LAMPIRAN C

NERACA PANAS

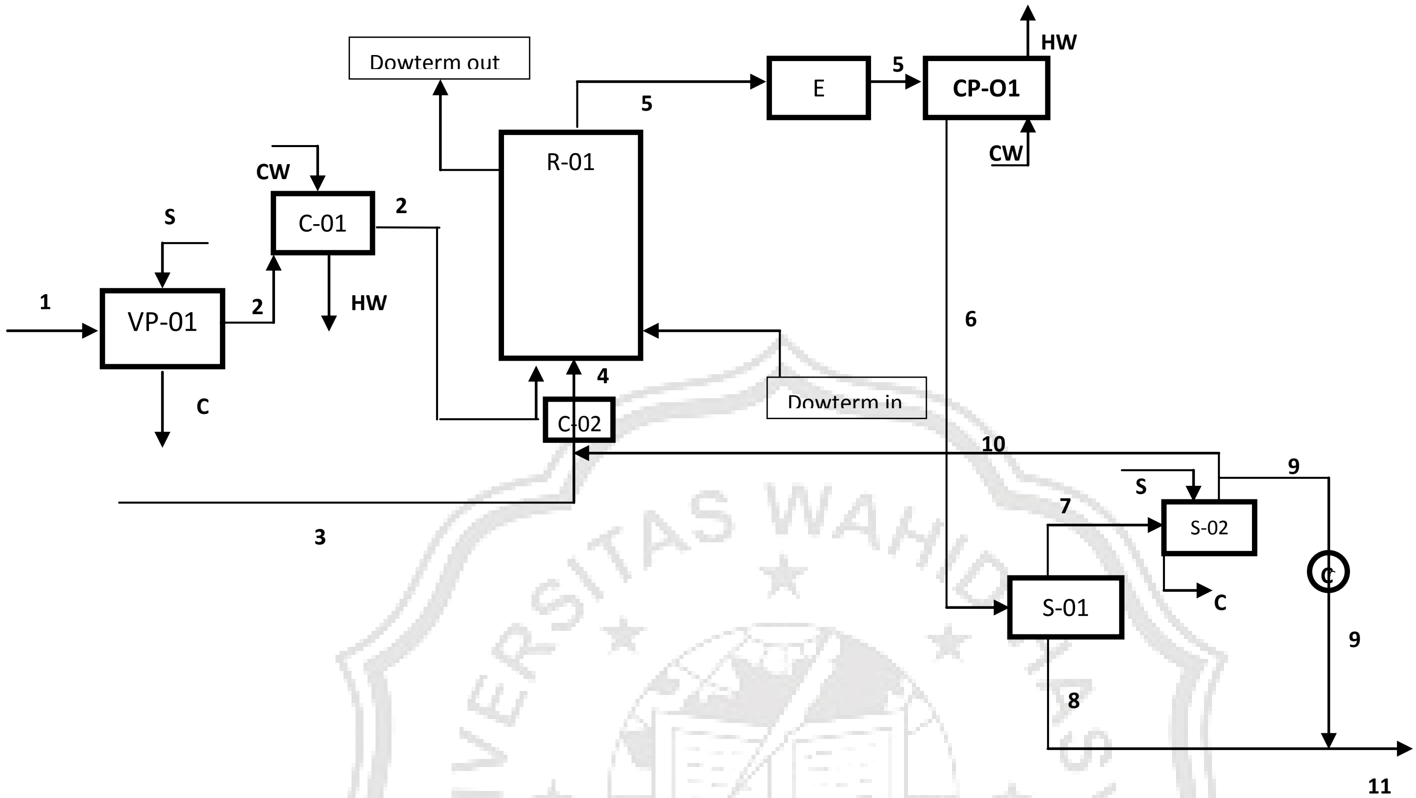


Diagram Alir Neraca Panas

Ada beberapa hal yang menjadi dasar perhitungan neraca panas yaitu :

- Basis perhitungan adalah 1 jam operasi
- Satuan massa yang digunakan adalah kmol
- Suhu referensi adalah 25^0C = 298,15 K
- Satuan kapasitas panas yang digunakan adalah KJ/Kmol
- Satuan perubahan entalpi adalah KJ

Data yang Dibutuhkan

a. Data Berat Molekul Komponen

Tabel C.1 Data Berat Molekul Komponen

Komponen	BM
H_2	2
C_6H_6	78
C_6H_{12}	84
C_7H_8	92

b. Kapasitas Panas

$$Cp = A + BT + CT^2 + DT^3$$

$$\int_{Tref}^{T} Cp\, dT = Cp_A\,(T-T_0) + \frac{C_{pB}}{2} \times (T^2 - T_0^2) + \frac{C_{pC}}{3} \times (T^3-T_0^3) + \frac{C_{pD}}{4} \times (T^4-T_0^4)$$

$$\Delta H = m. \int_{T0}^{T} Cp\, dT$$

Tabel C.2 Data Kapasitas Panas Cairan

Komponen	A	B	C	D
H_2	50,607	-6,11	0,309	-0,00415
C_6H_6	-31,662	1,30E+00	-3,61E-03	3,82E-06
C_6H_{12}	-44,417	1,60E+00	-4,47E-03	4,76E-06
C_7H_8	83,703	5,17E-01	-1,49E-03	1,97E-06

Yaws (1999)

Tabel C.3 Data Kapasitas Panas Gas

Komponen	A	B	C	D	E
H_2	25,399	2,02E-02	-3,85E-05	3,19E-08	-8,76E-12
C_6H_6	-31,368	4,75E-01	-3,11E-04	8,52E-08	-5,05E-12
C_6H_{12}	13,783	2,07E-01	5,37E-04	-6,30E-07	1,90E-10
C_7H_8	-24,097	5,22E-01	-2,98E-04	6,12E-08	1,26E-12

c. Panas Penguapan (Hvap)

$H_{vap} = A\,(1 - (T/Tc))^n$

Dengan : ΔHvap : entalpi penguapan, kJ/mol

Tc : Temperatur kritis, K

T : Suhu operasi, K

A, n : Konstanta

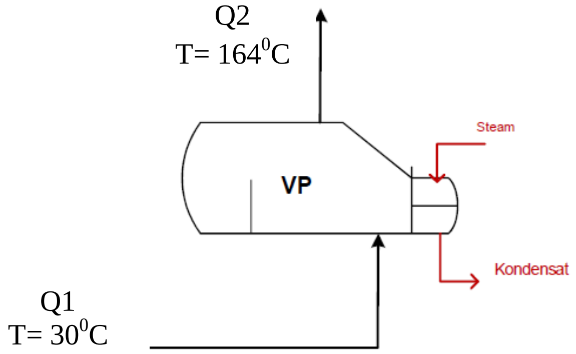
Tabel C. 4 Data Enhalpi Penguapan

Komponen	A	Tc	n
H_2	0,655	33,18	0,38
C_6H_6	49,888	562,16	0,489
C_6H_{12}	49,06	553,54	0,486
C_7H_8	50,139	591,79	0,383

1. Neraca Panas di Vaporizer

Fungsi : Menguapkan umpan sebelum masuk reaktor

Tujuan : Menghitung jumlah kebutuhan steam



Gambar C.1 Skema Neraca Panas pada Vaporizer

Q1 = Enthalpy Umpan (Benzena +toluena) masuk VP

Q2 = Enthalpy Produk

Q s = Enthalpy steam

Q p = Enthalpy penguapan

Neraca Panas total :

Q1+ Q steam = Q2 + Q penguapan

INPUT

- Q1 dari Tangki Benzena (T-01)

Neraca Panas Umpan

T = 30^0C = 308,15 K

➢ Benzena (C_6H_6)

$$\int_{298,15}^{308,15} Cp\ dT = \int_{298,15}^{308,15} [-31,662 + 1,30 + (-3,61E\text{-}03) + 3,82E\text{-}06\ ]dT$$

= 1370,9629 kJ/kmol

Q_{C6H6} = m. Cp.dT

= 67,5827 kmol /jam x 1370,9629 kJ/kmol

= 92653,3770 kJ/jam

- Toluena (C_7H_8)

$\int_{298,15}^{308,15} Cp\ dT$ = $\int_{298,15}^{308,15}$[83,703 +5,17E-01 +$(-1{,}49E-03)+(1{,}97E-06)$]dT

= 1583,8632 kJ/kmol

Q_{C7H8} = m. Cp.dT

= 0,0574 kmol/jam x 1583,8632 kJ/kmol

= 90,8436 kJ/jam

Tabel C.5 Neraca Panas Benzena Masuk (Q1)

Komponen	F(kmol/jam)	Cp dT (Kj/kmol)	Q(kJ/jam)
C_6H_6	67,5827	3458,0504	233696,6372
C_7H_8	0,0574	1583,8632	90,8436
TOTAL	**67,6401**		**92744,2206**

OUTPUT

Q2 dari keluaran Vaporizer (V-01)

Vaporizing

T = 164 ^{O}C = 437,15 ^{0}K

- Benzena (C_6H_6)

H_{vap} = A(1-(T/Tc))^n

49,888 (1 –(427,15 /562,16)) ^{0,489} x 1000

= 23917, 7635 Kj/kmol

Q_{C6H6} = m . H vap

= 67,5805 x 23917, 7635

= 1616373,4873 kJ/jam

➢ Toluena (C_7H_8)

H_{vap} = 50,139 (1 –(437,15 /591,79)) ^{0,383}x 1000

=30999, 9773 kJ /kmol

Q_{C7H8} = m . H vap

= 0,0574 x 30999, 9773

= 1777, 9675 kJ/jam

Tabel C.6 Perhitungan Panas Penguapan

Komponen	F (kmol/jam)	Hvap(Kj/kmol)	Q (kj/jam)
C_6H_6	67,5827	23917,7635	1616373,4873
C7H8	0,0574	29987,8779	1719,9197
Total	**67,6401**		**1618093,4070**

Neraca Panas Produk

T = 164 ^{O}C = 437,15 K

Tref = 25 ^{o}C = 298,15 K

➢ Benzena (C_6H_6)

$$\int_{298,15}^{437,15} Cp\ dT = \int_{298,15}^{437,15} [-31,368 + 4,75E-01 + (-3,11E-04) + 8,52E-08 + (-5,05E-12)]dT$$

= 14597,0256 kJ/kmol

Q_{C6H6} = m. Cp.dT

= 67,5827 kmol x 14597,0256 kJ/kmol

= 986986506,4268 kJ/jam

➢ Toluena (C_7H_8)

$$\int_{298,15}^{437,15} Cp\ dT = \int_{298,15}^{437,15} [-24,097+5,22E-01 +(-2,98E-04) + 6,12E-08 + 1,26E-12]dT$$

$= 18102{,}1779$ kJ/kmol

Q_{C7H8} $= m.\ Cp.dT$

$= 0{,}0574$ kmol x $18102{,}1779$ kJ/kmol

$= 1038{,}2637$ kJ/jam

Tabel C.7 Neraca Panas Produk (Q2)

Komponen	F (kmol/jam)	Cp dT (kJ/kmol)	Q (kJ/jam)
C_6H_6	67,5827	14597,0256	986506,4268
C_7H_8	0,0574	18102,1779	1038,2293
TOTAL	**67,6401**		**987544,6904**

Q steam = Q output – Q input

= Q2 + Q penguapan – Q1

= 7544,6904 + 1618147,0572 – 92744,2206

= 2512947,5270 kJ/ jam

Menghitung Kebutuhan Massa Steam

Digunakan steam dengan (Kern, 1950) :

T = 184^0C = 457,15 K

P = 160 psi = 10,88 atm

Saturated steam, hs = 1195,1 Btu/lb

= 2779,8026 KJ/kg

Massa steam $= \frac{Q\ Ssteam}{hs} = \frac{2512947{,}527}{2779{,}8026}$ = 904 kg/jam

Tabel C.8 Neraca Panas Total VP-01

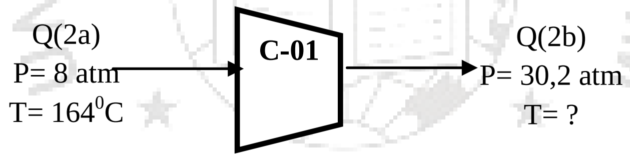
Keterangan	Q Input	Q Output
Q1	92744,2206	0
Q penguapan	0	1618147,0572
Q2	0	987544,6904
Q steam	2512947,5270	0
TOTAL	**2605691,7477**	**2605691,7477**

2. Neraca Panas Kompressor Benzena (C-01)

Fungsi : menaikkan tekanan gas Benzena dari 8 atm menjadi 30,2 atm

Tujuan : - menentukan jumlah stage

- menghitung suhu keluar kompressor
- menghitung panas kerja kompresor



Gambar C.2 Skema Neraca Panas Pada Kompresor

Keterangan :

Q(2a) = entalpi umpan benzena masuk kompresor

Q(2b) = entalpi keluar kompresor

Neraca Panas Total :

Q(2a) + Q kompresi = Q(2b)

Q (2a) sama dengan neraca panas produk dari vaporizer = 987544,6904 kJ/jam

Perhitungan jumlah stage:

Harga Rc untuk kompresor sentrifugal multistage disyaratkan Rc <4 (Coulson, J.M.,Richardson,J.F.,1983).

$$Rc = \left(\frac{P_i}{P_0}\right)^{1/n}$$

Dengan : Po = tekanan masuk kompresor

Pi = tekanan keluar kompresor

n = jumlah stage

$$Rc = \left(\frac{30,2}{8}\right)^{1/1}$$

= 3,78 .

Dari trial n diperoleh dengan 1 stage rasio kompresi kurang dari 4.

Menghitung suhu keluar Kompresor

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{R/Cp}$$ (Pers. 7.18 Smith Van Ness ed.5)

To = 164^{0}C = 437,15 K

Tabel C.9 Kapasitas Panas Gas Komponen

komponen	kmol/jam	Yi	Cpi	Cpi*yi
C_6H_6	67,5827	0,9991	1,24E+02	123,6743
C_7H_8	0,0574	0,0008	1,52E+02	0,1291
TOTAL	**67,6401**	**1,0000**		**123,8034**

R = 8,314 Kj/kmol. K

(R/Cp) = 8,314 Kj/kmol. K : 123,8034 = 0,0672

$$T_2 = 437\left(\frac{30,2}{8}\right)^{0,0672}$$

= 477,94 K

= 204,79 C

Jadi suhu keluar kompresor adalah 477,94 K (204, 79^{0}C)

T2 = 204,79 C = 477,9 K

➢ Benzena (C_6H_6)

$$\int_{298,15}^{477,94} Cp\ dT = \int_{298,15}^{477,94} [-31,368 + 4,75E-01 + (-3,11E-04) + 8,52E-08 + (-5,05E-12)]dT$$

= 19849,5621 kJ/kmol

Q_{C6H6} = m. Cp.dT

= 67,5827 kmol x 19849,5621 kJ/kmol

= 1341487,0347 kJ/jam

➢ Toluena (C_7H_8)

$$\int_{298,15}^{477,94} Cp\ dT = \int_{298,15}^{477,94} [-24,097+5,22E-01 +(-2,98E-04) + 6,12E-08 + 1,26E-12]dT$$

= 24556,9197 kJ/kmol

Q_{C7H8} = m . Cp . dT

= 0,0574 kmol x 24556,9197 kJ/kmol

= 1408,4801 kJ/jam

Tabel C.10. Neraca Panas Output pada Kompresor

Komponen	F (kmol/jam)	Cp dT (kJ/jam)	Q (Kj/jam)
C_6H_6	67,5827	19849,5621	1341487,0347
C_7H_8	0,0574	24556,9197	1408,4801
Total	**67,6401**		**1342895,5148**

Tabel C.11 Neraca Panas Pada Kompresor (C-01)

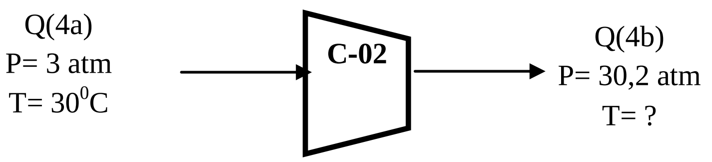
Komponen	Q_{Input}	Q_{Output}
Q umpan(Q2a)	987511,9481	
Q produk(Q2b)		1342850,9907
Q kompresi	355339,0426	
Total	**1342850,9907**	**1342850,9907**

3. Neraca Panas Kompresor Hidrogen (C-02)

Fungsi : Menaikkan tekanan gas recycle dari 3 atm menjadi 30,2 atm

Tujuan : - Menentukan jumlah stage

- Menghitung suhu keluar kompresor



Gambar C.3 Skema Neraca Panas Pada Kompresor

Keterangan :

Q(4a) = Entalpi umpan hidrogen masuk kompresor

Q (4b) = entalpi hidrogen keluar kompresor

Neraca Panas Total :

Q(4a) + Q kompresi = Q(4b)

Perhitungan jumlah stage:

Harga Rc untuk kompresor sentrifugal multistage disyaratkan Rc <4 (Coulson, J.M.,Richardson,J.F.,1983).

$$Rc = \left(\frac{P_i}{P_0}\right)^{1/n}$$

Dengan : Po = tekanan masuk kompresor

Pi = tekanan keluar kompresor

n = jumlah stage

$$Rc = \left(\frac{30,2}{3}\right)^{1/1}$$

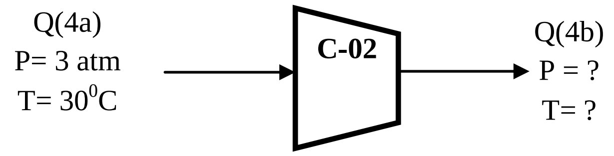
= 10,07

$$Rc = \left(\frac{30,2}{3}\right)^{1/2}$$

= 3,17

Dari trial n diperoleh dengan 2 stage rasio kompresi kurang dari 4.

a. Kompresor Stage 1



Gambar C.4 Skema Neraca Panas Pada Kompresor Stage 1

Tekanan gas masuk, P1 = 3 atm

Tekanan gas keluar, P2 = rasio kompresi x P1

= 3,17 x 3

= 9,52 atm

<u>Perhitungan Panas Kompresor stage 1</u>

Panas Input stage 1

T = 30 ^{0}C = 303,15 K

Tref = 25 ^{0}C = 298,15 K

Tabel C.12 Neraca Panas Input Stage 1

Komponen	kmol/jam	Cp dT(kJ/kmol)	Q (kJ/jam)
H2	236,5395	143,9370	34046,78706
Total	**236,5395**		**34046,78706**

Suhu Keluar stage 1 :

$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{R/Cp}$ (Pers. 7.18 Smith Van Ness ed.5)

Tabel C.13Kapasitas Panas Gas Komponen

Komponen	kmol/jam	Yi	Cpi	Cpi*yi
H2	236,5395	1,0000	2,89E+01	2,88E+01
TOTAL	**236,5395**	**1,0000**		**2,88E+01**

R = 8,314 Kj/kmol. K

(R/Cp) = 8,314 Kj/kmol. K : 34,9657

= 0,28

T_{1b} = $303,15\left(\frac{9,5}{3}\right)^{0,28}$

= 423,72 K

Jadi suhu keluar kompresor stage 1adalah 423,72 K

Komponen	kmol/jam	CpdT(kJ/kmol)	Q(Kj/Jam)
H_2	236,5395	3642,9607	861703,9404
Total	**236,5395**		**861703,9404**

Digunakan intercooler η 67%

Maka suhu keluar = T2 –(η*(T2-T1)

= 342,73 K

Panas Output intercooler

T = 69,58 ^{0}C = 342,73 K

Tref= 25 ^{0}C = 298,15K

Tabel C.14 Neraca Panas Output intercooler

Komponen	kmol/jam	Cp dT (KJ/kmol)	Q (Kj/jam)
H_2	236,5395	1287,1897	304471,1446
TOTAL	236,5395		304471,1446

Qserap = Qoutput intrcooler – Q output stage 1

= 1233017,9473 - 861703,9404

= 371314,0069 kj/jam

Massa pendingin = $\frac{Q\ serap}{Cp\ H20\ dT}$

$= \frac{371314{,}0069 \text{ kj/jam}}{1129{,}8234 \text{ kj/kmol}}$

= 328,67 kmol/jam

= 5915 kg/jam

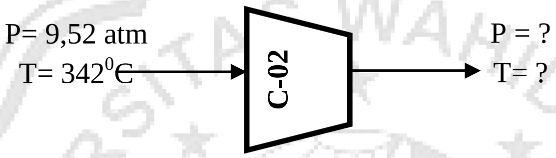
Qc = 328,67 kmol/jam x $\int_{298{,}15}^{303{,}15} cp\ H2O\ dT$

= 127806,6162 Kj/jam

Qh = 328,67 kmol/jam x $\int_{298{,}15}^{318{,}15} cp\ H2O\ dT$

= 10359247,84 kJ/jam

b. Kompresor Stage 2



Gambar C.5 Skema Neraca Panas Pada Kompresor Stage 2

Tekanan gas masuk, P2 = 9,52 atm

Tekanan gas keluar, P3 = rasio kompresi x P2

= 3,17 x 9,52

= 30,2 atm

Suhu Keluar stage 2 :

$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{R/Cp}$ (Pers. 7.18 Smith Van Ness ed.5)

Tabel C.15 Kapasitas Panas Gas Komponen

Komponen	Kmol	Yi	Cpi	Cpi*yi
H_2	236,5395	1,0000	2,91E+01	2,90E+01
TOTAL	**38,0546**	**1,0000**		**2,90E+01**

R = 8,314 Kj/kmol. K

(R/Cp) = 8,314 Kj/kmol. K : 2,9E+01 = 0,28

Suhu Keluaran Stage 2 :

$T_2 = \left(\frac{30,2}{9,52}\right)^{0,28}$

= 477,41 K

Jadi suhu keluar kompresor stage 2 adalah 477,41 K (204,41 ^{0}C)

Panas Ouput Stage 2

T = 204,41 ^{0}C = 477,41 K

Tref= 25^{0}C = 298,15 K

Tabel C.16 Neraca Panas Output Kompresor Stage 2

Komponen	Kmol	CpdT	Q(kJ/jam)
H2	236,5395	5212,7369	1233017,9473
TOTAL	**236,5395**		**1233017,9473**

Tabel C.17 Neraca Panas Kompresor Hidrogen

komponen	Q_{Input}	Q_{Output}
Q(4a)	34046,78706	0
Q(6b)	0	1233017,9473
Q kompresi	11430412,3841	0
Qc	127806,6162	0
Qh	0	10359247,84
TOTAL	**11592265,78735**	**11592265,7873**

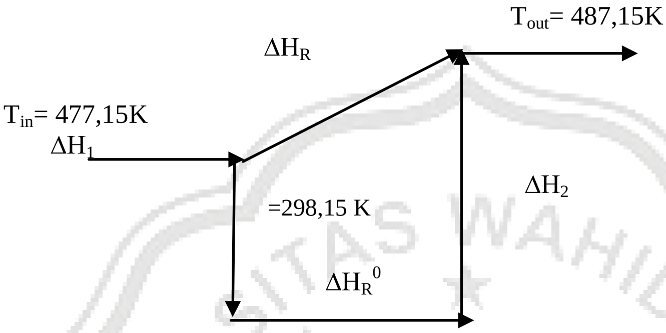
4. Neraca Panas Reaktor

Fungsi : Tempat berlangsungnya reaksi antara hidrogen dan benzena menjadi produk *cyclohexane*

Tujuan : Menghitung kebutuhan air pendingin

Reaksi : C_6H_6 + $3H_2$ ⟶ C_{12}

Reaksi :	C_6H_6 +	$3H_2$ ⟶	C_6H_{12}
	Benzena	Hidrogen	cyclohexane



Neraca Panas Total :

Qumpan + Qreaksi = Qproduk + Qpendingin

Q umpan = Q(2b) + Q(4b)

INPUT

<u>Panas Umpan (ΔH_1)</u>

Pannas Umpan Reaktor terdiri dari

T = 204 C = 477,15 K

Tr = 25^0C = 298,15 K

➢ Hidrogen (H2)

$\int_{298,15}^{477,94} Cp\ dT = \int_{298,15}^{477,94} [$ 25,399 + 2,02E-02 + (-3,85E-05)+ 3,19E-08+ (-8,76E-12)]dT

= 5205,2397 Kj/kmol

Q_{H2} = m .CpdT

= 236,5395 kmol/jam x 5205,2397 Kj/jam

= 1231244,5746 Kj/jam

➢ Benzena (C_6H_6)

$$\int_{298,15}^{477,94} Cp\ dT = \int_{298,15}^{477,94} [-31,368 + 4,75E-01 + (-3,11E-04) + 8,52E-08 + (-5,05E-12)]dT$$

= 19744,0701 kJ/kmol

Q_{C6H6} = m. Cp.dT

= 67,5827 kmol x 19744,0701 kJ/kmol

= 1334357,6011 kJ/jam

➢ Toluena (C_7H_8)

$$\int_{298,15}^{477,94} Cp\ dT = \int_{298,15}^{477,94} [-24,097+5,22E-01 +(-2,98E-04) + 6,12E-08 + 1,26E-12]dT$$

= 24427,4203 kJ/kmol

Q_{C7H8} = m. Cp.dT

= 0,0574 kmol x 24427,4203 kJ/kmol

= 1401,0526 kJ/jam

Tabel C.18 Perhitungan Panas Umpan Reaktor

Komponen	Kmol	Cp Dt (Kj/kmol)	Q (Kj/jam)
H_2	236,5395	5205,2397	1231244,5746
C_6H_6	67,5827	19744,0701	1334357,6011
C_6H_{12}	0,0000	25462,9988	0,0000
C_7H_8	0,0574	24427,4203	1401,0526
TOTAL	**304,1795**		**2567003,2283**

Panas Reaksi Standar ((ΔH_R)

Persamaan Reaksi :

Reaksi beropersi pada suhu 204°C

Data harga (ΔH_f^0) untuk masing-masing komponen pada 298 K (Yaws, 1999) :

(ΔH_f^0) C_6H_6 = 82,9 kJ/jam

(ΔH_f^0) H_2 = 0 kJ/jam

(ΔH_f^0) C_6H_{12} = -123,4 kJ/jam

$\Delta H_{f\,(298,15)}^0$ = $\Delta H_{f\,Produk}^0$ - $\Delta H_{f\,reaktan}^0$

= ΔH_f^0 C_6H_{12} - (ΔH_f^0 C_6H_6 + (ΔH_f^0 H_2)

= –123,4 – (82,9 + 0) kJ/mol

= –206,3 kJ/mol

= -206.300 kJ/kmol

Banyak mol C_6H_6 yang bereaksi = 67,5151 kmol

Panas reaksi = -206.300 kJ/kmol x 67,5151 kmol

= -13928369,0684 kJ

Q = - ΔH_f^0 = 13928369,0684 **kJ**

<u>OUTPUT</u>

<u>Panas Produk (ΔH_2)</u>

T = 214 ^{0}C = 487,15K

Contoh perhitungan (ΔH_2) :

- Hidrogen (H_2)

$\int_{298,15}^{487,15} Cp\, dT = \int_{298,15}^{477,15}$ [25,399 + 2,02E-02 + (-3,85E-05)+ 3,19E-08+ (-8,76E-12)]dT

= 5498,1442 Kj/kmol

Q_{H2} = m .CpdT

= 33,9941kmol/jam x 55498,1442 Kj/jam

= 186904,4586 Kj/jam

- Benzena (C_6H_6)

$$\int_{298,15}^{487,15} Cp\ dT = \int_{298,15}^{487,15} [-31,368 + 4,75E-01 + (-3,11E-04) + 8,52E-08 + (-5,05E-12)]dT$$

= 21090, 3760 kJ/kmol

Q_{C6H6} = m. Cp.dT

= 0,0676 kmol x 21090, 3760 kJ/kmol

= 1425,3446 kJ/jam

- Toluena (C_7H_8)

$$\int_{298,15}^{487,15} Cp\ dT = \int_{298,15}^{487,15} [-24,097+5,22E-01 + (-2,98E-04) + 6,12E-08 + 1,26E-12]dT$$

= 26079,7763 kJ/kmol

Q_{C7H8} = m. Cp.dT

= 0,0574 kmol x 26079,7763 kJ/kmol

= 1495,8247 kJ/jam

➢ Cyclohexane (C_6H_{12})

$\int_{298,15}^{487,15} Cp\ dT$ = $\int_{298,15}^{487,15}$[13,783 + 2,07E-01 + 5,37E-04 + (-6,30E-07) + 1,90E-10]dT

= 27243,7719 kJ/kmol

QC_6H_{12} = m. Cp.Dt

= 67,5151 kmol/jam x 27243,7719 kJ/kmol

= 1839366,5047 Kj/jam

Tabel C.19 Perhitungan Panas Produk ΔH_2

Komponen	Kmol	Cp dT (kJ/jam)	Q (kJ/jam)
H_2	33,9941	5498,1442	186904,4586
C_6H_6	0,0676	21090,3760	1425,3446
C_6H_{12}	67,5151	27243,7719	1839366,5047
C_7H_8	0,0574	26079,7763	1495,8247
TOTAL	**101,6342**		**2029192,1325**

<u>Perhitungan Panas Pendingin (Qp)</u>

Jenis pendingin : dowterm A

Cp = 1,5993 kJ/kg.K

Qp = $Q_{input} + \Delta Hr - Q_{Output}$

Q_P = 2567003,2283 +13928369,0684 - 2029192,1325

= **14466180,1641 kJ/jam**

<u>Menghitung Kebutuhan Massa Pendingin</u>

Suhu pendingin masuk (T1) = 30^0C = 303,15 K

Suhu pendingin keluar (T2) = 100^0C = 373,15 K

Cp dowterm A = 1,5993 kJ/Kg.K (max S Peters “plant design and economics for chemical engineering)

Densitas dowterm = 1051,6121 kg/m^3

Qp = m_p . Cp. ΔT

Sehingga massa pendingin (mp) = $\frac{Qp}{Cp.\Delta T}$ = $\frac{14466180,16}{1,5993.\ 70}$ = 129218,8561 kg/jam

Volume pendingin = $\frac{massa\ dowterm\ A}{massa\ jenis}$ = $\frac{129178,8561}{1051,6121}$ = 122,88 m^3/jam

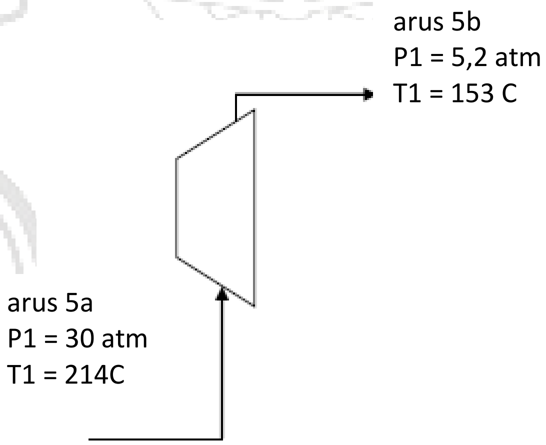
Tabel C.20 Neraca Panas di Reaktor

Keterangan	Q input (Kj/jam)	Q Output (kj/jam)
Q umpan	2567003,2283	0
Qproduk	0	2029192,1325
Q reaksi	13928369,0684	0
Q pendingin	0	14466180,1641
Total	**16495372,2967**	**16495372,2967**

5. Neraca Panas Expander (E-01)

Fungsi : Menurunkan tekanan produk Reaktor dari 30 atm menjadi 5,2 atm

Tujuan : megetahui panas yang dilepas expander



Gambar C.6 Skema Neraca Panas pada Expander

Keterangan :

Q(5a) = Entalpi keluaran reaktor

Q(5b) = Entalpi produk keluar reaktor

Neraca Panas :

Q(5a) = Q(5b) + Qloss

2029192,1325 Kj/Jam = Q(5a)+Qloss

Output (Q5b)

T = 153 C = 426,15 K

Tref = 25 C = 298,15 K

- Hidrogen (H2)

$\int_{298,15}^{426,15} Cp\ dT = \int_{298,15}^{477,15}$ [25,399 + 2,02E-02 + (-3,85E-05)+ 3,19E-08+ (-8,76E-12)]dT

= 3714,2416 Kj/kmol

Q_{H2} = m .CpdT

= 33,9941kmol/jam x 3714,2416Kj/jam

= 126262,2969 Kj/jam

- Benzena (C_6H_6)

$\int_{298,15}^{426,15} Cp\ dT = \int_{298,15}^{426,15}$ [-31,368 $+4{,}75E-01 + (-3{,}11E-04) + 8{,}52E-08$

$+(-5{,}05E-12)$]dT

= 13253,4508 kJ/kmol

Q_{C6H6} = m. Cp.dT

= 0,0676 kmol x 13253,4508 kJ/kmol

= 895,7040 kJ/jam

Toluena (C_7H_8)

$\int_{298,15}^{426,15} Cp\ dT = \int_{298,15}^{426,15}$ [-24,097+5,22E-01 +(-2,98E-04) + 6,12E-08 + 1,26E-12]dT

= 16447,5234 kJ/kmol

Q_{C7H8} = m. Cp.dT

= 0,0574 kmol x 16447,5234 kJ/kmol

= 943,3598 kJ/jam

➢ Cyclohexane (C_6H_{12})

$\int_{298,15}^{426,15} Cp\, dT$ = $\int_{298,15}^{426,15}$ [13,783 + 2,07E-01 + 5,37E-04 + (-6,30E-07) + 1,90E-10]dT

= 16958,4986 kJ/kmol

QC_6H_{12} = m. Cp.Dt

= 67,5151 kmol/jam x 16958,4986 kJ/kmol

= 1144955,0525 Kj/jam

Tabel C.21 Neraca Panas Output Expander

Komponen	kmol	Cp Dt	Q (Kj/jam)
H2	33,9941	3714,2416	126262,2969
C6H6	0,0676	13253,4508	895,7040
C6H12	67,5151	16958,4986	1144955,0525
C7H8	0,0574	16447,5234	943,3598
TOTAL	**101,6342**		**1273056,4131**

Neraca Panas :

Q(5a) = Q(5b) + Qloss

2029192,1325 Kj/Jam = 1273056,4131 Kj/jam +Qloss

Qloss = 756135,7194 kJ/Jam

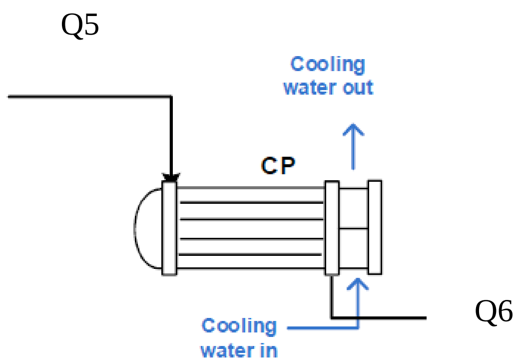
Tabel C.22 Neraca Panas Total Expander (E-01)

Komponen	Input	Output
Q 5a	2029192,1325	0
Q5b	0	1273056,4131
Q loss	0	756135,7194
TOTAL	**2029192,1325**	**2029192,1325**

6. Neraca Panas Kondensor Parsial

Fungsi : Mencairkan sebagian hasil keluaran reaktor dan memisahkan uncondensable gas dari hasil keluaran rekator.

Tujuan : Menghitung kebutuhan air pendingin (Cw) pada kondensor parsial.



Gambar C.7 Skema Neraca Panas di sekitar Kondensor Parsial

Keterangan :

Neraca Panas Total :

Q masuk = Q keluar

$Q_5 + Q_{cw\ in} = Q_8 + Q_7 + Q_{cw\ out} + Q_{pengembunan}$

INPUT

Arus 5

T = 153°C = 426,15 K

Tabel C.23 Perhitungan Panas Aliran Masuk CP-01

Komponen	kmol	Cp dT	Q (kJ/jam)
H_2	33,9944	3713,8993	126250,6588
C_6H_6	0,0676	13250,6853	895,5171
C_6H_{12}	67,5151	16963,2738	1145277,4492
C_7H_8	0,0574	16444,8735	943,2078
TOTAL	**101,6330**		**1273366,8329**

OUTPUT

Arus 6

T = 35^{O}C = 308,15 K

Tabel C.24 Perhitungan Panas Aliran Keluar CP Untuk Cair

Komponen	kmol	Cp dT	Q (KJ/jam)
C_6H_6	0,0662	1370,9629	90,7729
C_6H_{12}	65,8259	1624,4021	106927,6662
C_7H_8	0,0570	1583,8632	90,2448
TOTAL	**65,9491**		**107108,6839**

Tabel C.25 Perhitungan Panas Aliran Keluar CP untuk Gas

Komponen	Kmol	Cp Dt	Q (KJ/jam)
H_2	33,9941	287,9910	9789,9936
C_6H_6	0,0014	863,7638	1,1848
C_6H_{12}	1,6893	1099,3908	1857,1544
C_7H_8	0,0004	1084,7475	0,4101
TOTAL	**35,6851**		**11648,7429**

Menghitung Panas Pengembuan Kondenser Parsial(Q pengembunan)

Q pengembunan = m $_{\text{air yang diembunkan}}$.λ

Diketahui

m $_{\text{air yang diembunkan}}$ = 65,9491kmol/jam

= 5539,7788 kg/jam

Panas laten pengembunan = .λ =H_1-H_V

Pada T = 35^{O}C

H_v = 1197,14 btu/lb = 2784,5476 Kj/kg

H_1 = 345,98 btu/lb = 804,7495 kj/kg (Smith and Van Ness)

.λ = H_1- H_v

λ = 804,7495 kj/kg - 2784,5476 Kj/kg

= -1979,79816 kj/kg

$Q_{pengembunan}$ = 5539,7788 x -1979,7982

= **-10967643,8019 kJ/jam**

Menghitung kebutuhan cooling water

$Q_{umpan} + Q_{cw\ in}$ = $Q_{gas} + Q_{liquid} + Q_{pengembunan} + Q_{cwout}$

1273366,8329 + Qcw in = 11648,7429 + 107108,6839 + -10967643,8019+ $Q_{cw\ out}$

1273362,4405 + $Q_{cw\ in}$= -10848886,3751 + $Q_{cw\ out}$

Qcwout – Qcw in = 1273362,4405 + 10848886,3751

= 12122253,2080 kJ/jam

Untuk menyerap panas tersebut maka dibutuhkan cooling water dengan kondisi :

T_{in} = 303,15 K = $\int_{298,15}^{303,15} Cp\ H20\, dT$ = 388,8676 kJ/kmol

T_{out} = 318,15 K = $\int_{298,15}^{318,15} Cp\ H20\, dT$ =1.518,6910 kJ/kmol

Maka $\int_{303,15}^{318,15} Cp\ H20\, dT$ = 1129,8234 kJ/jam

Massa cooling water = $\frac{12122253{,}2080\ kJ/jam}{1129{,}8234\ kJ/jam}$

= 10729,3345 kmol/jam

= 193128,0214 kg/jam

$Q_{cw\ in}$ = massa x $\int_{298,15}^{303,15} Cp\ H20\, dT$

= 10410729,3345 kmol/jam x 388,8676 kJ/kmol

= 4172290,5647 kJ/jam

$Q_{cw\ out}$ = massa x $\int_{298,15}^{318,15} Cp\ H20\, dT$

= 10410729,3345 kmol/jam x 1518,6910 kJ/kmol

= 16294543,7727 kJ/jam

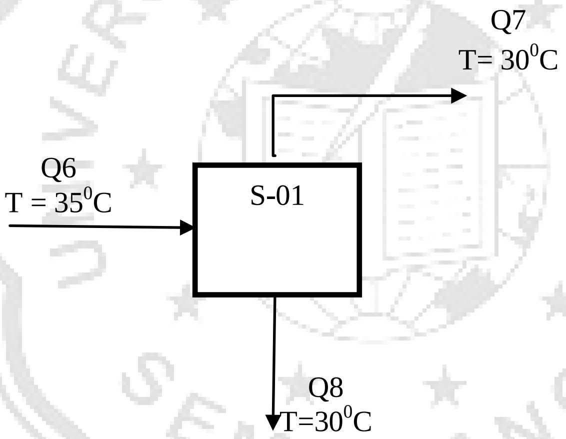
Tabel C.26 Neraca Panas sekitar Kondenser Parsial

Keterangan	Input	Q Output
Q5	1273366,8329	0
Q6(cair)	0	107108,6839
Q6(gas)	0	11648,7429
Q pengembunan	0	-10967643,8019
Q pendingin in	4172290,5647	0
Q Pendingin out	0	16294543,7727
TOTAL	**5445657,3976**	**5445657,3976**

7. Neraca Panas Separator 01

Fungsi : Memisahkan fase cair dan gas dari kondensor Parsial

Tujuan : mengetahui panas yang dilepas separator



Gambar C.8 Skema Neraca Panas pada Separator

Keterangan :

Q6 = Entalpi gas cair keluaran kondensor Parsial

Q7 = Entalpi gas keluaran separator

Q8 = Entalpi cair keluaran separator

Input :

Input separator = Output keluaran kondensor parsial

Q6 = 118757,4268 kJ/jam

Output :

Q7

T = 30^O C = 308,15 K

Tref = 25^O C = 298,15 K

- Hidrogen (H2)

$\int_{298,15}^{303,15} Cp\ dT = \int_{298,15}^{308,15}$ [25,399 + 2,02E-02 + (-3,85E-05)+ 3,19E-08+ (-8,76E-12)]dT

= 143,9370 Kj/kmol

Q_{H2} = m .CpdT

= 33,9941kmol/jam x 143,9370 Kj/jam

= 4893,0097 Kj/jam

- Benzena (C_6H_6)

$\int_{298,15}^{308,15} Cp\ dT = \int_{298,15}^{308,15}$ [-31,368 +4,75E − 01 +(−3,11E − 04) + 8,52E − 08 +(−5,05E − 12)]dT

= 428,0148 kJ/kmol

Q_{C6H6} = m. Cp.dT

= 0,0014 kmol x 428,0148 kJ/kmol

= 0,5871 kJ/jam

- Toluena (C_7H_8)

$\int_{298,15}^{308,15} Cp\ dT = \int_{298,15}^{308,15}$ [-24,097+5,22E-01 +(-2,98E-04) + 6,12E-08 + 1,26E-12]dT

= 16447,5234 kJ/kmol

Q_{C7H8} = m. Cp.dT

= 0,0004 kmol x 16447,5234 kJ/kmol

= 0,2034 kJ/jam

➢ Cyclohexane (C_6H_{12})

$\int_{298,15}^{308,15} Cp\ dT$ = $\int_{298,15}^{308,15}$[13,783 + 2,07E-01 + 5,37E-04 + (-6,30E-07) + 1,90E10]dT

= 544,9447 kJ/kmol

QC_6H_{12} = m. Cp.Dt

= 1,6893 kmol/jam x 16958,4986 kJ/kmol

= 920,5520 Kj/jam

Tabel C.27 Neraca Panas Output Gas pada Separator 01

Komponen	Kmol	CpdT	Q
H_2	33,9941	143,9370	4893,0097
C_6H_6	0,0014	428,0148	0,5871
C_6H_{12}	1,6893	544,9447	920,5520
C_7H_8	0,0004	537,8945	0,2034
TOTAL	**35,6851**		**5814,3521**

Q8

➢ Benzena (C_6H_6)

$\int_{298,15}^{308,15} Cp\ dT$ = $\int_{298,15}^{308,15}$ [-31,662 +1,30 + (-3,61E-03)+3,82E-06]dT

= 683,4255 kJ/kmol

Q_{C6H6} = m. Cp.dT

= 0,0662 kmol /jam x 683,4255 kJ/kmol

= 45,2503 kJ/jam

➢ Toluena (C_7H_8)

$\int_{298,15}^{308,15} Cp\ dT$ = $\int_{298,15}^{308,15}$[83,703 +5,17E-01 +$(-1{,}49E-03)+(1{,}97E-06)$]dT

= 789,9720 kJ/kmol

Q $_{C7H8}$ = m. Cp.dT

= 0,0570 kmol/jam x 789,9720 kJ/kmol

= 45,0108 kJ/jam

- Cyclohexane (C_6H_{12})

$\int_{298,15}^{303,15} Cp\ dT$ = $\int_{298,15}^{303,15}$ [13,783 + 2,07E-01 + 5,37E-04 + (-6,30E-07) + 1,90E-10]dT

= 809,6732 kJ/kmol

QC_6H_{12} = m. Cp.Dt

= 65,8259kmol/jam x 809,6732 kJ/kmol

= 53297,4341 Kj/jam

Tabel . C.28 Neraca panas Output Cair

Komponen	**Kmol**	**CpdT**	**Q**
H_2	0,0000	-433213,9124	0,0000
C_6H_6	0,0662	683,4255	45,2503
C_6H_{12}	65,8259	809,6732	53297,4341
C_7H_8	0,0570	789,9720	45,0108
TOTAL	**65,9491**		**53387,6951**

Qyang dilepas = Q in-Qout

= 118757,4268 kj/jam – (5814,3521 kj/jam+ 53387,6951 kj/jam)

= 59555,3796 kJ/jam

Tabel.C.29 Neraca Panas pada Seprator 01

Keterangan	Input	Output
Q6	118757,4268	0
Q7	0	5814,3521
Q8	0	53387,6951
Qloss	0	59555,3796
TOTAL	**118757,4268**	**118757,4268**

8. Neraca Panas Adsorber Ketika Regenerasi

Fungsi : mengeluarkan gas *cyclohexane* yang terjerap.

Tujuan : mengetahui steam yang dibutuhkan

INPUT

Tin = 30^{o}C = 303,15 K

Tabel C.30 Neraca Panas Input Absorber

Komponen	F, kmol/jam	CpdT(kJ/kmol)	Q(kJ/jam)
C_6H_6	0,0014	428,0148	0,587
C_6H_{12}	1,6893	544,9447	920,5519
C_7H_8	0,0004	537,8945	0,2033
TOTAL	**1,6910**		**921,3424**

OUTPUT

Tout = 100^{o}C =373,15K

Tabel C.31 Neraca Panas Output Adsorber

Komponen	F, kmol	cpdT (Kj/kmol)	Q(kj/jam)
C_6H_6	0,0014	7205,9059	9,88411581
C_6H_{12}	1,6893	9177,3335	15502,8812
C_7H_8	0,0004	8981,9394	3,39584568
TOTAL	**1,6910**		**15516,1612**

Qsteam = Qout-Qin

= 15516,1612 - 921,3424

= 14594,8187 Kj/jam

Tabel C.32 Neraca Panas Adsorber Regenerasi

keterangan	Q_{input}	Q_{output}
Q adsorbser	921,3424	0
Q output	0	15516,1612
Q steam	14594,8187	0
TOTAL	**15516,1612**	**15516,1612**

Menghitung Kebutuhan steam

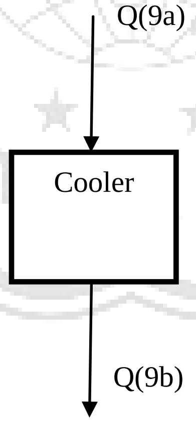
Digunakan steam dengan T= 135^{O}C, P= 45,4 psi (Kern,1950) Hs = 1172,1 Kj/kg

Massa steam = 12,45 kg/jam.

9. Neraca Panas Sekitar Cooler

Fungsi : Menurun suhu keluaran desorbsi.

Tujuan : Menghitung kebutuhan air pendingin.



Gambar C.9 Skema Neraca Panas disekitar Cooler

Keterangan :

Q(9a) = entalpi gas keluar doserbsi

Q(9b) = entalpi gas keluar cooler

Q(9a):

T in = 100°C =373,15 K

- Benzena (C_6H_6)

$\int_{298,15}^{373,15} Cp\ dT = \int_{298,15}^{373,15} [-31,368 + 4,75E-01 + (-3,11E-04) + 8,52E-08 + (-5,05E-12)]dT$

= 7205,9059 kJ/kmol

Q $_{C6H6}$ = m. Cp.dT

= 0,0014 kmol x 7205,9059 kJ/kmol

= 9,8841 kJ/jam

- Toluena (C_7H_8)

$\int_{298,15}^{308,15} Cp\ dT = \int_{298,15}^{373,15}$ [-24,097+5,22E-01 +(-2,98E-04) + 6,12E-08 + 1,26E-12]dT

= 8981,9394 kJ/kmol

Q_{C7H8} = m. Cp.dT

= 0,0004 kmol x 8981,9394 kJ/kmol

= 3,3958 kJ/jam

- Cyclohexane (C_6H_{12})

$\int_{298,15}^{308,15} Cp\ dT = \int_{298,15}^{373,15}$ [13,783 + 2,07E-01 + 5,37E-04 + (-6,30E-07) + 1,90E-10]dT

= 9177,3335 kJ/kmol

QC_6H_{12} = m. Cp.Dt

= 1,6893 kmol/jam x 9177,3335 kJ/kmol

= 15502,8812 Kj/jam

Q(9b) :

Tout :30°C = 303,15K

- Benzena (C_6H_6)

$\int_{298,15}^{303,15} Cp\ dT = \int_{298,15}^{303,15}$[-31,368 +4,75E − 01 +(−3,11E − 04) + 8,52E − 08

+(−5,05E − 12)]dT

= 568,5751 kJ/kmol

Q $_{C6H6}$ = m. Cp.dT

= 0,0014 kmol x 568,5751 kJ/kmol

= 0,7799 kJ/jam

- Toluena (C_7H_8)

$\int_{298,15}^{303,15} Cp\ dT = \int_{298,15}^{303,15}$[-24,097+5,22E-01 +(-2,98E-04) + 6,12E-08 + 1,26E-12]dT

= 672,5794 kJ/kmol

Q_{C7H8} = m. Cp.dT

= 0,0004 kmol x 672,5794 kJ/kmol

= 0,2543 kJ/jam

- Cyclohexane (C_6H_{12})

$\int_{298,15}^{303,15} Cp\ dT = \int_{298,15}^{303,15}$[13,783 + 2,07E-01 + 5,37E-04 + (-6,30E-07) + 1,90E-10]dT

= 302,2408 kJ/kmol

QC_6H_{12} = m. Cp.Dt

= 1,6893 kmol/jam x 302,2408 kJ/kmol

= 510,5626 Kj/jam

Qserap = Q(9a) – Q(9b)

= 15516,1612 - 511,5968

= 15004,5644 kJ/jam

Untuk menyerap panas tersebut maka dibutuhkan cooling water dengan kondisi :

Tin = 30°C, $\int_{298,15}^{303,15} Cp\ H20\ dT$ = 388,8676 kJ/kmol

Tout = 45°C = $\int_{298,15}^{318,15} Cp\ H20\ dT$ = 1.518,6910 kJ/kmol, Maka ∫ Cp $_{H2O}$ dT

= 1129,8234 Kj/kmol

Massa cooling water = $\frac{Qserap}{\int Cp\ H20\ dT}$

= 13,2805 kmol/jam = 239,0481 kg/jam

Tabel C.33 Neeraca Panas sekitar cooler

keterangan	QInput	QOutput
Q (9a)	15516,1612	0
Q (9b)	0	511,5968
Qpendingin	0	15004,5644
TOTAL	**15516,1612**	**15516,1612**