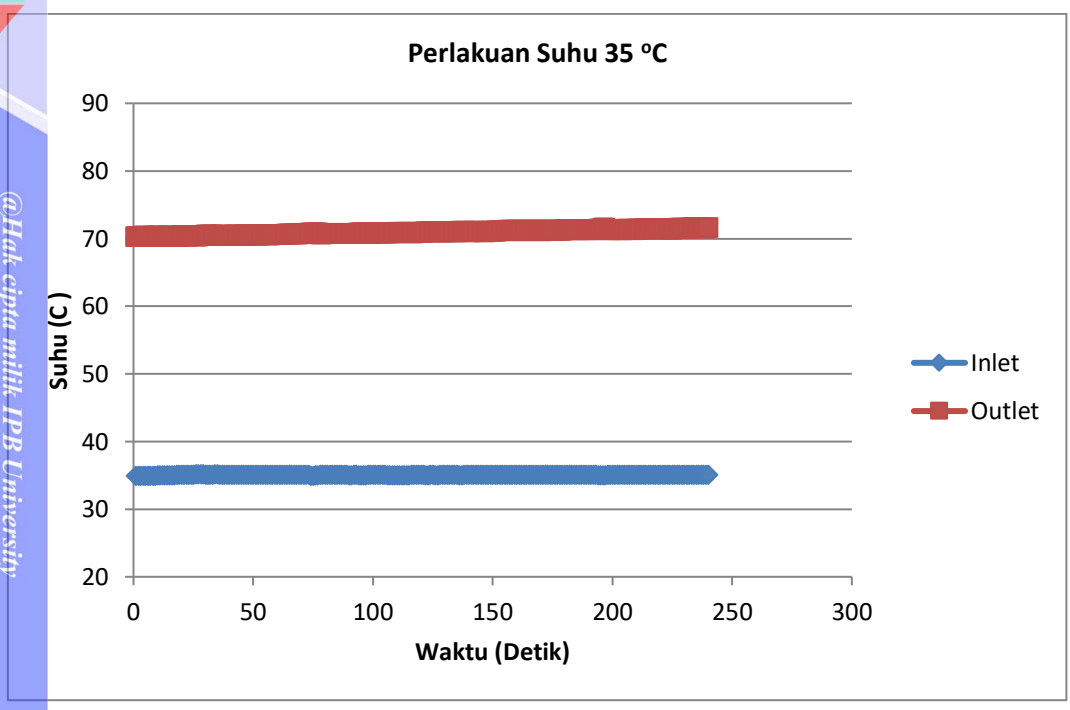
Lampiran 2 Data pengukuran uji kinerja siklus kompressi

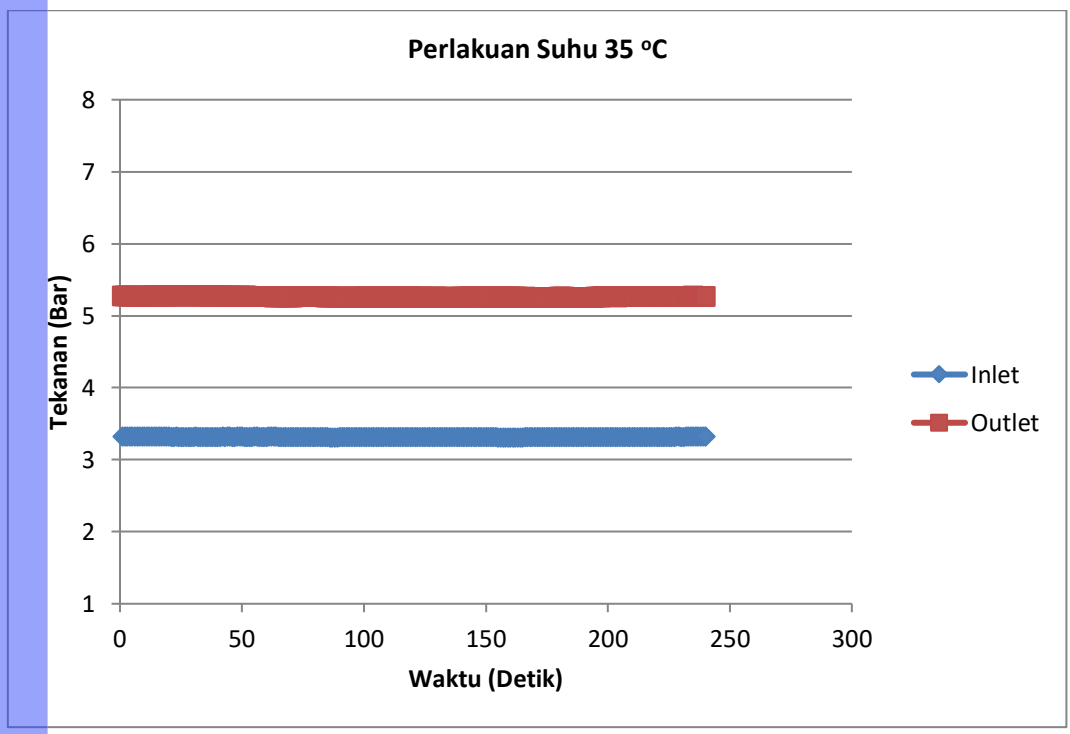


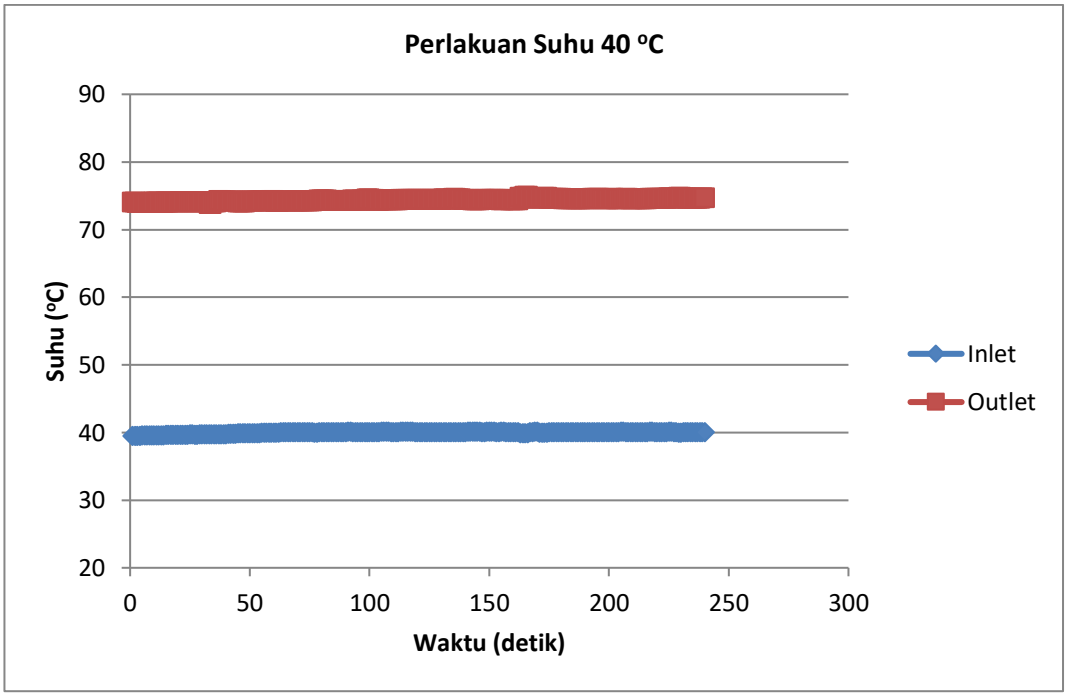


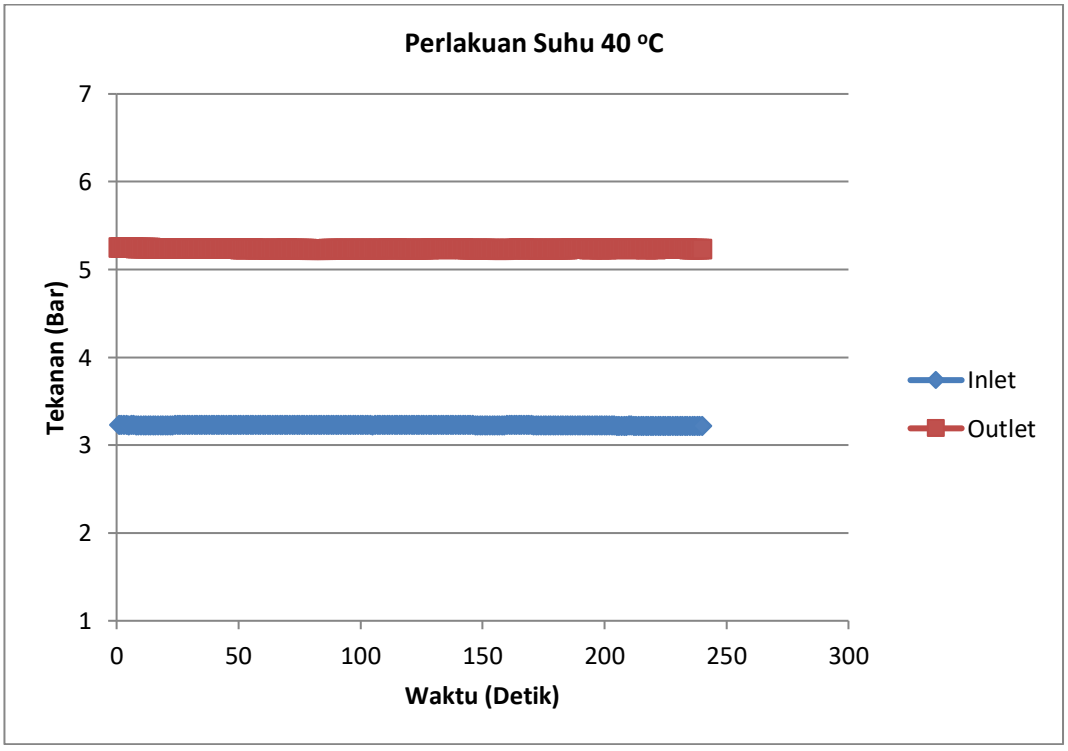


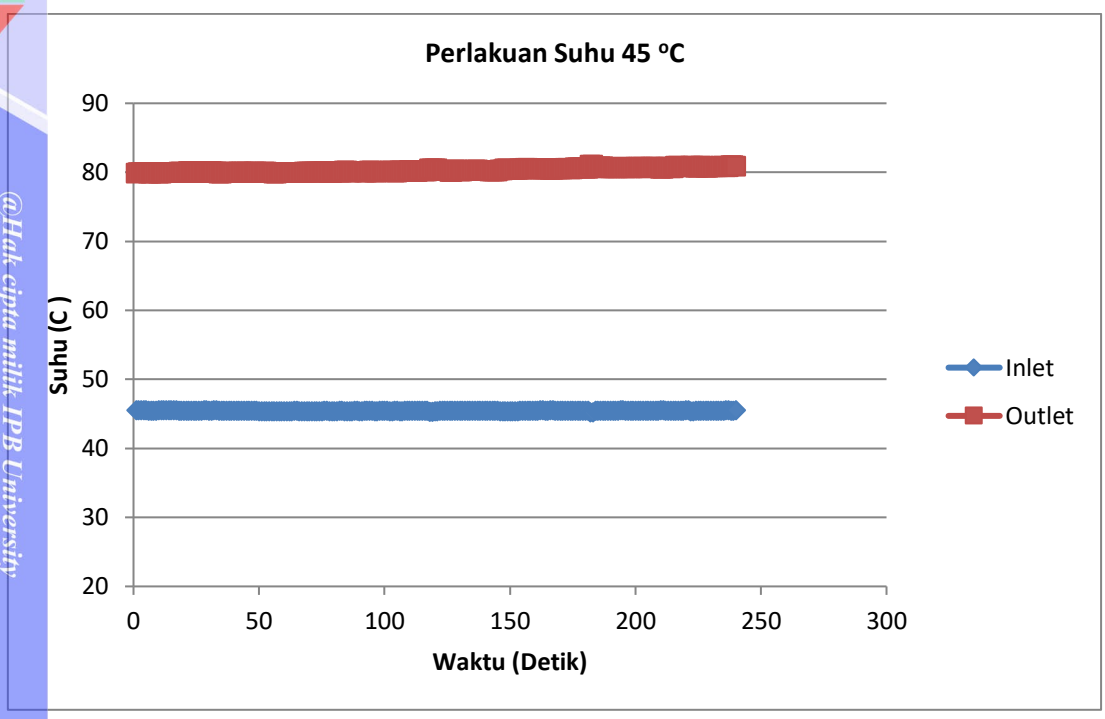


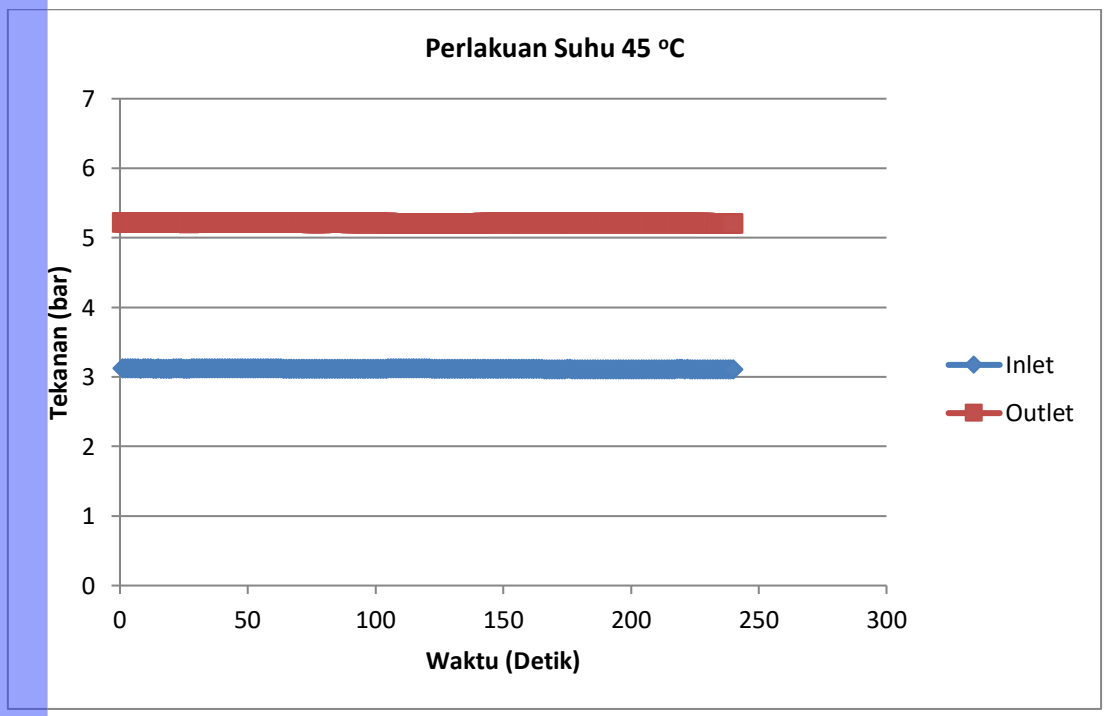


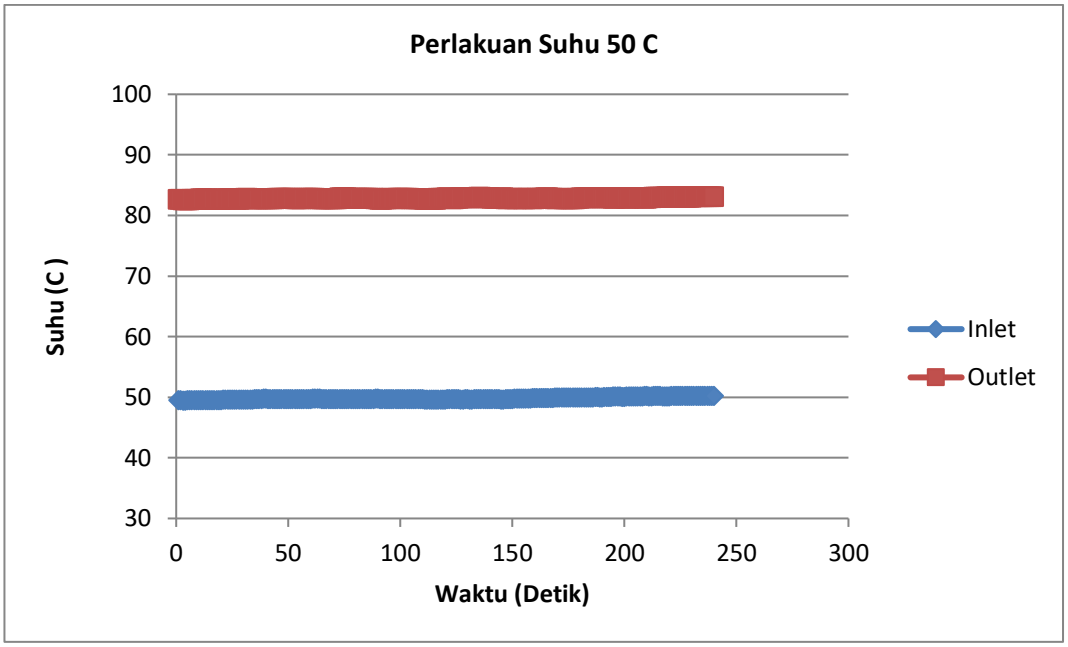


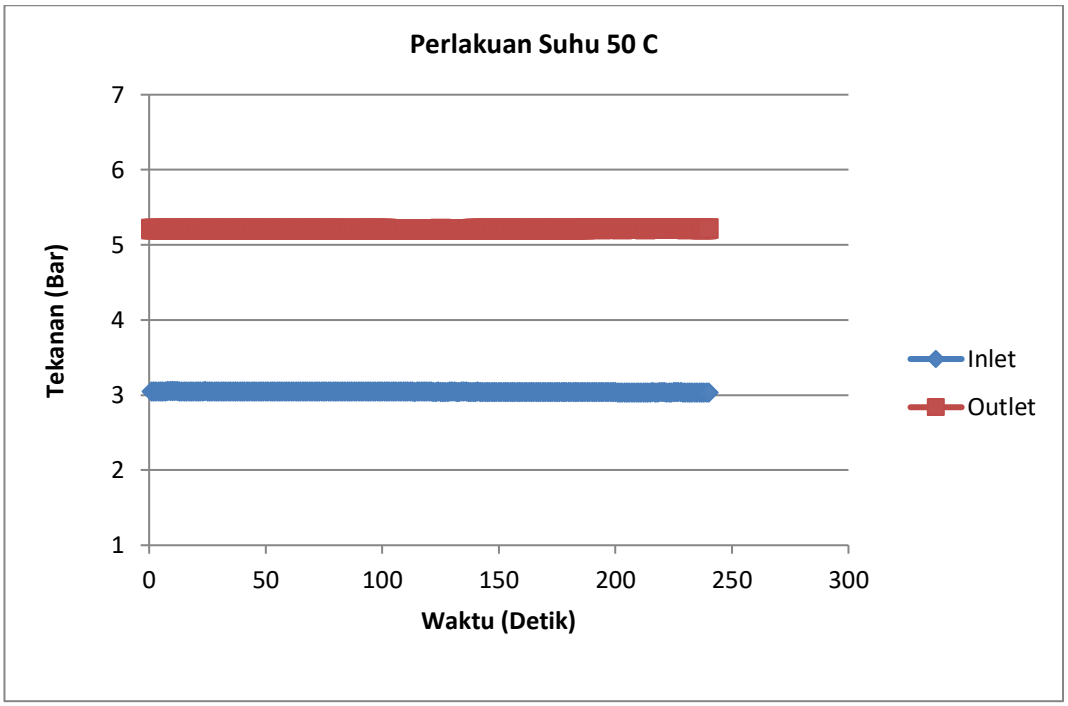










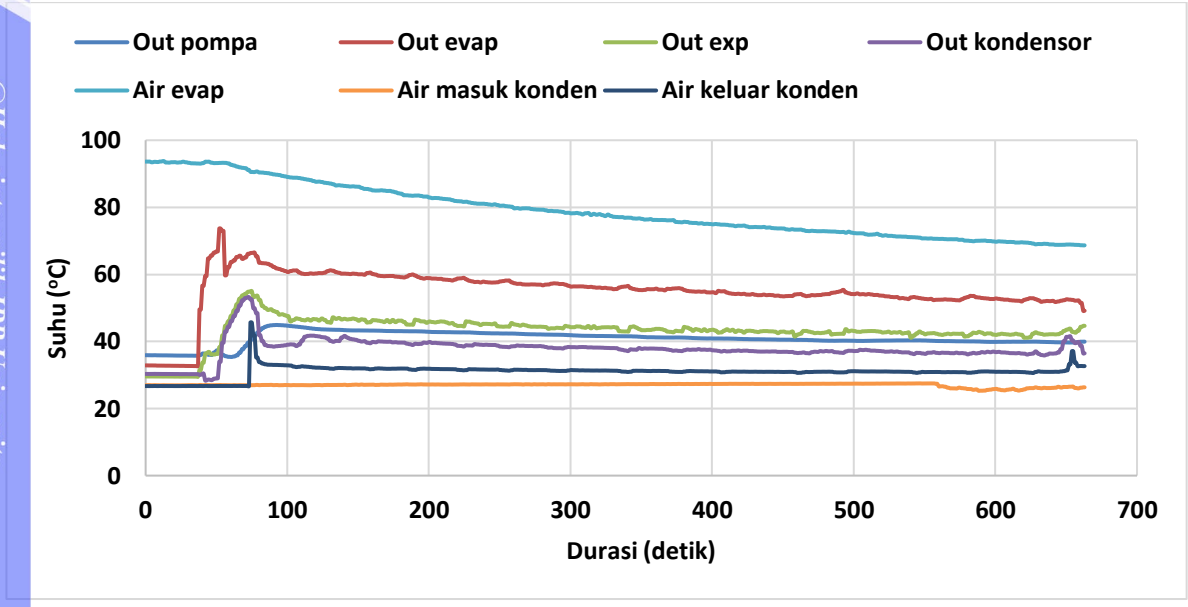


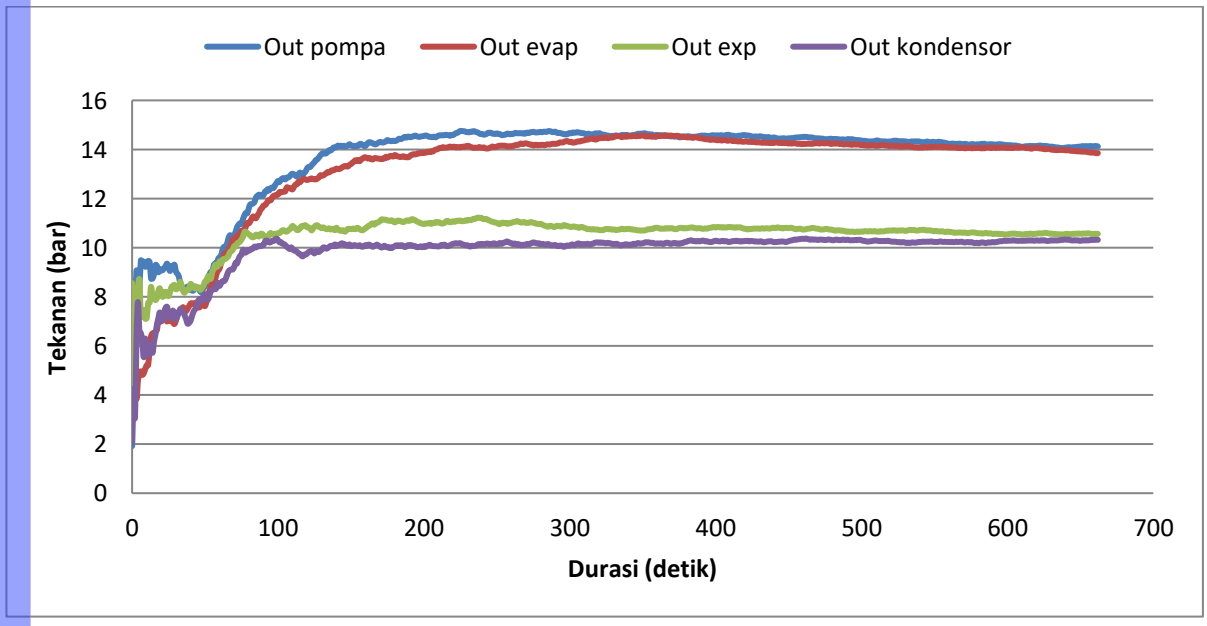
Lampiran 3 Hasil pengukuran daya dan debit siklus kompressi

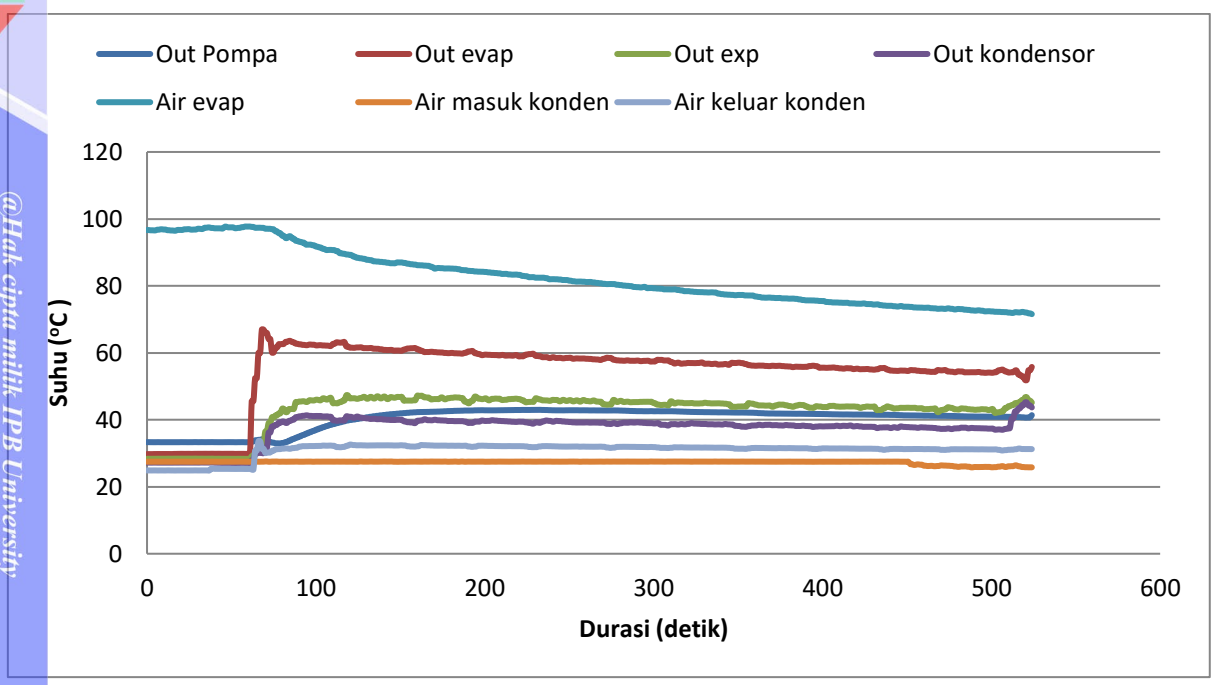
Suhu Lingkungan						Suhu 30						Suhu 35				
Ulangan Ke		Arus (A)	Debit (LPM)	Daya Input (watt)	Daya Aktual (watt)	Ulangan Ke		Arus (A)	Debit (LPM)	Daya Input (watt)	Daya Aktual (watt)	Ulangan Ke		Arus (A)	Debit (LPM)	Daya Input (watt)	Daya Aktual (watt)
1		2.71	1.0	1516.12	1137.09	1		2.75	1.0	1538.49	1153.87	1		2.79	1.1	1560.87	1170.65
		2.69	1.0	1504.93	1128.70			2.75	1.0	1538.49	1153.87			2.72	1.0	1521.71	1141.28
		2.68	1.0	1499.33	1124.50			2.75	1.0	1538.49	1153.87			2.74	1.0	1532.90	1149.67
		2.72	1.0	1521.71	1141.28			2.75	1.0	1538.49	1153.87			2.73	1.1	1527.31	1145.48
Rata-Rata		**2.70**	**1.0**	**1510.52**	**1132.89**	**Rata-Rata**		**2.75**	**1.0**	**1538.49**	**1153.87**	**Rata-Rata**		**2.75**	**1.1**	**1535.70**	**1151.77**
2		2.72	1.0	1521.71	1141.28	2		2.77	1.0	1549.68	1162.26	2		2.73	1.1	1527.31	1145.48
		2.74	1.0	1532.90	1149.67			2.76	1.0	1544.09	1158.07			2.74	1.1	1532.90	1149.67
		2.75	1.0	1538.49	1153.87			2.76	1.0	1544.09	1158.07			2.72	1.1	1521.71	1141.28
		2.75	1.0	1538.49	1153.87			2.78	1.0	1555.28	1166.46			2.74	1.1	1532.90	1149.67
Rata-Rata		**2.74**	**1.0**	**1532.90**	**1149.67**	**Rata-Rata**		**2.77**	**1.0**	**1548.28**	**1161.21**	**Rata-Rata**		**2.73**	**1.1**	**1528.70**	**1146.53**

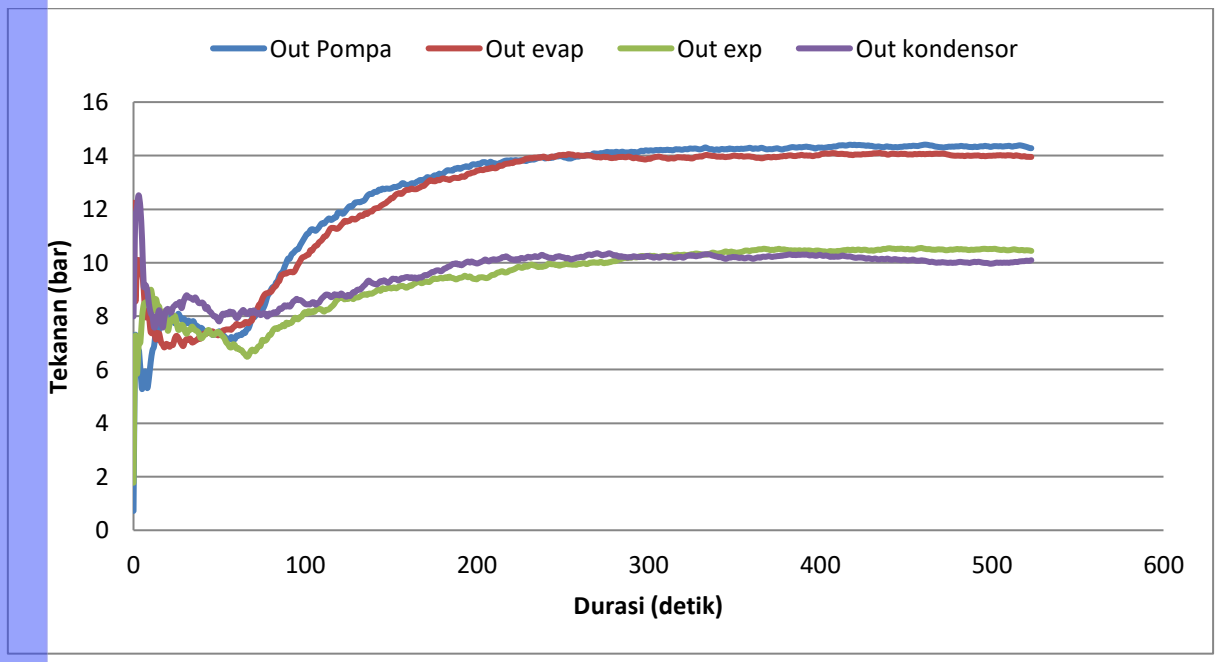
Suhu 40						Suhu 45						Suhu 45				
Ulangan Ke		Arus (A)	Debit (LPM)	Daya Input (watt)	Daya Aktual (watt)	Ulangan Ke		Arus (A)	Debit (LPM)	Daya Input (watt)	Daya Aktual (watt)	Ulangan Ke		Arus (A)	Debit (LPM)	Daya Input (watt)	Daya Aktual (watt)
1		2.71	1.0	1516.12	1137.09	1		2.72	1.0	1521.71	1141.28	1		2.73	1.1	1527.31	1145.48
		2.71	1.0	1516.12	1137.09			2.72	1.0	1521.71	1141.28			2.74	1.1	1532.90	1149.67
		2.72	1.0	1521.71	1141.28			2.71	1.1	1516.12	1137.09			2.73	1.0	1527.31	1145.48
		2.72	1.0	1521.71	1141.28			2.72	1.1	1521.71	1141.28			2.72	1.0	1521.71	1141.28
Rata-Rata		**2.72**	**1.0**	**1518.91**	**1139.18**	**Rata-Rata**		**2.72**	**1.1**	**1520.31**	**1140.23**	**Rata-Rata**		**2.73**	**1.1**	**1527.31**	**1145.48**
2		2.74	1.1	1532.90	1149.67	2		2.72	1.1	1521.71	1141.28	2		2.72	1.0	1521.71	1141.28
		2.74	1.0	1532.90	1149.67			2.72	1.1	1521.71	1141.28			2.72	1.0	1521.71	1141.28
		2.72	1.1	1521.71	1141.28			2.72	1.1	1521.71	1141.28			2.72	1.0	1521.71	1141.28
		2.72	1.1	1521.71	1141.28			2.72	1.1	1521.71	1141.28			2.72	1.0	1521.71	1141.28
Rata-Rata		**2.73**	**1.1**	**1527.31**	**1145.48**	**Rata-Rata**		**2.72**	**1.1**	**1521.71**	**1141.28**	**Rata-Rata**		**2.72**	**1.0**	**1521.71**	**1141.28**

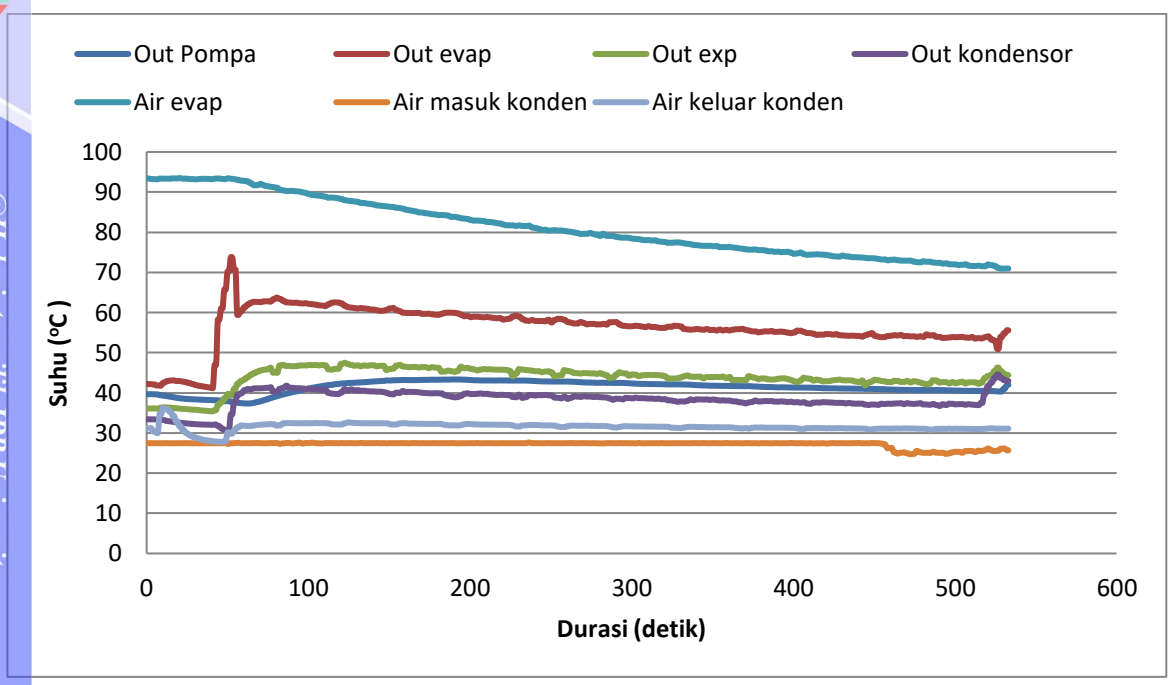
Lampiran 4 Hasil pengukuran suhu dan tekanan siklus ekspansi

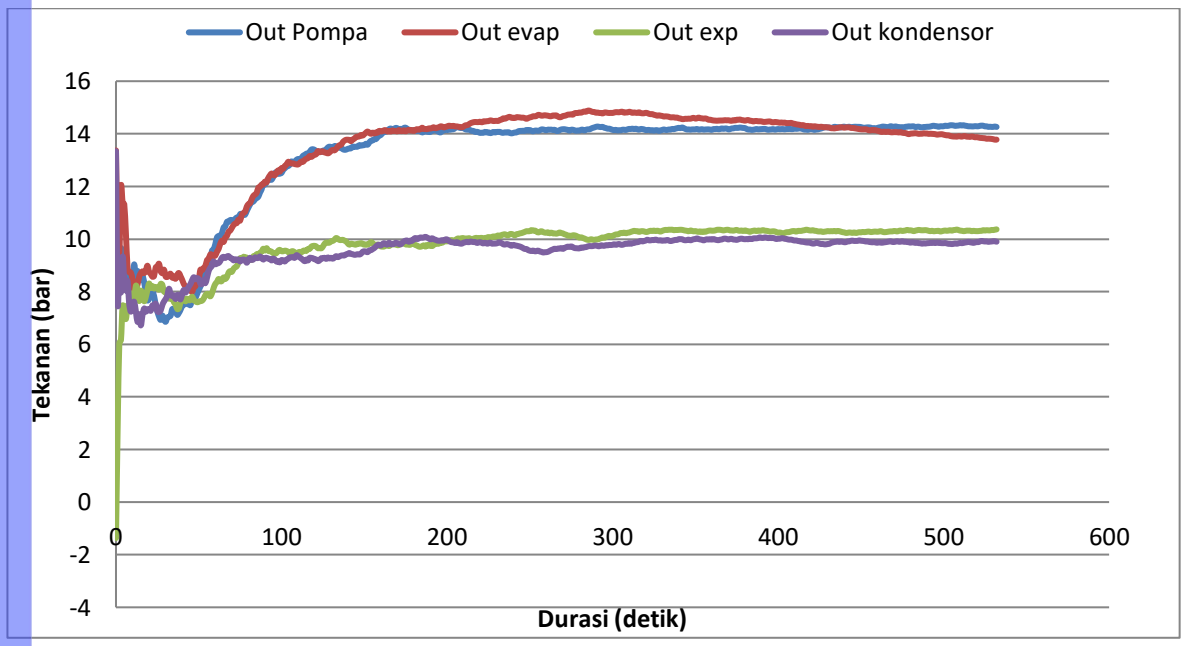






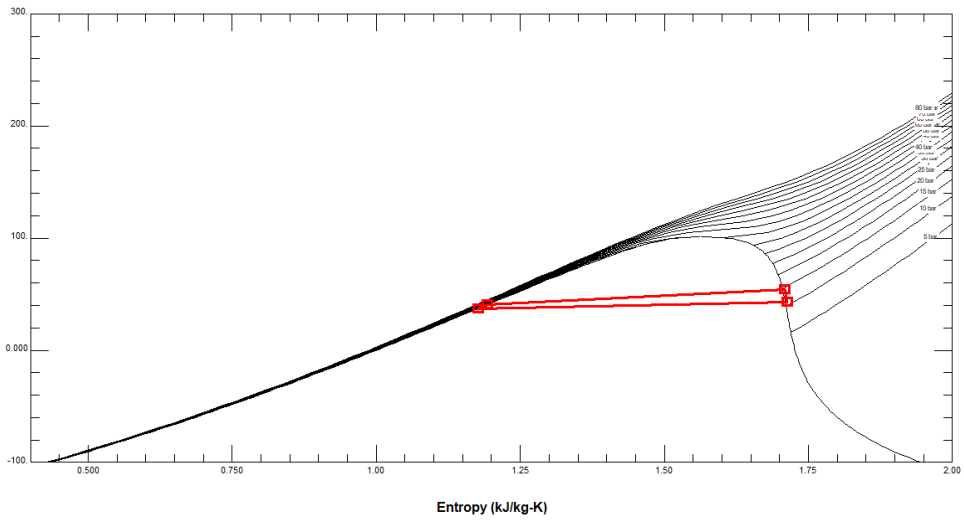


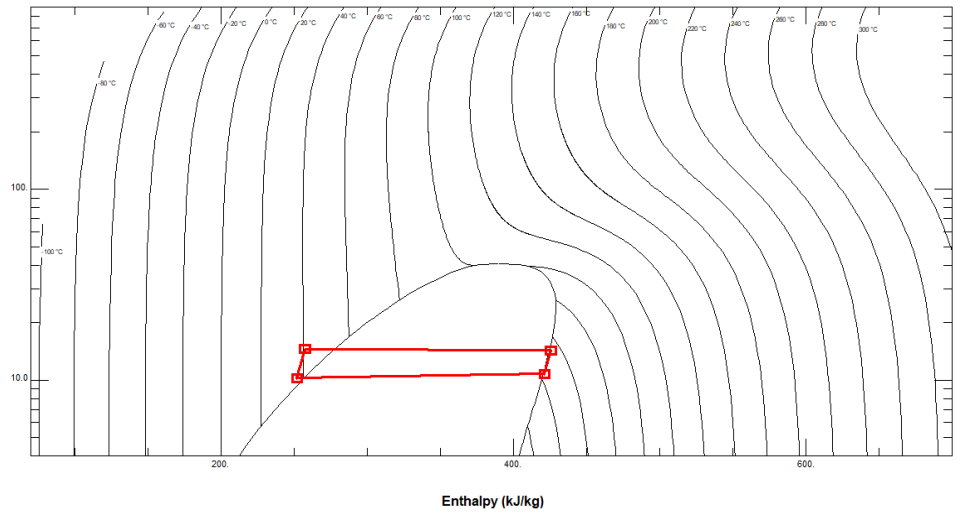




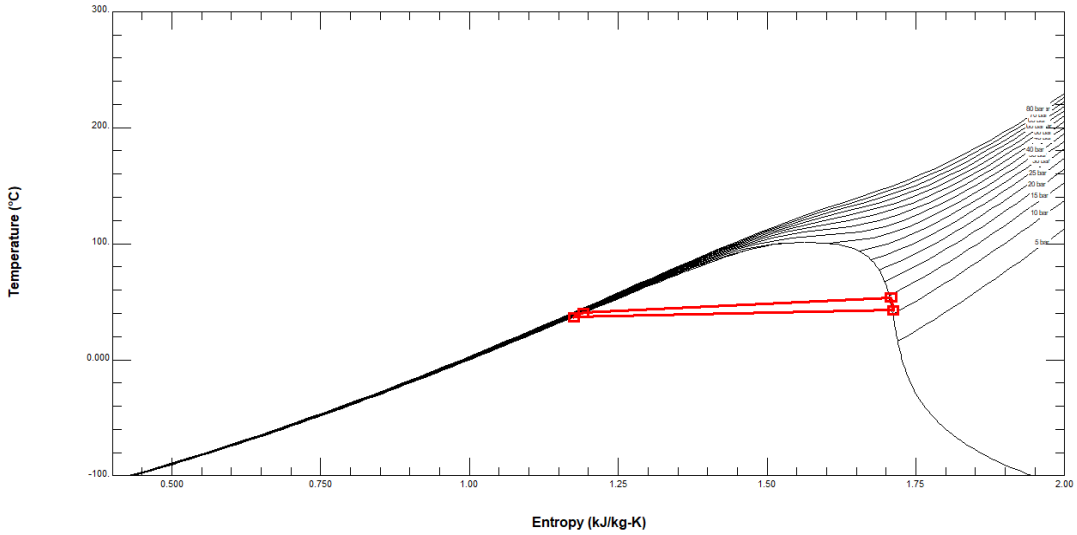
Lampiran 5 Hasil ploting kinerja SRO ke diagram P-h dan T-s

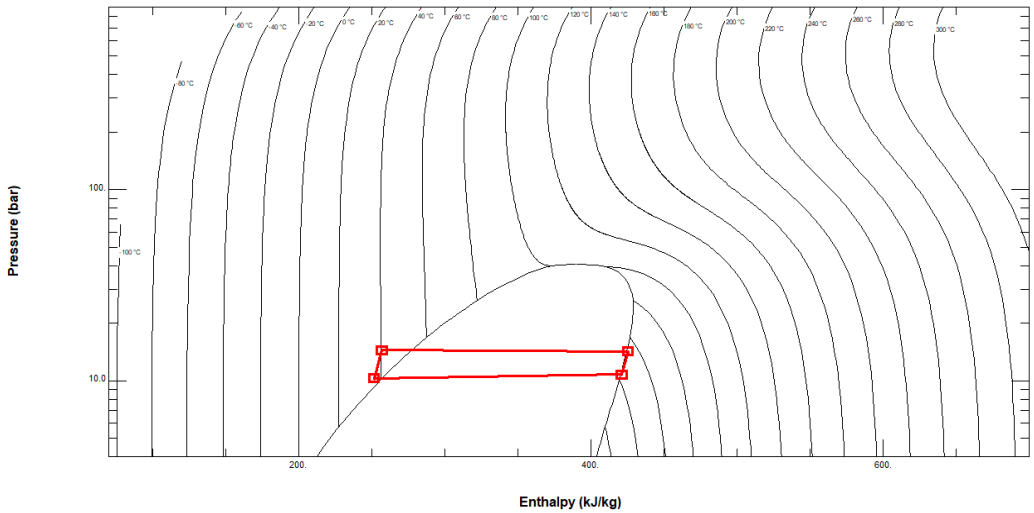
		T (C)	P (Bar)
Pompa	1	40.76	14.55
Evaporator	2	54.26	14.33
Ekspander	3	43.09	10.80
Kondensor	4	37.14	10.26
Pompa	5	40.76	14.55



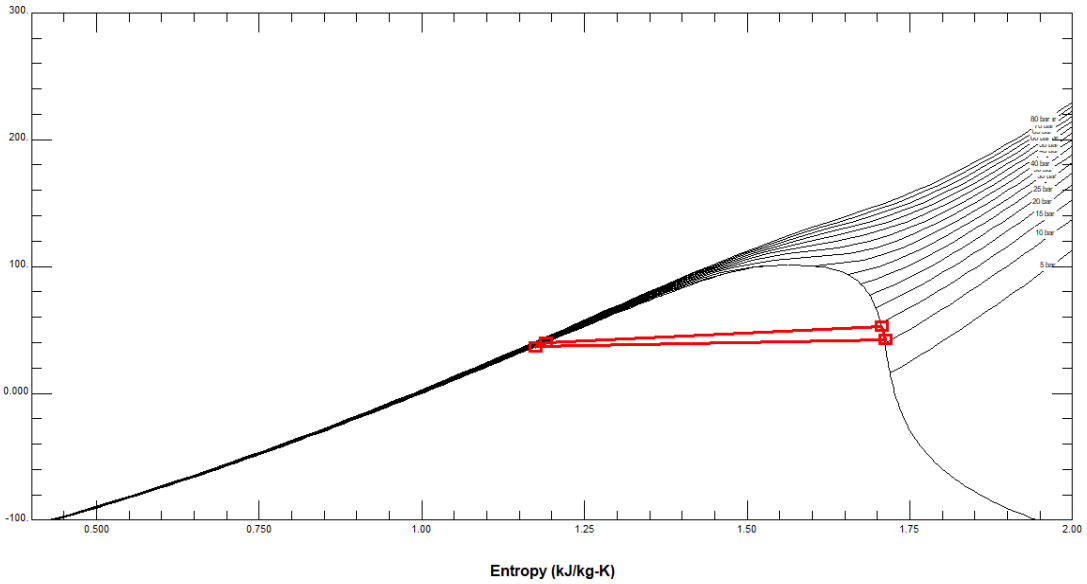


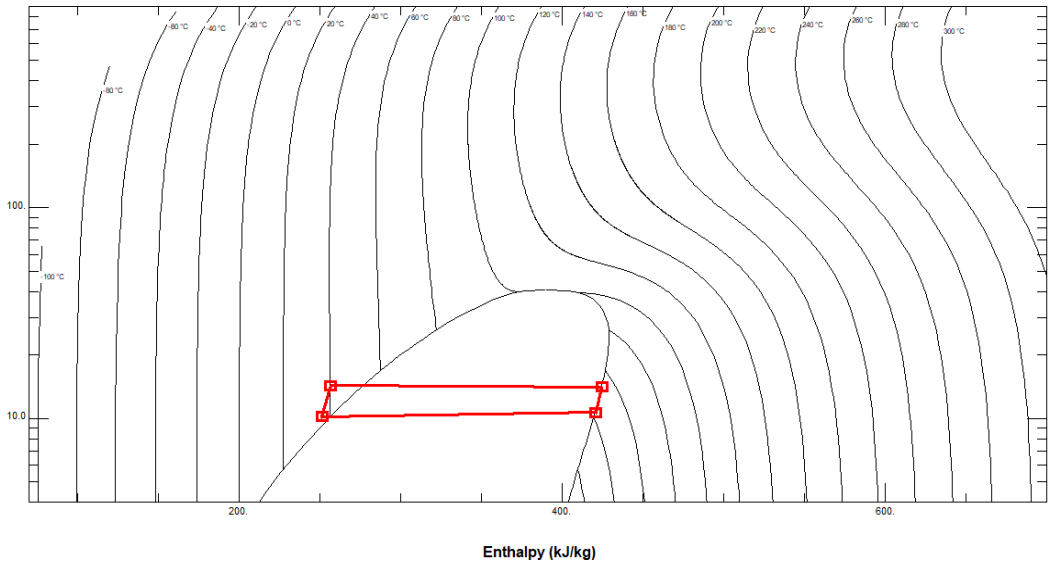
		T (C)	P (Bar)
Pompa	1	40.46	14.46
Evaporator	2	53.76	14.25
Ekspander	3	42.68	10.78
Kondensor	4	36.84	10.31
Pompa	5	40.46	14.46



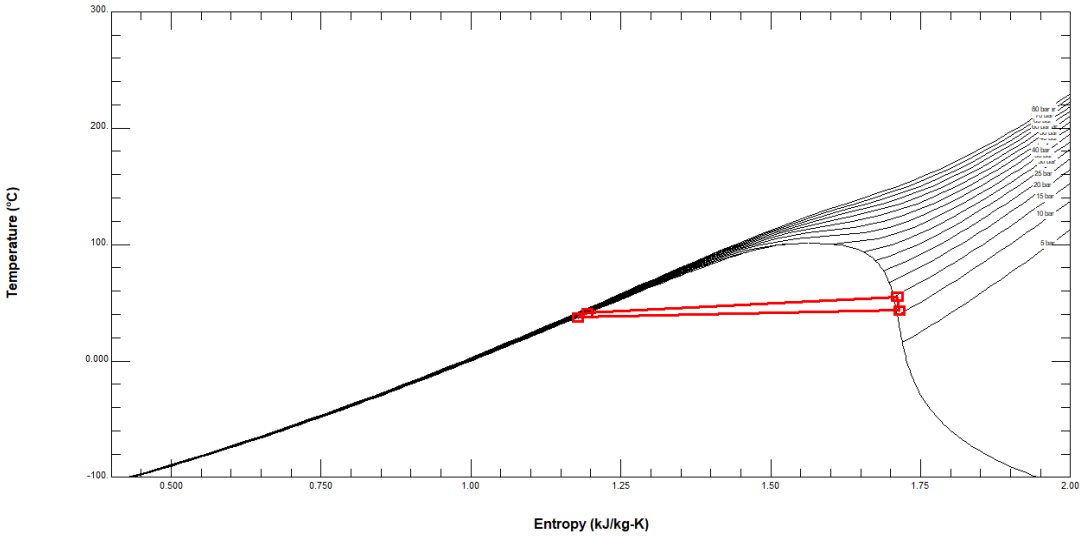


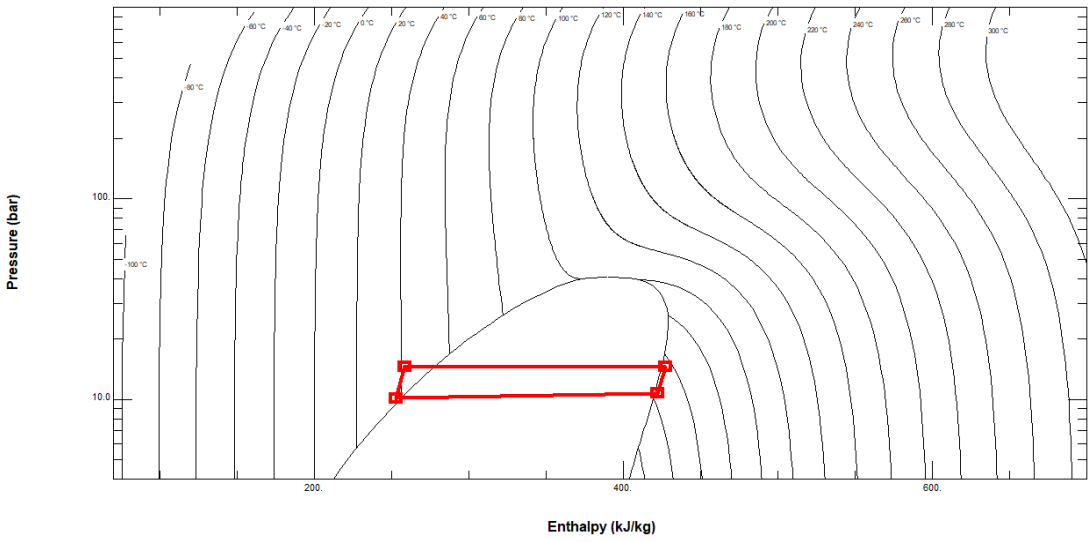
		T (C)	P (Bar)
Pompa	1	40.28	14.31
Evaporator	2	52.96	14.11
Ekspander	3	42.45	10.69
Kondensor	4	36.71	10.23
Pompa	5	40.28	14.31



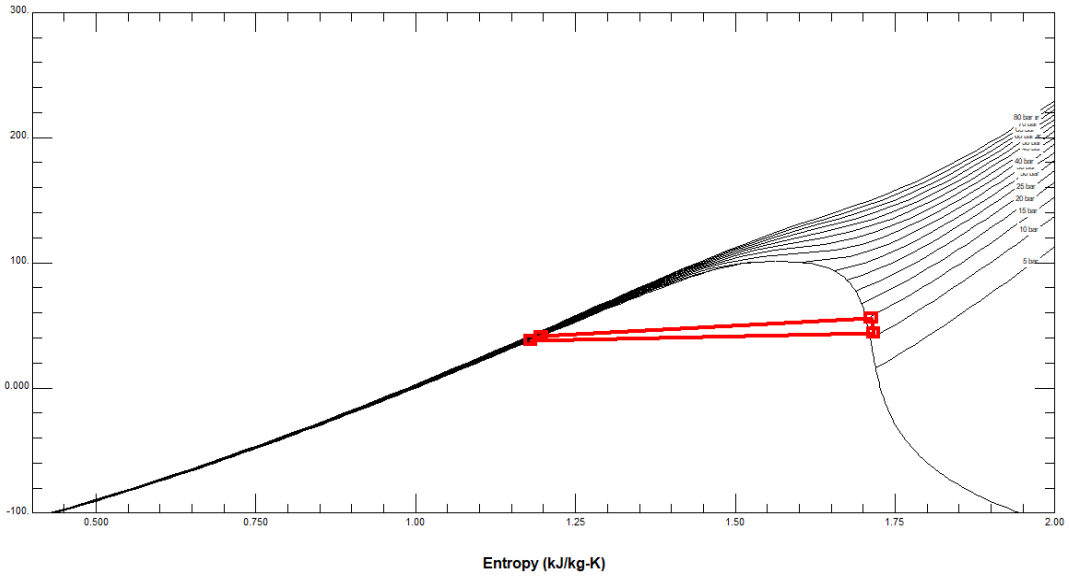


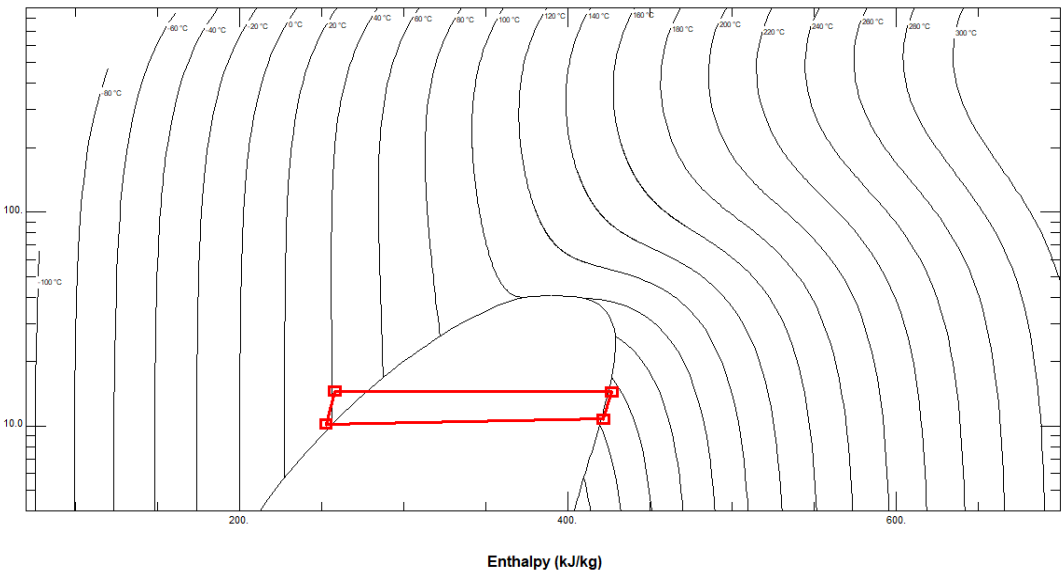
		T (C)	P (Bar)
Pompa	1	41.48	14.60
Evaporator	2	55.80	14.52
Ekspander	3	43.76	10.74
Kondensor	4	37.81	10.17
Pompa	5	41.48	14.60



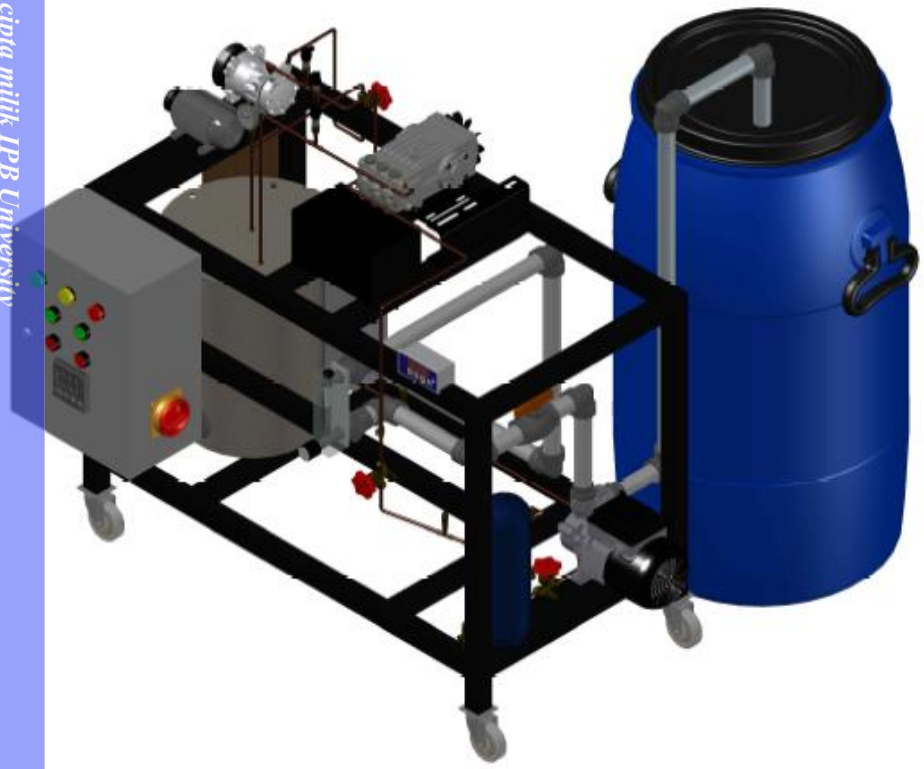


		T (C)	P (Bar)
Pompa	1	41.09	14.55
Evaporator	2	55.26	14.50
Ekspander	3	43.41	10.79
Kondensor	4	37.53	10.22
Pompa	5	41.09	14.55



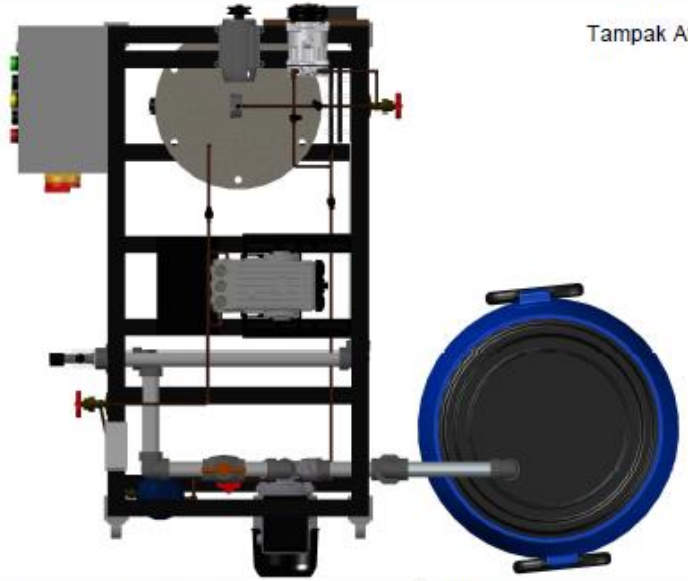


Tampak Isometric



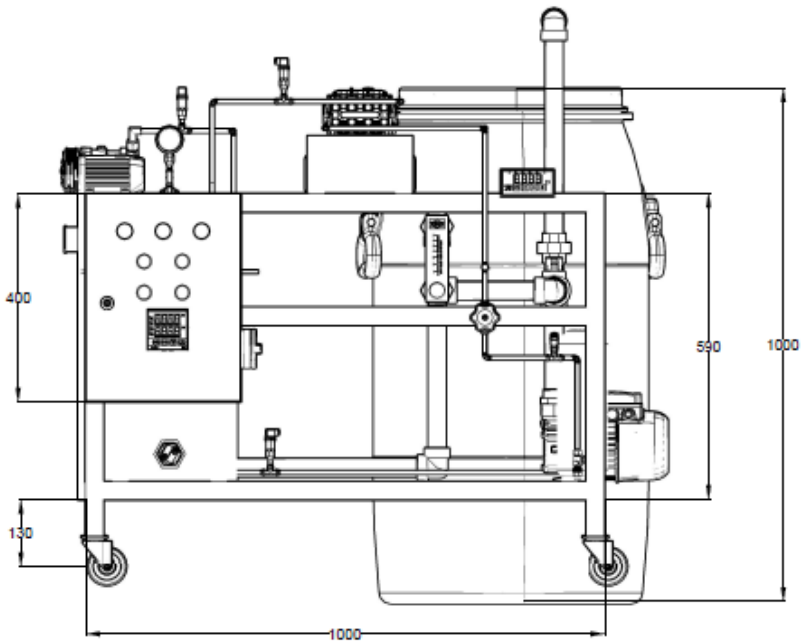
Tampak Kanan

Tampak Atas



	Skala : -	Digambar : Dwi Setiawan	No. Gambar
	Satuan : -	Diperiksa : AHT, YAP, IDM	1
	Tanggal : 30/9/2020	Disetujui : AHT, YAP, IDM	
Siklus Rankine Organik		TEP-TMB-IPB University	Revisi : 0 / A4

Tampak Depan



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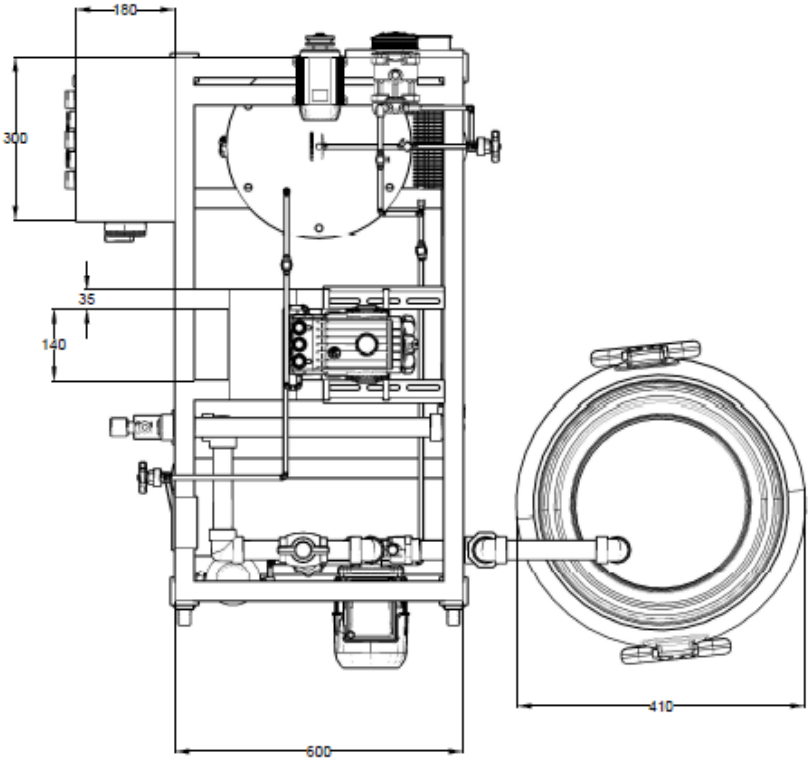
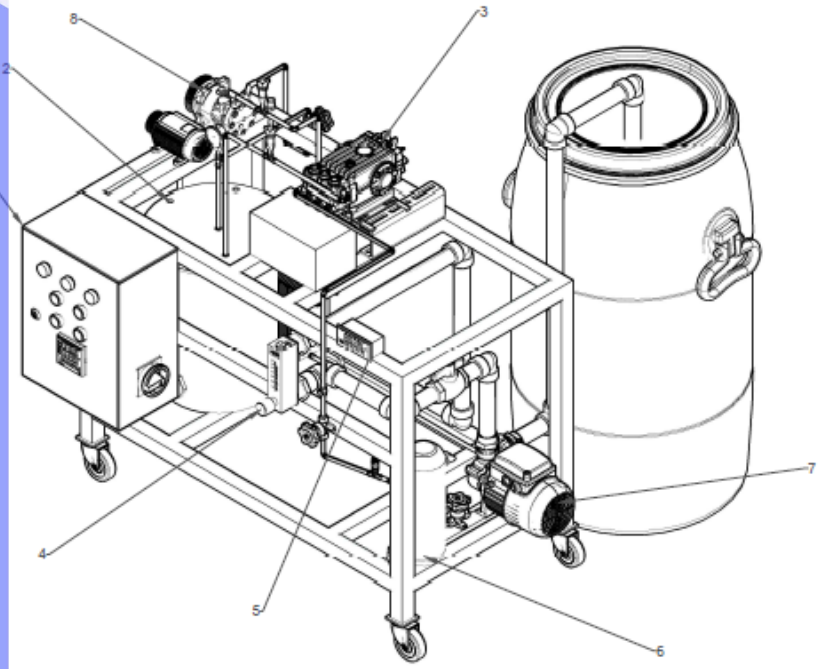
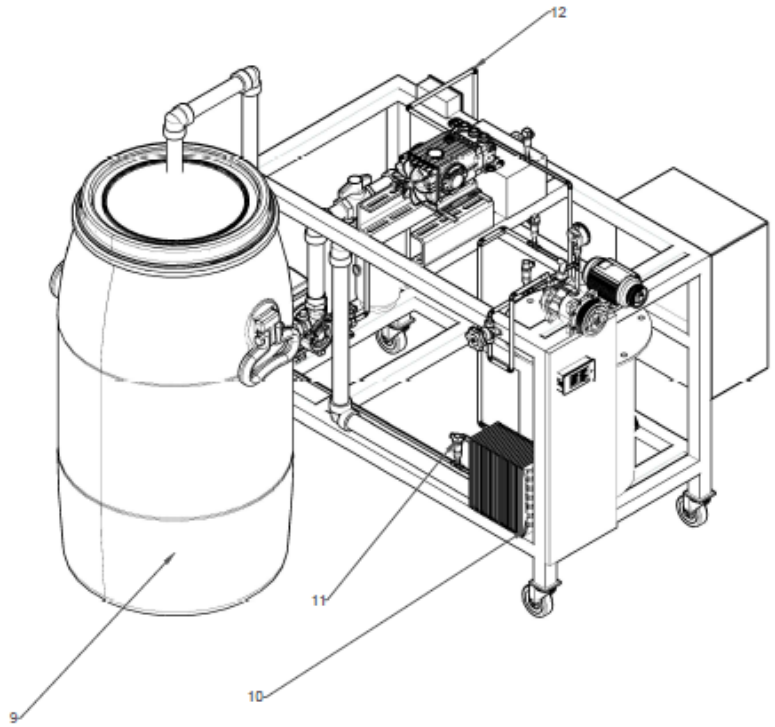


Skala : 1 : 12.5	Digambar : Dwi Setiawan	No. Gambar	
Satuan : mm	Diperiksa : AHT, YAP, IDM	2	
Tanggal : 30/9/2020	Disetujui : AHT, YAP, IDM		
Siklus Rankine Organik	TEP-TMB-IPB University	Revisi : 0	A4





No	Keterangan	Bahan
1	Kontrol panel	Plat baja
2	Tabung evaporator	Stainless steel
3	Pompa SRO	Besi
4	Flow meter air kondensor	Akrilik
5	Sensor flow meter SRO	Plastik
6	Liquid receiver	Tabung baja
7	Pompa air kondensor	Besi
8	Ekspander	Besi
9	Penampung air kondensor	Plastik
10	Kondensor	Tembaga
11	Sensor tekanan	Besi
12	Pipa SRO	Tembaga

	Skala : -	Digambar : Dwi Setiawan	No. Gambar 3
	Satuan : -	Diperiksa : AHT, YAP, IDM	
	Tanggal : 30/9/2020	Disetujui : AHT, YAP, IDM	
Bagian Siklus Rankine Organik (SRO)		TEP-TMB-IPB University	Revisi : 0 / A4