LAMPIRAN A

NERACA MASSA

Basis : Operasi batch. 1 batch = 3 jam

Operasional pabrik setiap hari = 6 batch

Dimana 1 tahun = 330 hari kerja

Basis : Kapasitas bahan baku = 60000 kg/hari = 10000 kg/batch

Tabel A-1. Komposisi Biji Jagung

Komponen	Komposisi (%)
Karbohidrat	78
Proein	10
Minyak	6,5
Air	2
Inert	3,5

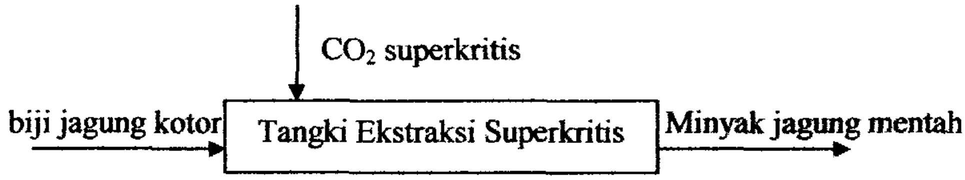
(www.delariva.com, Agricola de la Riva, S.L.)

Tabel A-2. Komposisi Asam Lemak yang terkandung dalam Minyak Jagung

Nama	Komponen	Berat Molekul (kg/kmol)	Komposisi (%)
Myristic acid	14 : 0	228	3
Palmitic acid	16 : 0	256	10
Stearic acid	18 : 0	284	3
Oleic acid	18 : 1n-9	282	50
Linoleic acid	18 : 2n-6	280	34

(Chemistry and Living Organism)

1. Tangki Ekstraksi Superkritis



Keterangan:

- Air yang dapat terekstrak sebesar 98 % (Catchpole, 2000)
- Minyak yang dapat terekstrak sebesar 99 % jika kondisi dalam tangki ekstraksi diatur pada P = 200 bar dan T = 50°C; dimana ρ = 650 kg/m^3 (M.Sc.Aymee Michel de Arevalo,2001)
- CO_2 yang masuk ke tangki ekstraktor = 8 x umpan yang masuk. (Catchpole, 2000)

Bahan masuk :

- Dari Tangki Penampungan CO_2

CO_2	= 79997,7885 kg/batch
Air	= 196,8120 kg/batch
Myristic acid	= 0,0015 kg/batch
Palmitic acid	= 0,0243 kg/batch
Stearic acid	= 0,0004 kg/batch
Oleic acid	= 0,0022 kg/batch
Linoleic acid	= 0,0023 kg/batch

- Dari Bin

Karbohidrat	: 78 % x 10000 kg/batch	= 7800 kg/batch
Protein	: 10 % x 10000 kg/batch	= 1000 kg/batch

Minyak jagung terdiri dari :

- Myristic acid : 3 % x 650 kg/batch = 19,5 kg/batch
- Palmitic acid : 10 % x 650 kg/batch = 65 kg/batch
- Stearic acid : 3 % x 650 kg/batch = 19,5 kg/batch
- Oleic acid : 50 % x 650 kg/batch = 325 kg/batch
- Linoleic acid : 34 % x 650 kg/batch = 221 kg/batch
- Air : 2 % x 10000 kg/batch = 200 kg/batch
- Inert : 3,5 % x 10000 kg/batch = 350 kg/batch

Bahan keluar :

- Ke Tangki Separator I

Massa CO_2 yang keluar = Massa CO_2 yang masuk = 80000 kg/batch

Air = 98 % × 200 = 196 + 196,8120 = 392,8120 kg/batch

Minyak yang terdiri dari :

- Myristic acid : 0,99 × 19,5 = 19,3050 + 0,0015 = 19,3065 kg/batch
- Palmitic acid : 0,99 × 65 = 64,3500 + 0,0243 = 64,3743 kg/batch
- Stearic acid : 0,99 × 19,5 = 19,3050 + 0,0004 = 19,3054 kg/batch
- Oleic acid : 0,99 × 325 = 321,7500 + 0,0022 = 321,7522 kg/batch
- Linoleic acid : 0,99 × 221 = 218,7900 + 0,0023 = 218,7923 kg/batch

- Ke Unit Pengolahan Limbah

Karbohidrat, protein, inert tidak terekstrak karena CO_2 dalam keadaan super kritis tidak mampu mengekstrak solid. (S.Ismadji, 2002).

Komponen yang tidak terekstrak :

Karbohidrat		7800	kg/batch
Protein		= 1000	kg/batch
Inert		= 350	kg/batch
Air	: 2 % × 200 kg/batch	= 4,0000	kg/batch
Myristic acid	: 1 % × 19,5 kg/batch	= 0,1950	kg/batch
Palmitic acid	: 1 % × 65 kg/batch	= 0,6500	kg/batch
Stearic acid	: 1 % × 19,5 kg/batch	= 0,1950	kg/batch
Oleic acid	: 1 % × 325 kg/batch	= 3,2500	kg/batch
Linoleic acid	: 1 % × 221 kg/batch	= 2,2100	kg/batch

Neraca Massa di Tangki Ekstraksi Superkritis

Masuk	kg/batch	Keluar	kg/batch
* Dari Bin		* Ke Tangki Separator I	
Karbohidrat	7800,0000	Air	392,8120
Protein	1000,0000	Myristic acid	19,3065
Myristic acid	19,5000	Palmitic acid	64,3743
Palmitic acid	65,0000	Stearic acid	19,3054
Stearic acid	19,5000	Oleic acid	321,7522
Oleic acid	325,0000	Linoleic acid	218,7923
Linoleic acid	221,0000	CO_2	79997,7885
Air	200,0000	* Ke Unit Pengolahan Limbah	
Inert	350,0000	Karbohidrat	7800,0000
* Dari Tangki Penampungan CO_2		Protein	1000,0000
CO_2	79997,7885	Air	4,0000
Myristic acid	0,0015	Inert	350,0000
Palmitic acid	0,0243	Myristic acid	0,1950
Stearic acid	0,0004	Palmitic acid	0,6500
Oleic acid	0,0022	Stearic acid	0,1950
Linoleic acid	0,0023	Oleic acid	3,2500

Air	196,8120	Linoleic acid	2,2100
Total	**90194,6312**	**Total**	**90194,6312**

2. **Tangki Separator I**

Minyak jagung + CO_2 dari tangki ekstraktor → Tangki Separator I → CO_2 menuju ke tangki penampungan CO_2

↓

CO_2, minyak jagung menuju ke tangki separator II

Kondisi operasi di dalam tangki separator I yaitu: tekanan = 100 bar,

suhu = 313,5 K

Bahan masuk :

CO_2 = 79997,7885 kg/batch

Air = 392,8120 kg/batch

Minyak yang terdiri dari :

- Myristic acid = 19,3065 kg/batch
- Palmitic acid 64,3743 kg/batch
- Stearic acid = 19,3054 kg/batch
- Oleic acid = 321,7522 kg/batch
- Linoleic acid 218,7923 kg/batch

Bahan Keluar :

- Ke Tangki Penampungan CO_2

Komponen	Massa masuk	BM	mol masuk	fraksi mol masuk (Z)
Myristic Acid	19,3065	228	0,0847	4,5964E-05
Palmitic Acid	64,3743	256	0,2515	0,0001
Stearic Acid	19,3054	284	0,0680	3,6898E-05
Oleic Acid	321,7522	282	1,1410	0,0006
Linoleic Acid	218,7522	280	0,7814	0,0004
Air	392,8120	18	21,8229	0,0118

CO_2	79997,7885	44	1818,1316	0,9927
Total	81034,1312		1842,2809	1

Untuk komponen air :

$$\text{Ln } P = A - \frac{B}{t + C} \qquad (\text{P dalam kPa, t dalam }^{\circ}\text{C})$$

$$\ln P = 16{,}262 - \frac{3799{,}83}{40{,}5 + 266{,}35}$$

$$= 3{,}8785$$

$$P^{o} = 48{,}3496 \text{ kPa} = 0{,}4772 \text{ bar}$$

$$K = \frac{P^{o}}{P_{op}} = \frac{0{,}4772}{100} = 0{,}004772$$

Dari buku Handbook of Chemical Engineering didapat konstanta A,B,C,D,E untuk menghitung P^{o} masing-masing komponen yang ditabelkan pada tabel berikut:

Komponen	A	B	C	D	E
Myristic Acid	-79.3115	-4693.6	43.573	-0.065469	0.000027919
Palmitic Acid	34.6559	-5264.5	-8.8645	0.0023028	-3.612E-13
Stearic Acid	-40.3638	-4772.4	24.502	-376.65	0.000014595
Oleic Acid	78.6973	-8822.7	-22.472	4.8353E-11	2.6578E-06
Linoleic Acid	40.6453	-7544.2	-7.5552	-0.010656	0.000005264
CO2	35.0169	-1511.9	-11.334	0.0093368	1.7136E-09

Untuk Komponen Myristic Acid :

$$\log P^{o} = A + \frac{B}{T} + C \log T + DT + ET^2 \qquad (\text{P} - \text{mmHg, T} - {}^{o}\text{K})$$

$$\log P^{O} = -79{,}3115 + \frac{-4{,}6936E+03}{313{,}5} - 43{,}573 \log(313{,}5) \quad (0{,}068469 \times 313{,}5) + (2{,}7919E-05 \times 313{,}5^2)$$

$= -4{,}2353$

$P^o = 5{,}81701E\text{-}05 \text{ mmHg} = 7{,}65396E\text{-}08 \text{ bar}$

$$K = \frac{P^o}{P_{op}} = \frac{7{,}65396E-08}{100} = 7{,}65396E-10$$

Dengan cara yang sama untuk komponen yang lain (Palmitic Acid, Stearic Acid, Oleic Acid, dan Linoleic Acid serta CO_2) dapat dilampirkan dalam tabel berikut :

Komponen	log P	P (mmHg)	P (bar)	K
Myristic Acid	-4,2353	5,81701E-05	7,65396E-08	7,65396E-10
Palmitic Acid	-3,5427	0,000286616	3,77126E-07	3,77126E-09
Stearic Acid	-4,7975	1,59404E-05	2,09742E-08	2,09742E-10
Oleic Acid	-5,2795	5,25412E-06	6,91332E-09	6,91332E-11
Linoleic Acid	-5,102	7,90679E-06	1,04037E-08	1,04037E-10
CO2	4,8292	67483,87309	88,79456985	0,8879

Trial V = 0,995 kmol

Keterangan : Z_1 = fraksi mol Myristic Acid

Z_2 = fraksi mol Palmitic Acid

Z_3 = fraksi mol Stearic Acid

Z_4 = fraksi mol Oleic Acid

Z_5 = fraksi mol Linoleic Acid

Z_6 = fraksi mol Air

Z_7 = fraksi mol CO_2

$$\frac{Z_1 \times K_1}{1+V(K_1+1)} + \frac{Z_2 \times K_2}{1+V(K_2+1)} + \frac{Z_3 \times K_3}{1+V(K_3+1)} + \frac{Z_4 \times K_4}{1+V(K_4+1)} + \frac{Z_5 \times K_5}{1+V(K_5+1)} + \frac{Z_6 \times K_6}{1+V(K_6+1)} + \frac{Z_7 \times K_7}{1+V(K_7+1)} = 1$$

$$\frac{4{,}5964E-05\times7{,}65396E-10}{1+0{,}995\times(7{,}65396E-10-1)}+\frac{0{,}0001\times3{,}77126E-09}{1+0{,}995\times(3{,}77126E-09-1)}+\frac{3{,}6898E-05\times2{,}09742E-10}{1+0{,}995\times(2{,}09742E-10-1)}+$$

$$\frac{0{,}0006\times6{,}91332E-11}{1+0{,}995\times(6{,}91332-E11-1)}+\frac{0{,}0004\times1{,}04037E-10}{1+0{,}995\times(1{,}04037E-10-1)}+\frac{0{,}0118\times0{,}004772}{1+0{,}995\times(0{,}004772-1)}+$$

$$\frac{0{,}9927\times0{,}8879}{1+0{,}995\times(0{,}8879-1)}$$

=7,0357E-12+1,0294E-10+1,5478E-12+8,5628E-12+8,8283E-12+0,0058+0,9863

= 0,9921 ≈ 1 (bisa dianggap trial benar)

$Massa_1$ = (7,0357E-12 x 0,995 x 1842,2809) kmol x 228 kg/kmol

= 2,94E-06 kg

$Massa_2$ = (1,0294E-10 x 0, 995 x 1842,2809) kmol x 256 kg/kmol

= 4,83E-05 kg

$Massa_3$ = (1,5478E-12 x 0, 995 x 1842,2809) kmol x 284 kg/kmol

= 8,06E-07 kg

$Massa_4$ = (8,5628E-12 x 0, 995 x 1842,2809) kmol x 282 kg/kmol

= 4,43E-06 kg

$Massa_5$ = (8,8283E-12 x 0, 995 x 1842,2809) kmol x 280 kg/kmol

= 4,53E-06 kg

$Massa_6$ = (0,0058 x 0, 995 x 1842,2809) kmol x 18 kg/kmol = 191,3260 kg

$Massa_7$ = (0,9863 x 0, 995 x 1842,2809) kmol x 44 kg/kmol = 79547,5570 kg

- **Ke Tangki Separator II**

Massa Myristic Acid = 19,3065 - 2,94E-06 = 19,3065 kg/batch

Massa Palmitic Acid = 64,3743 - 4,83E-05 = 64,3743 kg/batch

Massa Stearic Acid = 19,3054 - 8,06E-07 = 19,3054 kg/batch

Massa Oleic Acid = 321,7522 - 4,43E-06 = 321,7522 kg/batch

Massa Linoleic Acid = 218,7923 - 4,53E-06 = 218,7923 kg/batch

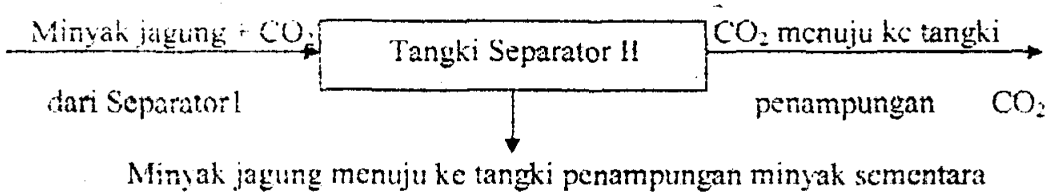
Massa Air = 392,8120 - 191,3260 = 201,4860 kg/batch

Massa CO_2 = 79997,7885   79547,5570   450,2315 kg/batch

Neraca Massa di Tangki Separator I

Masuk	kg/batch	Keluar	kg/batch
* Dari Tangki Ekstraksi Superkritis		* Ke Tangki Penampungan CO_2	
Myristic acid	19,3065	Myristic acid	2,94E-06
Palmitic acid	64,3743	Palmitic acid	4,83E-05
Stearic acid	19,3054	Stearic acid	8,06E-07
Oleic acid	321,7522	Oleic acid	4,43E-06
Linoleic acid	218,7923	Linoleic acid	4,53E-06
Air	392,8120	Air	191,3260
CO_2	79997,7885	CO_2	79547,5570
		* Ke Tangki Separator II	
		Myristic acid	19,3065
		Palmitic acid	64,3743
		Stearic acid	19,3054
		Oleic acid	321,7522
		Linoleic acid	218,7923
		Air	201,4860
		CO_2	450,2315
Total	**81034,1312**	**Total**	**81034,1312**

3. **Tangki Separator II**



Kondisi operasi di dalam tangki separator II yaitu: tekanan = 10 bar,

suhu = 303,94412 K

Bahan masuk :

CO_2 = 450,2315 kg/batch

Air = 201,4860 kg/batch

Minyak yang terdiri dari :

- Myristic acid = 19,3065 kg/batch
- Palmitic acid = 64,3743 kg/batch
- Stearic acid = 19,3054 kg/batch
- Oleic acid = 321,7522 kg/batch
- Linoleic acid = 218,7923 kg/batch

Bahan Keluar :

- Ke Tangki Penampungan CO_2

Komponen	Massa masuk	BM	mol masuk	fraksi mol masuk (Z)
Myristic Acid	19,3065	228	0,0847	0,0036
Palmitic Acid	64,3743	256	0,2515	0,0106
Stearic Acid	19,3054	284	0,0680	0,0029
Oleic Acid	321,7522	282	1,1410	0,0480
Linoleic Acid	218,7923	280	0,7814	0,0329
Air	201,4860	18	11,1937	0,4713
CO2	450,2315	44	10,2325	0,4307
Total	1295,2482		23,7527	1

Untuk komponen air :

$$Ln\ P = A - \frac{B}{t + C} \qquad \text{(P dalam kPa, t dalam °C)}$$

$$\ln P = 16{,}262 - \frac{3799{,}83}{40{,}5 + 266{,}35}$$

$$= 3{,}8785$$

$$P^o = 48{,}3496 \text{ kPa} = 0{,}4772 \text{ bar}$$

$$K = \frac{P^o}{P_{op}} = \frac{0{,}4772}{10} = 0{,}04771$$

Dari buku Handbook of Chemical Engineering didapat konstanta A,B,C,D,E untuk menghitung P^o masing-masing komponen yang ditabelkan pada tabel berikut:

Komponen	A	B	C	D	E
Myristic Acid	-79.3115	-4693.6	43.573	-0.065469	0.000027919
Palmitic Acid	34.6559	-5264.5	-8.8645	0.0023028	-3.612E-13
Stearic Acid	-40.3638	-4772.4	24.502	-376.65	0.000014595
Oleic Acid	78.6973	-8822.7	-22.472	4.8353E-11	2.6578E-06
Linoleic Acid	40.6453	-7544.2	-7.5552	-0.010656	0.000005264
CO2	35.0169	-1511.9	-11.334	0.0093368	1.7136E-09

Untuk Komponen Myristic Acid :

$$\log P^o = A + \frac{B}{T} + C \log T + DT + ET^2 \qquad (P - \text{mmHg}, T - {}^oK)$$

$$\log P^o = -79{,}3115 + \frac{-4{,}6936E+03}{313{,}5} + 43{,}573 \log(313{,}5) - (0{,}068469 \times 313{,}5) + (2{,}7919E-05 \times 313{,}5^2)$$

$$= -4{,}2353$$

P^o = 5,8170 E-05 mmHg = 7,65396 E-08 bar

$$K = \frac{P^o}{P_{op}} = \frac{7{,}65396E-08}{10} = 7.65396E-09$$

Dengan cara yang sama untuk komponen yang lain (Palmitic Acid, Stearic Acid, Oleic Acid, dan Linoleic Acid serta CO_2) dapat dilampirkan dalam tabel berikut :

Komponen	log P	P (mmHg)	P (bar)	K
Myristic Acid	-4,2353	5,82E-05	7,65E-08	7,65E-09
Palmitic Acid	-3,5427	0,0002866	3,77E-07	3,77E-08
Stearic Acid	-4,7975	1,59E-05	2,10E-08	2,10E-09
Oleic Acid	-5,2795	5,25E-06	6,91E-09	6,91E-10
Linoleic Acid	-5,102	7,91E-06	1,04E-08	1,04E-09
CO_2	4,8292	67483,873	88,79457	8,8785

Trial V = 0,995 kmol

Keterangan : Z_1 = fraksi mol Myristic Acid

Z_2 = fraksi mol Palmitic Acid

Z_3 = fraksi mol Stearic Acid

Z_4 = fraksi mol Oleic Acid

Z_5 = fraksi mol Linoleic Acid

Z_6 = fraksi mol Air

Z_7 = fraksi mol CO_2

$$\frac{Z_1 \times K_1}{1+V(K_1+1)}+\frac{Z_2 \times K_2}{1+V(K_2+1)}+\frac{Z_3 \times K_3}{1+V(K_3+1)}+\frac{Z_4 \times K_4}{1+V(K_4+1)}+\frac{Z_5 \times K_5}{1+V(K_5+1)}+$$
$$\frac{Z_6 \times K_6}{1+V(K_6+1)}+\frac{Z_7 \times K_7}{1+V(K_7+1)}=1$$

$$\frac{0{,}0036 \times 7{,}65E-09}{1+0{,}9999 \times (7{,}65E-09-1)}+\frac{0{,}0106 \times 3{,}77E-08}{1+0{,}9999 \times (3{,}77E-08-1)}+\frac{0{,}0029 \times 2{,}10E-09}{1+0{,}9999 \times (2{,}10E-09-1)}+$$
$$\frac{0{,}0480 \times 6{,}91E-10}{1+0{,}9999 \times (6{,}91E-10-1)}+\frac{0{,}0329 \times 1{,}04E-09}{1+0{,}9999 \times (1{,}04E-09-1)}+\frac{0{,}4712 \times 0{,}0477}{1+0{,}9999 \times (0{,}0477-1)}+$$
$$\frac{0{,}4308 \times 8{,}8785}{1+0{,}9999 \times (8{,}8785-1)}$$

=2,7283E-07+3,9907E-06+6,0024E-08+3,3207E-07+3,4225E-07+0,4703+0,4308 = 0,9012 ≈ 1 *(bisa dianggap trial benar)*

Massa$_1$ = (2,7283E-07 x 0,9999 x 18,2021) kmol x 228 kg/kmol = 0,0015 kg

Massa$_2$ = (3,9907E-06 x 0,9999 x 18,2021) kmol x 256 kg/kmol = 0,0243 kg

Massa$_3$ = (6,0024E-08 x 0,9999 x 18,2021) kmol x 284 kg/kmol = 0,0004 kg

Massa$_4$ = (3,3207E-07 x 0,9999 x 18,2021) kmol x 282 kg/kmol = 0,0022 kg

Massa$_5$ = (3,4225E-07 x 0,9999 x 18,2021) kmol x 280 kg/kmol = 0,0023 kg

$Massa_6$ = (0,4703 x 0,9999 x 18,2021) kmol x 18 kg/kmol = 201,0646 kg

$Massa_7$ = (0,4308 x 0,9999 x 18,2021) kmol x 44 kg/kmol = 450,2265 kg

❖ Ke Tangki Penampungan Minyak Sementara

Massa Myristic Acid = 19,3065 - 0,0015 = 19,3050 kg/batch

Massa Palmitic Acid = 64,3743 - 0,0243 = 64,3500 kg/batch

Massa Stearic Acid = 19,3054 - 0,0004 = 19,3050 kg/batch

Massa Oleic Acid = 321,7522 - 0,0022 = 321,7500 kg/batch

Massa Linoleic Acid = 218,7923 - 0,0023 = 218,7900 kg/batch

Massa Air = 201,4860 - 201,0646 = 0,4214 kg/batch

Massa CO_2 = 450,2315 - 450,2265 = 0,0050 kg/batch

Neraca Massa di Tangki Separator II

Masuk	kg/batch	Keluar	kg/batch
* Dari Tangki Separator I		* Ke Tangki Penampungan CO_2	
Myristic acid	19,3065	Myristic acid	0,0015
Palmitic acid	64,3743	Palmitic acid	0,0243
Stearic acid	19,3054	Stearic acid	0,0004
Oleic acid	321,7522	Oleic acid	0,0022
Linoleic acid	218,7923	Linoleic acid	0,0023
Air	201,4860	Air	201,0646
CO_2	450,2315	CO_2	450,2265
		* Ke Tangki Penampungan Sementara	
		Myristic acid	19,3050
		Palmitic acid	64,3500
		Stearic acid	19,3050
		Oleic acid	321,7500
		Linoleic acid	218,7900
		Air	0,4214
		CO_2	0,0050
Total	**1295,2481**	**Total**	**1295,2481**

4. Tangki Penampungan CO_2

CO_2 dari tangki separator I dan II → Tangki Penampungan CO_2 → CO_2 menuju ke tangki ekstraksi

Bahan Masuk :

*Dari Tangki Separator I

Myristic Acid = 2,96 E-06 kg/batch

Palmitic Acid = 4,83 E-05 kg/batch

Stearic Acid = 8,06 E-07 kg/batch

Oleic Acid = 4,43 E-06 kg/batch

Linoleic Acid = 4,53 E-06 kg/batch

Air = 191,3260 kg/batch

CO_2 = 79547,5570 kg/batch

*Dari Tangki Separator II

Myristic Acid = 0,0015 kg/batch

Palmitic Acid = 0,0243 kg/batch

Stearic Acid = 0,0004 kg/batch

Oleic Acid = 0,0022 kg/batch

Linoleic Acid = 0,0023 kg/batch

Air 201,0646 kg/batch

CO_2 = 450,2265 kg/batch

Bahan Keluar :

Ke Tangki Ekstraksi :

Myristic Acid = 0,0015 kg/batch

Palmitic Acid = 0,0243 kg/batch

Stearic Acid = 0,0004 kg/batch

Oleic Acid = 0,0022 kg/batch

Linoleic Acid = 0,0023 kg/batch

Air = 392,3906 kg/batch

CO_2 = 79997,7835 kg/batch

Neraca Massa di Tangki Penampungan CO_2

Masuk	kg/batch	Keluar	kg/batch
* Dari Tangki Separator I		* Ke Tangki Ekstraksi Superkritis	
Myristic acid	2,96E-06	Myristic acid	0,0015
Palmitic acid	4,83E-05	Palmitic acid	0,0243
Stearic acid	8,06E-07	Stearic acid	0,0004
Oleic acid	4,43E-06	Oleic acid	0,0022
Linoleic acid	4,53E-06	Linoleic acid	0,0023
Air	1,913,260	Air	3,923,906
CO_2	795,475,570	CO_2	799,977,835
* Dari Tangki Separator II			
Myristic acid	0,0015		
Palmitic acid	0,0243		
Stearic acid	0,0004		
Oleic acid	0,0022		
Linoleic acid	0,0023		
Air	2,010,646		
CO_2	4,502,265		
Total	**803.902,048**	**Total**	**803.902,048**

5. Tangki Penampungan Sementara

Minyak jagung dari tangki separator I dan II → Tangki Penampungan Sementara → Minyak jagung menuju ke tangki pemucat

Bahan Masuk :

Dari Tangki Separator II :

Myristic Acid = 19,3050 kg/batch

Palmitic Acid = 64,3500 kg/batch

Stearic Acid = 19,3050 kg/batch

Oleic Acid = 321,7500 kg/batch

Linoleic Acid = 218,7900 kg/batch

Air = 0,4214 kg/batch

CO_2 = 0,0050 kg/batch

Bahan Keluar :

Myristic Acid = 19,3050 kg/batch

Palmitic Acid = 64,3500 kg/batch

Stearic Acid = 19,3050 kg/batch

Oleic Acid = 321,7500 kg/batch

Linoleic Acid = 218,7900 kg/batch

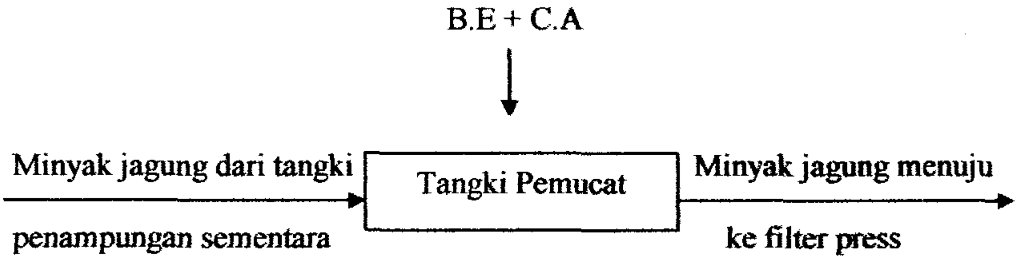
Air = 0,4214 kg/batch

CO_2 = 0,0050 kg/batch

Neraca Massa di Tangki Penampungan Sementara

Masuk	kg/batch	Keluar	kg/batch
* Dari Tangki Separator II		* Ke Tangki Pemucat	
Myristic acid	19,3050	Myristic acid	19,3050
Palmitic acid	64,7242	Palmitic acid	64,7242
Stearic acid	19,3050	Stearic acid	19,3050
Oleic acid	321,7500	Oleic acid	321,7500
Linoleic acid	218,7900	Linoleic acid	218,7900
Air	0,4214	Air	0,4214
CO_2	0,0050	CO_2	0,0050
Total	**643,9264**	**Total**	**643,9264**

6. Tangki Pemucat



Keterangan :

- Banyaknya bleaching earth-karbon akif yang dibutuhkan untuk pemucatan sebanyak 1 kg/100 kg minyak (Bernardini, 1983, hal 172)
- Karbon aktif : Bleaching earth = 1 : 9 (Bernardini, 1983, hal 173)

Bahan Masuk :

Myristic Acid = 19,3050 kg/batch

Palmitic Acid = 64,3500 kg/batch

Stearic Acid = 19,3050 kg/batch

Oleic Acid = 321,7500 kg/batch

Linoleic Acid = 218,7900 kg/batch

Air = 0,4214 kg/batch

CO_2 = 0,0050 kg/batch

Karbon aktif = [(1/10) x (1/100)] x 643,5000 = 0,6435 kg/batch

Bleaching earth = [(9/10) x (1/100)] x 643,5000 = 5,7915 kg/batch

Bahan Keluar :

Myristic Acid = 19,3050 kg/batch

Palmitic Acid = 64,3500 kg/batch

Stearic Acid = 19,3050 kg/batch

Oleic Acid = 321,7500 kg/batch

Linoleic Acid = 218,7900 kg/batch

Air = 0,4214 kg/batch

CO_2 = 0,0050 kg/batch

Karbon aktif = 0,6435 kg/batch

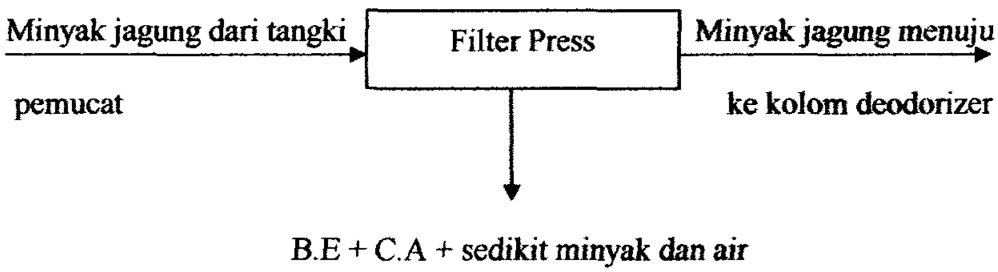
Bleaching earth = 5,7915 kg/batch

Neraca Massa di Tangki Pemucat

Masuk	kg/batch	Keluar	kg/batch
* Dari Tangki Penampungan Sementara		* Ke Filter Press	
Myristic acid	19,3050	Myristic acid	19,3050
Palmitic acid	64,3500	Palmitic acid	64,3500
Stearic acid	19,3050	Stearic acid	19,3050
Oleic acid	321,7500	Oleic acid	321,7500
Linoleic acid	218,7900	Linoleic acid	218,7900
Air	0,4214	Air	0,4214
CO_2	0,0050	CO_2	0,0050
* Dari Tangki Pencampuran B.E & C.A		Bleaching earth	5,7915
Bleaching earth	5,7915	Karbon aktif	0,6435

Karbon aktif	0,6435		
Total	**650,3614**	**Total**	**650,3614**

7. Filter Press



Keterangan :

- Bleaching earth-karbon aktif yang terpisah masih mengandung 30 % minyak dan air (Ulrich, 1984, hal 220)

Bahan Masuk :

Myristic Acid = 19,3050 kg/batch

Palmitic Acid = 64,3500 kg/batch

Stearic Acid = 19,3050 kg/batch

Oleic Acid = 321,7500 kg/batch

Linoleic Acid = 218,7900 kg/batch

Air = 0,4214 kg/batch

CO_2 = 0,0050 kg/batch

Karbon aktif = 0,6435 kg/batch

Bleaching earth = 5,7915 kg/batch

Bahan Keluar :

- Ke Tangki deodorisasi

Myristic Acid = 0,7 x 19,3050 = 13,5961 kg/batch

Palmitic Acid = 0,7 x 64,3500 = 45,3070 kg/batch

Stearic Acid = 0,7 x 19,3050 = 13,5969 kg/batch

Oleic Acid = 0,7 x 321,7500 = 226,6180 kg/batch

Linoleic Acid = 0,7 x 218,7900 = 154,0997 kg/batch

Air = 0,7 x 0,4214 = 0,4951 kg/batch

CO_2 = 0,7 x 0,0050 = 1,5480 kg/batch

❖ Ke Bin Penampungan Cake

Myristic Acid = 19,4230 - 13,5961 = 5,8269 kg/batch

Palmitic Acid = 64,7242 - 45,3070 = 19,4173 kg/batch

Stearic Acid = 19,4241 - 13,5969 = 5,8272 kg/batch

Oleic Acid = 323,7400 - 226,6180 = 97,1220 kg/batch

Linoleic Acid = 220,1424 - 154,0997 = 66,0427 kg/batch

Air = 0,7074 - 0,4951 = 0,2122 kg/batch

CO_2 = 2,2115 - 1,5480 = 0,6634 kg/batch

Karbon aktif = 0,6475 kg/batch

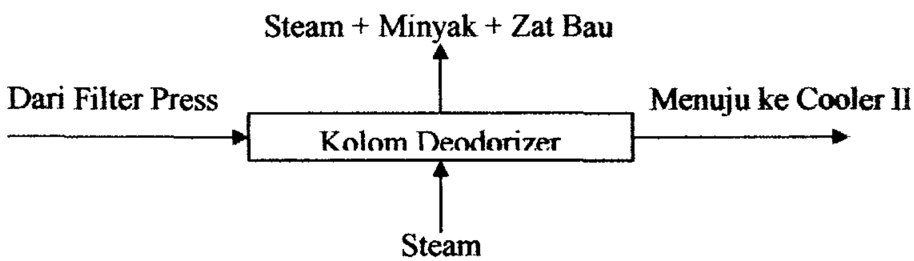
Bleaching earth = 5,8271 kg/batch

Neraca Massa di Filter Press

Masuk	kg/batch	Keluar	kg/batch
* Dari Tangki Pemucat		* Ke Kolom Deodorizer	
Myristic acid	19,3050	Myristic acid	13,5135
Palmitic acid	64,3500	Palmitic acid	45,0450
Stearic acid	19,3050	Stearic acid	13,5135
Oleic acid	321,7500	Oleic acid	225,2250
Linoleic acid	218,7900	Linoleic acid	153,1530
Air	0,4214	Air	0,2950
CO_2	0,0050	CO_2	0,0035
Bleaching earth	5,7915	* Ke Bin Penampung Cake	

Karbon aktif	0,6435	Myristic acid	5,7915
		Palmitic acid	19,3050
		Stearic acid	5,7915
		Oleic acid	96,5250
		Linoleic acid	65,6370
		Air	0,1264
		CO_2	0,0015
		Bleaching earth	5,7915
		Karbon aktif	0,6435
Total	**650,3614**	**Total**	**650,3614**

8. Kolom Deodorizer



Keterangan :

- Steam keluar kolom deodorizer akan membawa minyak sebesar 0,2% dan air sebesar 20% (Bernardini, hal 225)
- Massa steam yang dibutuhkan sebesar 50 kg/ton minyak (Bernardini, 1983, tabel 44 hal 239)
- Kandungan FFA pada minyak setelah keluar dari tangki deodorisasi sebesar 7% (Bernardini,1983)

Bahan Masuk :

- Dari Filter Press

  Air = 0,2950 kg/batch

CO_2 = 0,0035 kg/batch

FFA = 5,5% x (Myristic acid + Palmitic acid + Stearic acid)

FFA = 5,5% x (13,5135+45,0450+13,5135) = 3,9640 kg/batch

Oleic acid = 225,2250 kg/batch

Linoleic acid = 153,1530 kg/batch

✦ Dari Utilitas

Steam = 50 x (13,5135+45,0450+13,5135+225,2250+153,1530)/1000)

= 22,5225 kg.batch

Bahan Keluar :

❖ Ke Cooler I

Air = 80% x 0,2950 = 0,2360 kg/batch

CO_2 = 80% x 0,0035 = 0,0028 kg/batch

Myristic Acid = 7% x 13,5135 = 0,9459 kg/batch

Palmitic Acid = 7% x 45,0450 = 3,1531 kg/batch

Stearic Acid = 7% x 13,5135 = 0,9459 kg/batch

Oleic Acid = 99,8% x 225,2250 = 224,7745 kg/batch

Linoleic Acid = 99,8% x 153,1530 = 152,8467 kg/batch

❖ Ke Steam Jet Ejektor

Air = 20% x 0,2950 = 0,0590 kg/batch

CO_2 = 20% x 0,0035 = 0,0007 kg/batch

Myristic Acid = 93% x 13,5135 = 12,5676 kg/batch

Palmitic Acid = 93% x 45,0450 = 41,8918 kg/batch

Stearic Acid = 93% x 13,5135 = 12,5676 kg/batch

Oleic Acid = 0,2% x 225,2250 = 0,4504 kg/batch

Linoleic Acid = 0,2% x 153,1530 = 0,3063 kg/batch

Steam = 22,5225 kg/batch

Neraca Massa di Kolom Deodorizer

Masuk	kg/batch	Keluar	kg/batch
* Dari Filter Press		* Ke Cooler II	
Air	0,2950	Air	0,2360
CO_2	0,0035	CO_2	0,0028
Oleic acid	225,2250	Oleic acid	224,7745
Linoleic acid	153,1530	Linoleic acid	152,8467
FFA		FFA	
Myristic acid	13,5135	Myristic acid	0,9459
Palmitic acid	45,0450	Palmitic acid	3,1531
Stearic acid	13,5135	Stearic acid	0,9459
* Dari Utilitas		* Ke Steam Jet Ejektor	
Steam	22,5225	Air	0,0590
		CO_2	0,0007
		Oleic acid	0,4504
		Linoleic acid	0,3063
		FFA	
		Myristic acid	12,5676
		Palmitic acid	41,8918
		Stearic acid	12,5676
		Steam	22,5225
Total	**473,2709**	**Total**	**473,2709**

APPENDIKS B

NERACA ENERGI

APPENDIKS B

NERACA PANAS

1. Tangki Penampungan CO_2 (F-121)

Suhu Masuk = 297,2662 K

Suhu Keluar = 313 K

Tekanan Masuk = 10 bar

Tekanan Keluar = 20 bar

Keterangan : Massa myristic acid, palmitic acid, stearic acid, oleic acid, linoleic acid dan air diabaikan karena massanya terlalu kecil sehingga pada tangki penampungan CO_2 neraca panas hanya dihitung untuk komponen CO_2

$$\int_{T_1}^{T_2} \frac{\left(C_p^{ig}\right)_{CO_2}}{R} dT = \left[A + \frac{B}{2} T_1(\tau+1) + \frac{C}{3} T_1^2\left(\tau^2+\tau+1\right) + \frac{D}{\tau T_1^2}\right](T_2 - T_1)$$

$$= \left[5,457 + \frac{0,00145}{2} 297,2662(1,0529+1) + 0 + \frac{-115700}{1,0529 \times 297,2662^2}\right](313 - 297,2662)$$

$= 71,3114$ K

$$QCO_2 = \left(R \int_{T_1}^{T_2} \frac{\left(C_p^{ig}\right)_H}{R} dT \times mol\right) + H_2^R - H_1^R$$

$$= \left(8,314 \, kJ/_{Kmol\,K} \times 71,3114 K \times 1818,1316 \, Kmol/_{batch}\right) - 840,6933 + 413,9055$$

$= 1079194,0607$ kJ/batch

$Q_{total} = Q\ CO_2$

$Q_{total} = Q_{suplai} + Q_{loss}$

$Q_{total} = Q_{suplai} + 0,1\ Q_{total}$

$Q_{suplai} = 0,9\ Q_{total}$

$Q_{suplai} = 1199104,5119$ kJ/batch

$Q_{loss} = 119910,4512$ kJ/batch

Neraca Panas di Tangki Penampungan CO_2

Panas yang dibutuhkan	kJ/batch	Panas yang diberikan	kJ/batch
Q CO_2	1079194,0607	Qsuplai	1199104,5119
Q loss	119910,4512		
Total	**1199104,5119**	**Total**	**1199104,5119**

2. Compresor 1 (K-122)

Keterangan : - Massa air, myristic acid, palmitic acid, stearic acid, oleic acid, dan linoleic acid diabaikan karena massanya terlalu kecil sehingga pada piston pump neraca panas hanya dihitung untuk komponen CO_2 saja.

Bahan masuk :

Suhu masuk = 40 °C = 313 K

Tekanan masuk = 20 bar

Tekanan keluar = 200 bar

Tc = 304,2 K Pc = 73,83 bar ω = 0,2240

$Tr_1 = \frac{T1}{Tc} = \frac{313}{304,2} = 1,0289$ $Pr_1 = \frac{P1}{Pc} = \frac{20}{73,83} = 0,2709$

$$\frac{S_1^R}{R} = -Pr_1\left(\frac{dB^0}{dTr_1} + \omega\frac{dB^1}{dTr_1}\right)$$

Dimana : $\frac{dB^0}{dTr_1} = \frac{0,675}{Tr_1^{2,6}} = \frac{0,675}{1,0289^{2,6}} = 0,6268$

$$\frac{dB^1}{dTr_1} = \frac{0,722}{Tr_1^{5,2}} = \frac{0,722}{1,0289^{5,2}} = 0,6225$$

Sehingga : $S_1^R = \{-0,2709\ (0,6268 + 0,2240 \times 0,6225)\} \times 8,314$

$= -1,7256$ kJ/kmol K

$$\Delta S = \left\{R\left(\int_{T_1}^{T_2}\frac{\langle C_p^{ig}\rangle_S}{R} - \ln\frac{P_2}{P_1}\right)\right\} + S_2^R - S_1^R$$

Untuk η = 100 % maka ΔS = 0

Trial T_2 teoritis :

$T_2 = 500$ K

$Tr_2 = \frac{T_2}{Tc} = \frac{500}{304,2} = 1,6437$ $Pr_2 = \frac{P_2}{Pc} = \frac{200}{73,83} = 2,7089$

$$\frac{S_2^R}{R} = -Pr_2\left(\frac{dB^0}{dTr_2} + \omega\frac{dB^1}{dTr_2}\right)$$

Dimana : $\frac{dB^0}{dTr_2} = \frac{0,675}{Tr_2^{2,6}} = \frac{0,675}{1,6437^{2,6}} = 0,1854$

$$\frac{dB^1}{dTr_2} = \frac{0,722}{Tr_2^{5,2}} = \frac{0,722}{1,6437^{5,2}} = 0,0545$$

Sehingga S_2^R = {- 2,7089 (0,1854 + 0,2240 x 0,0545)} x 8,314

= - 4,4513 kJ kmol K

$$\int_{T_1}^{T_2} \frac{\left(C_P^{ig}\right)_S}{R} \frac{dT}{T} = A \ln \tau + \left[BT_1 + \left(CT_1^2 + \frac{D}{\tau^2 T_1^2} \right)\left(\frac{\tau+1}{2}\right)\right](\tau - 1)$$

Dimana : koefisien A, B, C, D untuk CO_2 diambil dari Smith, hal 638

A = 5,457 ; B = 0,00145; C = 0 ; D = -115700

$$\tau = \frac{T_2}{T_1} = \frac{500}{313} = 1,5974$$

$$\int_{T_1}^{T_2} \frac{\left(C_P^{ig}\right)_S}{R} \frac{dT}{T} = 5,457 \ln 1,5974 + \left[(0,00145 \times 313) + \left(0 + \frac{-115700}{1,5974^2 313^2} \right)\left(\frac{1,5974+1}{2}\right)\right](1,5974 - 1)$$

$$\int_{T_1}^{T_2} \frac{\left(C_P^{ig}\right)_S}{R} \frac{dT}{T} = 2,1639$$

$$\Delta S = \left\{ R \left(\int_{T_1}^{T_2} \frac{\left(C_P^{ig}\right)_S}{R} \frac{dT}{T} - \text{Ln} \frac{P_2}{P_1} \right) \right\} + S_2^R - S_1^R$$

$$= \left\{ 8,314 \left(2,1639 - \text{Ln} \frac{200}{20} \right) \right\} + (-4,4513) - (-1,7256)$$

= - 5,6045 kJ/kmol °K

Trial dilakukan sampai ΔS = 0, hasil trial mendapat T_2 teorities = 579,08 K.

Dari T_2 teorities dicari ΔH teorities.

$$\Delta H \text{ teorities} = \left(R \int_{T_1}^{T_2} \frac{\left(C_P^{ig}\right)_H}{R} dT \right) - H_2^R - H_1^R$$

Dimana :

$$\int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT - \left[A + \frac{B}{2} T_1 (\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1 \right) + \frac{D}{\tau T_1^2} \right] (T_2 - T_1)$$

$$= \left[5,457 + \frac{0,00145}{2} 313 (1,6622 + 1) + 0 + \frac{-115700}{1,6622 \times 313^2} \right] (520,2824 - 313)$$

$$= 1406,1727 \text{ K}$$

$$\frac{H_1^R}{R \times Tc} = \frac{\left(H_1^R \right)^0}{R \times Tc} + \omega \times \frac{\left(H_1^R \right)^1}{R \times Tc}$$

dimana : $\frac{\left(H_1^R \right)^0}{R \times Tc} = -2,7820$ (dari App E.5 hal 654 Smith)

$\frac{\left(H_1^R \right)^1}{R \times Tc} = -3,2410$ (dari App E.6 hal 655 Smith)

$$\frac{H_1^R}{8,314 \times 304,2} = -2,7820 + 0,2240 \times (-3,2410)$$

$H_1^R = -8872,1083$ Kj/kmol

$$\frac{H_2^R}{R \times Tc} = \frac{\left(H_2^R \right)^0}{R \times Tc} + \omega \times \frac{\left(H_2^R \right)^1}{R \times Tc}$$

dimana : $\frac{\left(H_2^R \right)^0}{R \times Tc} = -0,7971$ (dari App E.5 hal 654 Smith)

$\frac{\left(H_2^R \right)^1}{R \times Tc} = 0,2421$ (dari App E.6 hal 655 Smith)

$$\frac{H_2^R}{8,314 \times 304,2} = -0,7971 + 0,2240 \times (0,2421)$$

$H_2^R = -1878,8055$ Kj/kmol

$$\Delta H \text{ teorities} = \left(R \int_{T_1}^{T_2} \frac{\left(C_P^{ig}\right)_H}{R} dT \right) + H_2^R - H_1^R$$

$$= (8{,}314 \times 1074{,}1194) + (-1878{,}8055) - (-8872{,}1083)$$

$$= 18684{,}2227 \text{ kJ/kmol}$$

$$Ws = \frac{\Delta H \text{ teorities}}{\eta} = \frac{18684{,}2227}{70} = 26691{,}7467 \text{ ; } \eta = 70\% \text{ (Ulrich)}$$

$$\Delta H \text{ aktual} = \frac{\Delta H \text{ teorities}}{\eta} = 26691{,}7467 \text{ KJ/kmol}$$

Trial $T_2 = 725$ K

$$Tr_2 = \frac{T_2}{Tc} = \frac{725}{304{,}2} = 2{,}3833$$

$$\frac{H_2^R}{R \times Tc} = \frac{\left(H_2^R\right)^0}{R \times Tc} + \omega \times \frac{\left(H_2^R\right)^1}{R \times Tc}$$

dimana : $\frac{\left(H_2^R\right)^0}{R \times Tc} = -0{,}4769$ (dari App E.5 hal 654 Smith)

$\frac{\left(H_2^R\right)^1}{R \times Tc} = 0{,}3208$ (dari App E.6 hal 655 Smith)

$$\frac{H_2^R}{8{,}314 \times 304{,}2} = -0{,}4769 + 0{,}2240 \times (0{,}3208)$$

$H_2^R = -1024{,}3963$ KJ/kmol

$$\tau = \frac{T_2}{T_1} = \frac{725}{313} = 2{,}3163$$

$$\int_{T_1}^{T_2} \frac{\left(C_P^{ig}\right)_H}{R} dT = \left[A + \frac{B}{2} T_1(\tau + 1) + \frac{C}{3} T_1^2\left(\tau^2 + \tau + 1\right) + \frac{D}{\tau T_1^2} \right](T_2 - T_1)$$

$$= \left[5,457 + \frac{0,00145}{2} 313(2,3163+1) + 0 + \frac{-115700}{2,3163 \times 313^2}\right](725-313)$$

$= 2261,6719$ K

$$\Delta H \text{ aktual} = \left(R \int_{T_1}^{T_2} \frac{\langle C_P^{ig} \rangle_H}{R} dT \right) + H_2^R - H_1^R$$

$$= (8,314 \times 1526,2550) + (-1024,3963) - (-8872,1083)$$

$= 26651,2522$ kJ/kmol

Trial T_2 dilakukan sampai ΔH aktual = 26691,7467 kJ/kmol hasil trial mendapat T_2 = 725,7451 K

$Q\ CO_2$ = ΔH aktual x mol

$$= \left(26691,5954 \times \frac{80000}{44}\right)$$

= 48530173,4546 Kj/batch

$Q_{loss} = 0,3 \times Q_{suplai}$

$Q\ CO_2 + Q_{loss} = Q_{suplai}$

$48530173,4546 + 0,3\ Q_{suplai} = Q_{suplai}$

$48530173,4546 = 0,7\ Q_{suplai}$

$Q_{suplai} = 69328819,2209$ kJ/batch

Neraca Panas di Compresor 1

Panas yang dibutuhkan	kJ/batch	Panas yang diberikan	kJ/batch
Dari Tangki Penampungan CO_2		Ke Tangki Ekstraksi	
Q CO_2	48530173,4546	Q suplai	69328819,2209
Q loss	20798645,7663		
Total	69328819,2209	**Total**	69328819,2209

3. Cooler 1 (E-123)

Suhu CO_2 masuk cooler = 725,7451 K

Suhu CO_2 keluar cooler = 436,15114 K

Tc = 304,2 K Pc = 73,83 bar ω = 0,2240

T_1 = 633,456 K

$$Tr1 = \frac{T_1}{Tc} = \frac{725,7451}{304,2} = 2,3857 \qquad Pr_1 = \frac{P_1}{Pc} = \frac{200}{73,83} = 2,7089$$

$$\frac{H_1^R}{R \times Tc} = \frac{\left(H_1^R\right)^0}{R \times Tc} + \omega \times \frac{\left(H_1^R\right)^1}{R \times Tc}$$

dimana : $\frac{\left(H_1^R\right)^0}{R \times Tc}$ = -0,4757 (dari App E.5 hal 654 Smith)

$\frac{\left(H_1^R\right)^1}{R \times Tc}$ = 0,3211 (dari App E.6 hal 655 Smith)

$$\frac{H_1^R}{8,314 \times 304,2} = -0,4757 + 0,2240 \times (0,3211)$$

H_1^R = - 10121,1900 kJ/batch

T_2 = 436,15114 K

$$Tr_2 = \frac{T_2}{Tc} = \frac{436,15114}{304,2} = 1,4338 \qquad Pr_2 = \frac{P_2}{Pc} = \frac{200}{73,83} = 2,7089$$

$$\frac{H_2^R}{R \times Tc} = \frac{\left(H_2^R\right)^0}{R \times Tc} + \omega \times \frac{\left(H_2^R\right)^1}{R \times Tc}$$

dimana : $\frac{\left(H_2^R\right)^0}{R \times Tc}$ = -1,5870 (dari App E.5 hal 654 Smith)

$\frac{\left(H_2^R\right)^1}{R \times Tc}$ = -0,0028 (dari App E.6 hal 655 Smith)

$$\frac{H_2^R}{8{,}314 \times 304{,}2} = -1{,}5870 + 0{,}2240 \times (-0{,}0028)$$

H_2^R = - 4051,3000 kJ/batch

$$\text{Cp } CO_2 = \left[A + \frac{B}{2} T_1(\tau+1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1\right) + \frac{D}{\tau T_1^2} \right] \left(T_2 - T_1\right)$$

$$= \left\{ 5{,}457 + \frac{1{,}045E-03}{2} \times 725{,}7451 \times (0{,}0010 + 1) + \ldots \right.$$ [illegible]

= - 1650,2714 K

Suhu air pendingin masuk = 303 K

Suhu air pendingin keluar = 350 K

T_c = 647,1 K Pc = 220,55 bar ω = 0,3450

T_1 = 303 K

$$Tr1 = \frac{T_1}{Tc} = \frac{303}{647{,}1} = 0{,}4682 \qquad Pr_1 = \frac{P_1}{Pc} = \frac{1}{220{,}55} = 0{,}0045$$

$$\frac{H_1^R}{R \times Tc} = \frac{\left(H_1^R\right)^0}{R \times Tc} + \omega \times \frac{\left(H_1^R\right)^1}{R \times Tc}$$

dimana : $\dfrac{\left(H_1^R\right)^0}{R \times Tc}$ = -5,4643 (dari App E.5 hal 654 Smith)

$\dfrac{\left(H_1^R\right)^1}{R \times Tc}$ = -8,8684 (dari App E.6 hal 655 Smith)

H_1^R = - 45858,5 kJ/batch

T_2 = 350 K

$$Tr_2 = \frac{T_2}{Tc} = \frac{350}{647{,}1} = 0{,}5409 \qquad Pr_2 = \frac{P_2}{Pc} = \frac{1}{220{,}55} = 0{,}0045$$

$$\frac{H_2^{\ R}}{R \times Tc} = \frac{\left(H_2^{\ R}\right)^0}{R \times Tc} + \omega \times \frac{\left(H_2^{\ R}\right)^1}{R \times Tc}$$

dimana : $\frac{\left(H_2^{\ R}\right)^0}{R \times Tc}$ = -4,3510 (dari App E.5 hal 654 Smith)

$\frac{\left(H_2^{\ R}\right)^1}{R \times Tc}$ = -6,7312 (dari App E.6 hal 655 Smith)

H_2^R = -35902,1000 kJ/batch

$$\text{Cp air} = \left[A + \frac{B}{2}T_1(\tau+1) + \frac{C}{3}T_1^2\left(\tau^2+\tau+1\right) + \frac{D}{\tau T_1^2}\right]\left(T_2 - T_1\right)$$

$$= \left\{8{,}712 + \frac{1{,}25E-03}{2} \times 303 \times \left(\frac{3{,}00}{303} + 1\right) + [illegible]\right\}(T_2 - 303)$$

= 427,7425 K

$$Q\ CO_2 = \left\{\left(R\int_{T_1}^{T_2}\frac{\langle C_p^{ig}\rangle}{R}dT\right) + H_2^R - H_1^R\right\} \times mol$$

$$= \{(8{,}314 \times -1650{,}2714) + (-4051{,}3) - (-10121{,}19)\} \times \frac{80000}{44}$$

= -13909939,1639 kJ/batch

$|Q\ CO_2| + |Q_{loss}| = |Q_{pendingin}|$

13909939,1639 + 0,05 $Q_{pendingin}$ = $Q_{pendingin}$

$Q_{pendingin}$ = 14642041,2252 kJ/batch

$$Q_{pendingin} = \left\{R\int_{T_1}^{T_2}\frac{\langle C_p^{ig}\rangle}{R}dT\right\} \times mol$$

14642041,2252 = (8,314 × 427,7425) × mol

Mol = 4117,2690 Kmol/batch

Massa air pendingin = 74110,8415 Kg/batch

Neraca Panas di Cooler I

Panas yang dibutuhkan	kJ/batch	Panas yang diberikan	kJ/batch
Q air pendingin	14642041,2252	Q CO_2	13909939,1639
		Q loss	732102,0613
Total	**14642041,2252**	**Total**	**14642041,2252**

4. Tangki Ekstraksi Superkritis (F-120)

$$|Q_{CO_2}| = |Q_{jagung}| + |Q_{loss}|$$

$$-(Q_{CO_2}) = Q_{jagung} + |Q_{loss}|$$

$$-(Q_{CO_2}) = Q_{jagung} - (Q_{loss})$$

$$-(Q_{CO_2}) = Q_{jagung} - (0,1\ Q_{loss})$$

$$0 = Q_{jagung} + 0,9\ Q\ CO_2$$

Dimana :

$Q_{jagung} = Q_{karbohidrat} + Q_{protein} + Q_{Myristic\ Acid} + Q_{Palmitic\ Acid} + Q_{Stearic\ Acid} + Q_{Oleic\ Acid} + Q_{Linoleic\ Acid} + Q_{air} + Q_{inert}$

$Cp_{karbohidrat} = A(T_2-T_1) + \frac{1}{2}B\ (T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D\ (T_2^4-T_1^4)$

$= 1,5488\ (50-30) + \frac{1}{2}\ 0,0020\ (50^2-30^2) + \frac{1}{3}\ (-5,94E-06)\ (50^3-30^3) + 0$

$= 32,3520$ kJ/Kg °C

$Cp_{protein} = A(T_2-T_1) + \frac{1}{2}B\ (T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D\ (T_2^4-T_1^4)$

$= 2,0082\ (50-30) + \frac{1}{2}\ 0,0012\ (50^2-30^2) + \frac{1}{3}\ (-1,31E-06)\ (50^3-30^3) + 0$

$= 41,0882$ kJ/Kg °C

$Cp_{Myristic\ Acid} = A(T_2-T_1) + \frac{1}{2}B\ (T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D\ (T_2^4-T_1^4)$

$= 80,2660(323-303) + \frac{1}{2}\ 2,8162\ (323^2-303^2) + \frac{1}{3}\ (-0,00601)\ (323^3-303^3) +$

$\frac{1}{4}\ (5,1299E-06)\ (323^4-303^4)$

$= 10604,1584$ kJ/Kmol °K

$Cp_{\text{Palmitic Acid}} = A(T_2-T_1) + ½B(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D(T_2^4-T_1^4)$

$= 86,2900(323-303) + ½\ 3,5237\ (323^2-303^2) + ⅓(-0,007322)(323^3-303^3) +$

$¼\ (6,1001E\text{-}06)\ (323^4-303^4)$

$= 13178,2125$ kJ/Kmol °K

$Cp_{\text{Stearic Acid}} = A(T_2-T_1) + ½B(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D(T_2^4-T_1^4)$

$= 99,0120(323-303) + ½\ 3,5874\ (323^2-303^2) + ⅓(-0,007248)(323^3-303^3) +$

$¼\ (5,9035E\text{-}06)\ (323^4-303^4)$

$= 13854,3909$ kJ/Kmol °K

$Cp_{\text{Oleic Acid}} = A(T_2-T_1) + ½B(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D(T_2^4-T_1^4)$

$= 278,6860(323-303) + ½\ 2,5434(323^2-303^2) + ⅓(-0,005436)(323^3-303^3) +$

$¼\ (4,924E\text{-}06)\ (323^4-303^4)$

$= 13864,4727$ kJ/Kmol °K

$Cp_{\text{Linoleic Acid}} = A(T_2-T_1) + ½B(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D(T_2^4-T_1^4)$

$= 241,3480(323-303) + ½\ 2,3065(323^2-303^2) + ⅓(-0,005056)(323^3-303^3) +$

$¼\ (4,7468E\text{-}06)\ (323^4-303^4)$

$= 12249,5828$ kJ/Kmol °K

$Cp_{\text{Air}} = A(T_2-T_1) + ½B(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D(T_2^4-T_1^4)$

$= 95,0530(323-303) + ½\ 0,04\ (323^2-303^2) + ⅓(-0,000211)(323^3-303^3) +$

$¼\ (5,35E\text{-}07)\ (323^4-303^4)$

$= 2006,3330$ kJ/Kmol °K

$Cp_{Inert} = A(T_2-T_1) + ½B(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D(T_2^4-T_1^4)$

$= 2{,}4780\ (50-30) + ½\ 0{,}1652\ (50^2-30^2) + ⅓\ (-0{,}000968)\ (50^3-30^3) + 0$

$= 150{,}1245$ kJ/Kg °C

$$\int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT = \left[A + \frac{B}{2} T_1(\tau+1) + \frac{C}{3} T_1^2(\tau^2+\tau+1) + \frac{D}{\tau T_1^2} \right] (T_2 - T_1)$$

$$= \left\{ 5{,}457 + \frac{1{,}045E-03}{2} \times T_1 \left(\frac{323}{T_1} + 1 \right) + 0 + \frac{-115700}{\frac{323}{T_1} \times T_1^2} \right\} \times (323 - T_1)$$

$$= \left\{ \left(5{,}457 + 0{,}2342 + 7{,}25E-04 \times T_1 - \frac{115700}{323 T_1} \right) \times (323 - T_1) \right\}$$

$$= -115700T_1 + 2196{,}4619 - 5{,}457T_1 - 7{,}25E-04T_1^2$$

$Q_{karbohidrat}$ = massa x $Cp_{karbohidrat}$ x ΔT

$$= 7800\,Kg \times 32{,}3520\ \frac{Kj}{Kg\,°C} \times (50-30)°C = 5046905{,}76 \text{ kJ/batch}$$

$Q_{protein}$ = massa x $Cp_{protein}$ x ΔT

$$= 1000\,Kg \times 41{,}0882\ \frac{Kj}{Kg\,°C} \times (50-30)°C = 821764{,}6 \text{ kJ/batch}$$

$Q_{Myristic\ Acid}$ = mol x $Cp_{Myristic\ Acid}$ x ΔT

$$= \frac{19{,}5}{228}\ \frac{Kj}{batch} \times 10604{,}1584\ \frac{Kj}{Kmol°K} \times (323-303)°K$$

= 18138,6920 kJ/batch

$Q_{Palmitic\ Acid}$ = mol x $Cp_{Palmitic\ Acid}$ x ΔT

$$= \frac{65}{256}\ \frac{Kj}{batch} \times 13178{,}2125\ \frac{Kj}{Kmol°K} \times (323-303)°K$$

= 66920,6104 kJ/batch

$Q_{Stearic\ Acid}$ = mol x $Cp_{Stearic\ Acid}$ x ΔT

$$= \frac{19,5}{284} \,{}^{Kj}\!/\!_{batch} \times 13854,3909 \,{}^{Kj}\!/\!_{Kmol^{o}K} \times (323 - 303)^{o}K$$

= 19025,3960 kJ/batch

$Q_{Oleic\ Acid}$ = mol x $Cp_{Linoleic\ Acid}$ x ΔT

$$= \frac{325}{280} \,{}^{Kj}\!/\!_{batch} \times 13864,4727 \,{}^{Kj}\!/\!_{Kmol^{o}K} \times (323 - 303)^{o}K$$

= 321853,8306 kJ/batch

$Q_{Linoleic\ Acid}$ = mol x $Cp_{Oleic\ Acid}$ x ΔT

$$= \frac{221}{282} \,{}^{Kj}\!/\!_{batch} \times 12249,5828 \,{}^{Kj}\!/\!_{Kmol^{o}K} \times (323 - 303)^{o}K$$

= 191997,0070 kJ/batch

Q_{air} = massa x Cp_{Air} x ΔT

$$= 200\,Kg \times 2006,3330 \,{}^{Kj}\!/\!_{Kg^{o}C} \times (50 - 30)^{o}C$$

= 445851,7869 kJ/batch

Q_{inert} = massa x Cp_{Inert} x ΔT

$$= 350\,Kg \times 150,1245 \,{}^{Kj}\!/\!_{Kg^{o}C} \times (50 - 30)^{o}C$$

= 1050871,2667 kJ/batch

Q_{jagung} = 5046905,7600 + 821764,6387 + 18138,6920 + 66920,6104 + 19025,3960 + 321853,8306 + 191997,0070 + 445851,7869 + 1050871,2667

= 7983328,9300 kJ/batch

$$\mathbf{Q} = \left(R \int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT \right) \times mol$$

$$= \left\{8,314\left(5,457 + 0,2342 + 7,25E-04 \times T_1 - \frac{115700}{323T_1}\right) \times (323 - T_1)\right\} \frac{80000}{44}$$

$$= -1748963268,52T_1 + 33202516,7139 - 82489,9962T_1 - 10,9594T_1^2$$

Mencari T_1 untuk komponen CO_2 dari tangki penampungan CO_2 :

$0 = Q_{jagung} + 0,9\ Q\ CO_2$

$$= 7983328,9300 + 0,9 \times \left(-1748963268,52T_1 + 33202516,7139 - 82489,9962T_1 - 10,9594T_1^2\right)$$

Mentrial T_1 = 400 K dan mendapat Q_{jagung} + 0,9 Q CO_2 = 2655874,4150 **kJ/batch** sehingga trial harus diulang kembali sampai mendapat Q_{jagung} + **0,9 Q CO_2 = 0** kJ/batch yaitu didapat T_1 sebesar 436,15114 K.

Q_{jagung} = 7983328,9300 kJ/batch

Q CO_2 = $\left(-1748963268,52T_1 + 33202516,7139 - 82489,9962T_1 - 10,9594T_1^2\right)$

= - 8870365,4780 kJ/batch

Q_{loss} = 0,1 x - 8870365,4780 kJ/batch = - 887036,5478 kJ/batch

Neraca Panas di Tangki Ekstraksi Superkritis

Panas yang dibutuhkan	kJ/batch	Panas yang diberikan	kJ/batch
CO_2	8870365,4780	Jagung	7983328,9300
		Q loss	887036,5478
Total	**8870365,4780**	**Total**	**8870365,4780**

5. **Ekspansion Valve 1 (K-124)**

Suhu masuk = 50 °C = 323 K

Tekanan masuk = 200 bar

Tekanan keluar = 100 bar

Komponen	Massa (kg/batch)	BM	Mol (kmol/batch)	TC	PC	omega	T1	P1
CO_2	80000	44	1818,1818	304,2000	73,8300	0,2240	323	200
Myristic Acid	19,4245	228	0,0852	756,0000	17,0000	1,0250	323	200
Palmitic Acid	64,7485	256	0,2529	722,0000	15,1000	1,0830	323	200
Stearic Acid	19,4245	284	0,0684	799,0000	13,6000	1,0840	323	200
Oleic Acid	323,7422	282	1,1480	781,0000	13,9000	1,1870	323	200
Linoleic Acid	220,1447	280	0,7862	775,0000	14,1000	1,1760	323	200
Air	197,5194	18	10,9733	647,1000	220,5500	0,3450	323	200

Trial $T_2 = 310$ K

$$Tr_1 = \frac{T1}{Tc} = \frac{323}{304,2} = 1,0618 \qquad Pr_1 = \frac{P1}{Pc} = \frac{200}{73,83} = 2,7089$$

$$\frac{H_1^R}{R \times Tc} = \frac{\left(H_1^R\right)^0}{R \times Tc} + \omega \times \frac{\left(H_1^R\right)^1}{R \times Tc}$$

$$\text{dimana : } \frac{\left(H_1^R\right)^0}{R \times Tc} = -3,4609 \text{ (dari App E.5 hal 654 Smith)}$$

$$\frac{\left(H_1^R\right)^1}{R \times Tc} = -2,4952 \text{ (dari App E.6 hal 655 Smith)}$$

$$\frac{H_1^R}{8,314 \times 304,2} = -3,4609 + 0,2240 \times (-2,4952)$$

H_1^R = -10166 6145 Kj/batch

$$Tr_2 = \frac{T_2}{Tc} = \frac{310}{304,2} = 1,0191 \qquad Pr_2 = \frac{P_2}{Pc} = \frac{100}{73,83} = 1,3545$$

$$\frac{H_2^R}{R \times Tc} = \frac{\left(H_2^R\right)^0}{R \times Tc} + \omega \times \frac{\left(H_2^R\right)^1}{R \times Tc}$$

$$\text{dimana : } \frac{\left(H_2^R\right)^0}{R \times Tc} = -3,2513 \text{ (dari App E.5 hal 654 Smith)}$$

$$\frac{\left(H_2^R\right)^1}{R \times Tc} = -2,2491 \text{ (dari App E.6 hal 655 Smith)}$$

$$\frac{H_2^{\ R}}{8{,}314 \times 304{,}2} = -3{,}2513 + 0{,}2240 \times (-2{,}2491)$$

H_2^{R} = -9497,0900 Kj/batch

Dihitung Cp masing – masing komponen dengan data A,B,C,D sebagai **berikut** :

Komponen	A	B	C	D
CO_2	5,457	0,001045	0	-115700
Myristic Acid	80,2660	2,8162	-0,00601	5,13E-06
Palmitic Acid	86,2900	3,5237	-0,0073217	[illegible]
Stearic Acid	99,0120	3,5874	-0,0072484	5,90E-06
Oleic Acid	278,6860	2,5434	-0,0051355	4,29E-06
Linoleic Acid	241,3480	2,3065	-0,0050663	[illegible]
Air	8,7120	0,00125	-1,81E-07	0

$$\int_{T_1}^{T_2} \frac{\langle C^{ig}_{p} \rangle_{CO_2}}{R} dT = \left[A + \frac{B}{2} T_1 (\tau + 1) + \frac{C}{3} T_1^2 (\tau^2 + \tau + 1) + \frac{D}{\tau T_1^{\ 2}} \right] (T_2 - T_1)$$

$$= \left[5{,}457 + \frac{0{,}00145}{2} 323 (1{,}0419 + 1) + 0 + \frac{-115700}{1{,}0419 \times 323^2} \right] (310 - 323)$$

$$= -\ 61{,}5843 \text{ K}$$

$$\int_{T_1}^{T_2} \frac{\langle C^{ig}_{p} \rangle}{R} dT = \left[A + \frac{B}{2} T_1 (\tau + 1) + \frac{C}{3} T_1^2 (\tau^2 + \tau + 1) + \frac{D}{\tau T_1^{\ 2}} \right] (T_2 - T_1)$$

$$= \left\{ 8{,}712 + \frac{1{,}25E-03}{2} \times 323 \times \left(\frac{310}{323} + 1 \right) + \frac{-0{,}18E-06}{3} \times 323^2 \left(\frac{310^2}{323^2} + \frac{310}{323} + 1 \right) + 0 \right\} (310 - 323)$$

$= -118{,}3603$ K

$Cp_{\text{Myristic Acid}} = A(T_2-T_1) + \frac{1}{2}B(T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D(T_2^4-T_1^4)$

$= 80{,}2660(310-323) + \frac{1}{2}\, 2{,}8162\,(310^2-323^2) + \frac{1}{3}(-0{,}00601)(310^3-323^3) + \frac{1}{4}(5{,}1299E\text{-}06)(310^4-323^4)$

$= -6918{,}3795$ kJ/Kmol °K

$Cp_{\text{Palmitic Acid}} = A(T_2-T_1) + \frac{1}{2}B(T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D(T_2^4-T_1^4)$

$= 86{,}2900(310-323) + \frac{1}{2}\, 3{,}5237\,(310^2-323^2) + \frac{1}{3}(-0{,}007322)(310^3-323^3) + \frac{1}{4}(6{,}1001E\text{-}06)(310^4-323^4)$

$= -8599{,}3579$ kJ/Kmol °K

$Cp_{\text{Stearic Acid}} = A(T_2-T_1) + \frac{1}{2}B(T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D(T_2^4-T_1^4)$

$= 99{,}0120(310-323) + \frac{1}{2}\, 3{,}5874\,(310^2-323^2) + \frac{1}{3}(-0{,}007248)(310^3-323^3) + \frac{1}{4}(5{,}9035E\text{-}06)(310^4-323^4)$

$= -9041{,}2405$ kJ/Kmol °K

$Cp_{\text{Oleic Acid}} = A(T_2-T_1) + \frac{1}{2}B(T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D(T_2^4-T_1^4)$

$= 278{,}6860(310-323) + \frac{1}{2}\, 2{,}5434(310^2-323^2) + \frac{1}{3}(-0{,}005436)(310^3-323^3) + \frac{1}{4}(4{,}924E\text{-}06)(310^4-323^4)$

$= -8778{,}9767$ kJ/Kmol °K

$Cp_{\text{Linoleic Acid}} = A(T_2-T_1) + \frac{1}{2}B(T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D(T_2^4-T_1^4)$

$= 241{,}3480(310-323) + \frac{1}{2}\, 2{,}3065(310^2-323^2) + \frac{1}{3}(-0{,}005066)(310^3-323^3) + \frac{1}{4}(4{,}7468E\text{-}06)(310^4-323^4)$

$= -7986{,}4162$ kJ/Kmol °K

$$Q_{Myristic\ Acid} = \left(Mol \times Cp_{Myristic\ Acid} \times \Delta T\right) + \left(Mol \times \lambda\right)$$

$$= \begin{matrix} \left(\frac{19,4245}{228} Kmol/_{batch} \times -6918,3795\ Kj/_{Kmol^oK} \times (310-323)^oK\right) + \\ \left(\frac{19,4245}{228} Kmol/_{batch} \times 197,0399\ kJ/_{Kmol}\right) \end{matrix}$$

= 7662,3632 kJ/batch - 16,7868 kJ/batch

= 7645,5764 kJ/batch

$$Q_{Palmitic\ Acid} = \left(Mol \times Cp_{Palmitic\ Acid} \times \Delta T\right) + \left(Mol \times \lambda\right)$$

$$= \begin{matrix} \left(\frac{64,7485}{256} Kmol/_{batch} \times -8599,3579\ kJ/_{Kmol^oK} \times (310-323)^oK\right) + \\ \left(\frac{64,7485}{256} Kmol/_{batch} \times -211,5828\ kJ/_{Kmol}\right) \end{matrix}$$

= 28274,7728 kJ/batch - 53,5143 kJ/batch

= 28221,2585 kJ/batch

$$Q_{Stearic\ Acid} = \left(Mol \times Cp_{Stearic\ Acid} \times \Delta T\right) + \left(Mol \times \lambda\right)$$

$$= \begin{matrix} \left(\frac{19,4245}{284} Kmol/_{batch} \times -9041,2405\ kJ/_{Kmol^oK} \times (310-323)^oK\right) + \\ \left(\frac{19,4245}{284} Kmol/_{batch} \times 219,4811\ kJ/_{Kmol}\right) \end{matrix}$$

= 8039,0158 kJ/batch - 15,0117 kJ/batch

= 8024,0041 kJ/batch

$$Q_{Oleic\ Acid} = \left(Mol \times Cp_{Oleic\ Acid} \times \Delta T\right) + \left(Mol \times \lambda\right)$$

$$= \left(\frac{323,7422}{282} Kmol/_{batch} \times -8778,9767\ kJ/_{Kmol^oK} \times (310-323)^oK\right) + 0$$

= 131019,9578 Kj/batch

$$Q_{Linoleic\ Acid} = \left(Mol \times Cp_{Linoleic\ Acid} \times \Delta T\right) + \left(Mol \times \lambda\right)$$

$$= \left(\frac{220,1447}{280} Kmol/_{batch} \times -7986,4162 kJ/_{Kmol^{0}K} \times (310-323)^{0}K\right) + 0$$

$= 81629,1911$ Kj/batch

$$Q_{air} = \left(R\int_{T_1}^{T_2} \frac{\langle C^{ig}_{p}\rangle_H}{R} dT \times mol\right)$$

$$= \left(8,314\ kJ/_{Kmol\ K} \times -118,3603\ K \times 10,9733\ Kmol/_{batch}\right)$$

$= -10798,2482$ Kj/batch

$$QCO_2 = \left(R\int_{T_1}^{T_2} \frac{\langle C^{ig}_{p}\rangle_H}{R} dT \times mol\right) + H^R_2 - H^R_1$$

$$= \left(8,314\ kJ/_{Kmol\ K} \times -61,5843\ K \times 1818,1818\ Kmol/_{batch}\right) - 9497,0900 + 10160,6145$$

$= - 911267,1841$ Kj/batch

$$Q_{total} = Q_{Myristic\ Acid} + Q_{Palmitic\ Acid} + Q_{Stearic\ Acid} + Q_{Oleic\ Acid} + Q_{Linoleic\ Acid} + Q_{Air} + QCO_2$$

$= 7645,5764 + 28221,2585 + 8024,0041 + 131019,9578 + 81629,1911 - 10798,2482 - 911267,1841$

$= -665525,4444$ kJ/batch

Trial T_2 dilakukan kembali sampai mencapai Q_{total} mendekati 0 kJ/batch, sehingga hasil trial mendapatkan T_2 = 313,5 K dengan Q_{total} = 0,0465 ≈ 0 (trial dianggap benar).

$$Tr_2 = \frac{T_2}{Tc} = \frac{313,5}{304,2} = 1,0306 \qquad Pr_2 = \frac{P_2}{Pc} = \frac{100}{73,83} = 1,3545$$

$$\frac{H_2^{\,R}}{R \times Tc} = \frac{\left(H_2^{\,R}\right)^0}{R \times Tc} + \omega \times \frac{\left(H_2^{\,R}\right)^1}{R \times Tc}$$

dimana : $\frac{(H_2^R)^0}{R \times Tc} = -2{,}9927$ (dari App E.5 hal 654 Smith)

$\frac{(H_2^R)^1}{R \times Tc} = -1{,}8456$ (dari App E.6 hal 655 Smith)

$$\frac{H_2^R}{8{,}314 \times 304{,}2} = -2{,}9927 + 0{,}2240 \times (-1{,}8456)$$

H_2^R = -8614,4680 Kj/batch

$$\int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_{CO_2}}{R} dT = \left[A + \frac{B}{2} T_1(\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1 \right) + \frac{D}{\tau T_1^2} \right] (T_2 - T_1)$$

$$= \left[5{,}457 + \frac{0{,}00145}{2} 323(1{,}0303 + 1) + 0 + \frac{-115700}{1{,}0303 \cdot 323^2} \right] (313{,}5 - 323)$$

$$= -44{,}8711 \text{ K}$$

$$\int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_{Air}}{R} dT = \left[A + \frac{B}{2} T_1(\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1 \right) + \frac{D}{\tau T_1^2} \right] (T_2 - T_1)$$

$$= \left\{ 8{,}712 + \frac{1{,}25E-03}{2} \times 323 \times (1{,}0303 + 1) + \frac{-0{,}18E-06}{3} \times 323^2 \left(1{,}0303^2 + 1{,}0303 + 1 \right) + 0 \right\} (313{,}5 - 323)$$

$$= -86{,}4739 \text{ K}$$

$Cp_{\text{Myristic Acid}} = A(T_2 - T_1) + ½B (T_2^2 - T_1^2) + ⅓C(T_2^3 - T_1^3) + ¼D (T_2^4 - T_1^4)$

= 80,2660(313,5-323) + ½ 2,8162 ($313{,}5^2 - 323^2$) + ⅓ (-0,00601) ($313{,}5^3 - 323^3$)

+ ¼ (5,1299E-06) ($313{,}5^4 - 323^4$)

= -5064,9807 kJ/Kmol °K

$Cp_{\text{Palmitic Acid}} = A(T_2-T_1) + \frac{1}{2}B\,(T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D\,(T_2^4-T_1^4)$

$= 86,2900(313,5-323) + \frac{1}{2}\ 3,5237\ (313,5^2-323^2) + \frac{1}{3}(-0,007322)(313,5^3-323^3) + \frac{1}{4}\,(6,1001E-06)\,(313,5^4-323^4)$

= -6296,2070 Kj/Kmol °K

$Cp_{\text{Stearic Acid}} = A(T_2-T_1) + \frac{1}{2}B\,(T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D\,(T_2^4-T_1^4)$

$= 99,0120(313,5-323) + \frac{1}{2}\ 3,5874\ (313,5^2-323^2) + \frac{1}{3}(-0,007248)(313,5^3-323^3) + \frac{1}{4}\,(5,9035E-06)\,(313,5^4-323^4)$

= -6619,9730 Kj/Kmol °K

$Cp_{\text{Oleic Acid}} = A(T_2-T_1) + \frac{1}{2}B\,(T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D\,(T_2^4-T_1^4)$

$= 278,6860(313,5-323) + \frac{1}{2}\ 2,5434(313,5^2-323^2) + \frac{1}{3}(-0,005436)(313,5^3-323^3) + \frac{1}{4}\,(4,924E-06)\,(313,5^4-323^4)$

= -6421,9891 Kj/Kmol °K

$Cp_{\text{Linoleic Acid}} = A(T_2-T_1) + \frac{1}{2}B\,(T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D\,(T_2^4-T_1^4)$

$= 241,3480(313,5-323) + \frac{1}{2}\ 2,3065(313,5^2-323^2) + \frac{1}{3}(-0,005066)(313,5^3-323^3) + \frac{1}{4}\,(4,7468E-06)\,(313,5^4-323^4)$

= -5844,9930 Kj/Kmol °K

$$Q_{\text{Myristic Acid}} = \left(\text{Mol} \times Cp_{\text{Myristic Acid}} \times \Delta T\right) + \left(\text{Mol} \times \lambda\right)$$

$$= \left(\frac{19,4245}{228}\ \text{Kmol/batch} \times -5064,9807\ \text{Kj/Kmol°K} \times (313,5-323)\text{°K}\right) + \left(\frac{19,4245}{228}\ \text{Kmol/batch} \times 197,0399\ \text{kJ/Kmol}\right)$$

= 19939,7127 Kj/batch - 16,7868 kJ/batch

= 19922,9258 kJ/batch

$$Q_{\text{Palmitic Acid}} = \left(\text{Mol} \times Cp_{\text{Palmitic Acid}} \times \Delta T\right) + \left(\text{Mol} \times \lambda\right)$$

$$= \begin{pmatrix} \frac{64,7485}{256} \text{Kmol}/_{\text{batch}} \times -6296,2070 \text{ kJ}/_{\text{Kmol}^\circ\text{K}} \times (313,5-323)^\circ\text{K} \end{pmatrix} + \begin{pmatrix} \frac{64,7485}{256} \text{Kmol}/_{\text{batch}} \times -211,5828 \text{ kJ}/_{\text{Kmol}} \end{pmatrix}$$

= 73585,9400 kJ/batch - 53,5143 kJ/batch

= 73532,4257 kJ/batch

$$Q_{\text{Stearic Acid}} = (\text{Mol} \times Cp_{\text{Stearic Acid}} \times \Delta T) + (\text{Mol} \times \lambda)$$

$$= \begin{pmatrix} \frac{19,4245}{284} \text{Kmol}/_{\text{batch}} \times -6619,9730 \text{ kJ}/_{\text{Kmol}^\circ\text{K}} \times (313,5-323)^\circ\text{K} \end{pmatrix} + \begin{pmatrix} \frac{19,4245}{284} \text{Kmol}/_{\text{batch}} \times 219,4811 \text{ kJ}/_{\text{Kmol}} \end{pmatrix}$$

= 20922,5122 kJ/batch - 15,0117 kJ/batch

= 20907,5005 kJ/batch

$$Q_{\text{Oleic Acid}} = (\text{Mol} \times Cp_{\text{Oleic Acid}} \times \Delta T) + (\text{Mol} \times \lambda)$$

$$= \left(\frac{323,7422}{282} \text{Kmol}/_{\text{batch}} \times -6421,9891 \text{ kJ}/_{\text{Kmol}^\circ\text{K}} \times (313,5-323)^\circ\text{K} \right) + 0$$

= 340679,3987 Kj/batch

$$Q_{\text{Linoleic Acid}} = (\text{Mol} \times Cp_{\text{Linoleic Acid}} \times \Delta T) + (\text{Mol} \times \lambda)$$

$$= \left(\frac{220,1447}{280} \text{Kmol}/_{\text{batch}} \times -5844,9930 \text{ kJ}/_{\text{Kmol}^\circ\text{K}} \times (313,5-323)^\circ\text{K} \right) + 0$$

= 212353,9275 Kj/batch

$$Q_{\text{air}} = \left(R \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT \times \text{mol} \right)$$

$$= \left(8,314 \text{ kJ}/_{\text{Kmol K}} \times -86,4739 \text{ K} \times 10,9733 \text{ Kmol}/_{\text{batch}} \right)$$

= -7389,1862 Kj/batch

$$QCO_2 = \left(R\int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT \times mol \right) + H_2^R - H_1^R$$

$$= \left(8{,}314 \, {}^{kJ}/_{Kmol\ K} \times -44{,}8711\ K \times 1818{,}1818 \, {}^{Kmol}/_{batch}\right) - 8614{,}4680 + 10166{,}6145$$

= - 659506,9456 Kj/batch

$Q_{total} = Q_{Myristic\ Acid} + Q_{Palmitic\ Acid} + Q_{Stearic\ Acid} + Q_{Oleic\ Acid} + Q_{Linoleic\ Acid} + Q_{Air} + QCO_2$

= 19922,9258 + 73532,4257 + 20907,5005 + 340679,3987 + 212353,9275 − 7889,1862 − 659506,9456

= 0,0465 Kj/batch ≈ 0 (Trial dianggap benar)

$|Q\ suplai| = |Q\ total| + |Q\ loss|$

Dimana : Q loss = 0,1 Q suplai

Q suplai = 0,0465 + 0,1 Q suplai

0,9 Q suplai = 0,0465 kJ/batch

Q suplai = 0,0517 kJ/batch

Q loss = 0,1 x 0,0517 = 0,0052 kJ/batch

Neraca Panas di Expansion Valve 1

Panas yang dibutuhkan	**kJ/batch**	**Panas yang diberikan**	**kJ/batch**
Q total	0,0465	Q suplai	0,0517
Q loss	0,0052		
Total	**0,0517**	**Total**	**0,0517**

6. Ekspansion Valve 2 (K-126)

Suhu masuk = 40,5 °C = 313,5 K

Tekanan masuk = 100 bar

Tekanan keluar = 10 bar

Trial T_2 = 303,5 K

$$Tr_1 = \frac{T1}{Tc} = \frac{313,5}{304,2} = 1,0306 \qquad Pr_1 = \frac{P1}{Pc} = \frac{100}{73,83} = 1,3545$$

$$\frac{H_1^R}{R \times Tc} = \frac{(H_1^R)^0}{R \times Tc} + \omega \times \frac{(H_1^R)^1}{R \times Tc}$$

dimana : $\frac{(H_1^R)^0}{R \times Tc}$ = - 2,9927 (dari App E.5 hal 654 Smith)

$\frac{(H_1^R)^1}{R \times Tc}$ = - 1,8456 (dari App E.6 hal 655 Smith)

$$\frac{H_1^R}{8,314 \times 304,2} = -2,9927 + 0,2240 \times (-1,8456)$$

H_1^R = -8614,4680 Kj/batch

$$Tr_2 = \frac{T_2}{Tc} = \frac{303,5}{304,2} = 0,9977 \qquad Pr_2 = \frac{P_2}{Pc} = \frac{10}{73,83} = 0,1354$$

$$\frac{H_2^R}{R \times Tc} = \frac{(H_2^R)^0}{R \times Tc} + \omega \times \frac{(H_2^R)^1}{R \times Tc}$$

dimana : $\frac{(H_2^R)^0}{R \times Tc}$ = - 0,1422 (dari App E.5 hal 654 Smith)

$\frac{(H_2^R)^1}{R \times Tc}$ = - 0,1290 (dari App E.6 hal 655 Smith)

$$\frac{H_2^R}{8,314 \times 304,2} = -0,1422 + 0,2240 \times (-0,1290)$$

H_2^R = -432,7221 kJ/batch

Dihitung Cp masing – masing komponen dengan data A,B,C,D sebagai **berikut** :

Komponen	A	B	C	D
CO_2	5,457	0,001045	0	-115700
Myristic Acid	80,2660	2,8162	-0,00601	5,13E-06
Palmitic Acid	86,2900	3,5237	-0,0073217	6,1E-06
Stearic Acid	99,0120	3,5874	-0,0072484	5,904E-06
Oleic Acid	278,6860	2,5434	-0,0054355	4,294E-06
Linoleic Acid	241,3480	2,3065	-0,0050663	4,747E-06
Air	8,7120	0,00125	-1,8E-07	0

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_{CO_2}}{R} dT = \left[A + \frac{B}{2} T_1 (\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1 \right) + \frac{D}{\tau T_1^2} \right] \left(T_2 - T_1 \right)$$

$$= \left[5,457 + \frac{0,00145}{2} 313,5 (1,0329 + 1) + 0 + \frac{-115700}{1,0329 \times 313,5^2} \right] (303,5 - 313,5)$$

= - 46,5033 K

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_{Air}}{R} dT = \left[A + \frac{B}{2} T_1 (\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1 \right) + \frac{D}{\tau T_1^2} \right] \left(T_2 - T_1 \right)$$

$$= \left\{ 8,712 + \frac{1,25E-03}{2} \times 313,5 \times \left(\frac{303,5}{313,5} + 1 \right) + \frac{-0,18E-06}{3} \times 313,5^2 \left(\frac{303,5^2}{313,5^2} + \frac{303,5}{313,5} + 1 \right) + 0 \right\} (303,5 - 3$$

= -90,9205 K

Cp $_{\text{Myristic Acid}}$ = $A(T_2-T_1) + ½B (T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D (T_2^4-T_1^4)$

= 80,2660(303,5-313,5) + ½ 2,8162 ($303,5^2$-$313,5^2$) + ⅓ (-0,00601) **($303,5^3$-**

$313,5^3$) + ¼ (5,1299E-06) ($303,5^4$-$313,5^4$)

= -5276,8510 Kj/Kmol °K

Cp $_{\text{Palmitic Acid}}$ = $A(T_2-T_1) + ½B (T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D (T_2^4-T_1^4)$

= 86,2900(303,5-313,5) + ½ 3,5237 ($303,5^2$-$313,5^2$) + ⅓(-0,007322)**($303,5^3$-**

$313,5^3$) + ¼ (6,1001E-06) ($303,5^4$-$313,5^4$)

= -6556,1765 Kj/Kmol °K

$Cp_{Stearic\ Acid} = A(T_2-T_1) + \frac{1}{2}B\ (T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D\ (T_2^4-T_1^4)$

= 99,0120(303,5-313,5) + ½ 3,5874 (303,5²-313,5²) + ⅓(-0,007248)(303,5³-313,5³) + ¼ (5,9035E-06) (303,5⁴-313,5⁴)

= -6891,9402 Kj/Kmol °K

$Cp_{Oleic\ Acid} = A(T_2-T_1) + \frac{1}{2}B\ (T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D\ (T_2^4-T_1^4)$

= 278,6860(303,5-313,5) + ½ 2,5434(303,5-313,5²) + ⅓(-0,005436)(303,5³-313,5³) + ¼ (4,924E-06) (303,5⁴-313,5⁴)

= -6720,7854 Kj/Kmol °K

$Cp_{Linoleic\ Acid} = A(T_2-T_1) + \frac{1}{2}B\ (T_2^2-T_1^2) + \frac{1}{3}C(T_2^3-T_1^3) + \frac{1}{4}D\ (T_2^4-T_1^4)$

= 241,3480(303,5-313,5) + ½ 2,3065(303,5²-313,5²) + ⅓(-0,005066)(303,5³-313,5³) + ¼ (4,7468E-06) (303,5⁴-313,5⁴)

= -6100,9555 Kj/Kmol °K

$$Q_{Myristic\ Acid} = \left(Mol \times Cp_{Myristic\ Acid} \times \Delta T\right) + \left(Mol \times \lambda\right)$$

$$= \left(\frac{19,4245}{228}\ {}^{Kmol}\!/\!_{batch} \times -5276,8510\ {}^{Kj}\!/\!_{Kmol\ ^oK} \times (303,5-313,5)^oK\right) + \left(\frac{19,4245}{228}\ {}^{Kmol}\!/\!_{batch} \times -197,0399\ {}^{kJ}\!/\!_{Kmol}\right)$$

= 1072,9409 Kj/batch - 16,7868 kJ/batch

= 1056,1541 kJ/batch

$$Q_{Palmitic\ Acid} = \left(Mol \times Cp_{Palmitic\ Acid} \times \Delta T\right) + \left(Mol \times \lambda\right)$$

$$= \frac{\left(\frac{64{,}7485}{256}\,\text{Kmol}/\text{batch} \times -6556{,}1765\,\text{kJ}/\text{Kmol}^{\circ}\text{K} \times (303{,}5-313{,}5)^{\circ}\text{K}\right)+}{\left(\frac{64{,}7485}{256}\,\text{Kmol}/\text{batch} \times -211{,}5828\,\text{kJ}/\text{Kmol}\right)}$$

= 3957,5496 kJ/batch - 53,5143 kJ/batch

= 3904,0352 kJ/batch

$$Q_{\text{Stearic Acid}} = \left(\text{Mol} \times Cp_{\text{Stearic Acid}} \times \Delta T\right) + \left(\text{Mol} \times \lambda\right)$$

$$= \frac{\left(\frac{19{,}4245}{284}\,\text{Kmol}/\text{batch} \times -6891{,}9402\,\text{kJ}/\text{Kmol}^{\circ}\text{K} \times (303{,}5-313{,}5)^{\circ}\text{K}\right)+}{\left(\frac{19{,}4245}{284}\,\text{Kmol}/\text{batch} \times -219{,}4811\,\text{kJ}/\text{Kmol}\right)}$$

= 1125,0167 kJ/batch - 15,0117 kJ/batch

= 1110,0051 kJ/batch

$$Q_{\text{Oleic Acid}} = \left(\text{Mol} \times Cp_{\text{Oleic Acid}} \times \Delta T\right) + \left(\text{Mol} \times \lambda\right)$$

$$= \left(\frac{323{,}7422}{282}\,\text{Kmol}/\text{batch} \times -6720{,}7854\,\text{kJ}/\text{Kmol}^{\circ}\text{K} \times (303{,}5-313{,}5)^{\circ}\text{K}\right) + 0$$

= 18414,3423 Kj/batch

$$Q_{\text{Linoleic Acid}} = \left(\text{Mol} \times Cp_{\text{Linoleic Acid}} \times \Delta T\right) + \left(\text{Mol} \times \lambda\right)$$

$$= \left(\frac{220{,}1447}{280}\,\text{Kmol}/\text{batch} \times -6100{,}9555\,\text{kJ}/\text{Kmol}^{\circ}\text{K} \times (303{,}5-313{,}5)^{\circ}\text{K}\right) + 0$$

= 11448,1165 Kj/batch

$$Q_{\text{air}} = \left(R \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R}\, dT \times \text{mol}\right)$$

$$= \left(8{,}314\,\text{kJ}/\text{Kmol K} \times -90{,}9205\,\text{K} \times 5{,}6286\,\text{Kmol}/\text{batch}\right)$$

= -4254,7031 Kj/batch

$$QCO_2 = \left(R \int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT \times mol \right) + H_2^R - H_1^R$$

$$= \left(8{,}314 \, {}^{kJ}\!/_{Kmol\,K} \times -46{,}5033\,K \times 102{,}3282 \, {}^{Kmol}\!/_{batch} \right) - 432{,}7221 + 8614{,}4680$$

$$= -\,30515{,}8260 \text{ Kj/batch}$$

$$Q_{total} = Q_{Myristic\ Acid} + Q_{Palmitic\ Acid} + Q_{Stearic\ Acid} + Q_{Oleic\ Acid} + Q_{Linoleic\ Acid} + Q_{Air} + QCO_2$$

$$= 1072{,}9409 + 3957{,}5496 + 1125{,}0167 + 18414{,}3423 + 11448{,}1165 - 4254{,}7031 - 30515{,}8260$$

$$= 1162{,}?241 \text{ Kj/batch}$$

Trial T_2 dilakukan kembali sampai mencapai Q_{total} mendekati 0 kJ/batch, sehingga hasil trial mendapatkan T_2 = 303,94412 K dengan Q_{total} = - 0,0288 ≈ 0 (trial dianggap benar).

$$Tr_2 = \frac{T_2}{Tc} = \frac{303{,}94412}{304{,}2} = 0{,}9992 \qquad Pr_2 = \frac{P_2}{Pc} = \frac{10}{73{,}83} = 0{,}1354$$

$$\frac{H_2^R}{R \times Tc} = \frac{\left(H_2^R\right)^0}{R \times Tc} + \omega \times \frac{\left(H_2^R\right)^1}{R \times Tc}$$

dimana : $\frac{\left(H_2^R\right)^0}{R \times Tc} = -\,0{,}1418$ (dari App E.5 hal 654 Smith)

$\frac{\left(H_2^R\right)^1}{R \times Tc} = -\,0{,}1282$ (dari App E.6 hal 655 Smith)

$$\frac{H_2^R}{8{,}314 \times 304{,}2} = -0{,}1418 + 0{,}2240 \times (-0{,}1282)$$

H_2^R = -431,2572 Kj/batch

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_{CO_2}}{R} dT = \left[A + \frac{B}{2} T_1 (\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1 \right) + \frac{D}{\tau T_1^2} \right] \left(T_2 - T_1 \right)$$

$$= \left[5{,}457 + \frac{0{,}00145}{2} 313{,}5(1{,}0314+1) + 0 + \frac{-115700}{1{,}0314 \times 313{,}5^2}\right](303{,}94412 - 313{,}5)$$

$= -44{,}4197$ K

$$\int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_{Air}}{R} dT = \left[A + \frac{B}{2} T_1(\tau+1) + \frac{C}{3} T_1^2(\tau^2+\tau+1) + \frac{D}{\tau T_1^2}\right](T_2 - T_1)$$

$$= \left\{8{,}712 + \frac{1{,}25E-03}{2} \times 313{,}5 \times (1{,}0314+1) + \frac{-0{,}18E-06}{3} \times 313{,}5^2\left(1{,}0314^2 + 1{,}0314 + 1\right) + 0\right\}$$

$(303{,}94412 - 313{,}5)$

$= -86{,}8800$ K

$Cp_{\text{Myristic Acid}} = A(T_2-T_1) + ½B\,(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D\,(T_2^4-T_1^4)$

$= 80{,}2660(303{,}94412-313{,}5)+½\ 2{,}8162\ (303{,}94412^2-323^2) + ⅓\ \mathbf{(-0{,}00601)}$

$(303{,}94412^3-323^3)+ ¼\ (5{,}1299E-06)\ (303{,}94412^4-323^4)$

$= -5043{,}7192$ kJ/Kmol °K

$Cp_{\text{Palmitic Acid}} = A(T_2-T_1) + ½B\,(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D\,(T_2^4-T_1^4)$

$= 86{,}2900(303{,}94412-313{,}5)+½3{,}5237(303{,}94412^2-313{,}5^2)+⅓\mathbf{(-0{,}007322)}$

$(303{,}94412^3-313{,}5^3) + ¼\ (6{,}1001E-06)\ (303{,}94412^4-313{,}5^4)$

$= -6266{,}6017$ Kj/Kmol °K

$Cp_{\text{Stearic Acid}} = A(T_2-T_1) + ½B\,(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D\,(T_2^4-T_1^4)$

$= 99{,}0120(303{,}94412-313{,}5)+½3{,}5874(303{,}94412^2-313{,}5^2)+⅓\mathbf{(-0{,}007248)}$

$(303{,}94412^3-313{,}5^3) + ¼\ (5{,}9035E-06)\ (303{,}94412^4-313{,}5^4)$

$= -6587{,}5662$ Kj/Kmol °K

$Cp_{\text{Oleic Acid}} = A(T_2-T_1) + ½B\,(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D\,(T_2^4-T_1^4)$

$=278{,}6860(303{,}94412-313{,}5)+½2{,}5434(303{,}94412^2-313{,}5^2)+⅓\mathbf{(-{,}005436)}$

$(303{,}94412^3-313{,}5^3) + ¼\ (4{,}924E-06)\ (303{,}94412^4-313{,}5^4)$

$= -6423{,}1936$ Kj/Kmol °K

$Cp_{Linoleic\ Acid} = A(T_2-T_1) + ½B(T_2^2-T_1^2) + ⅓C(T_2^3-T_1^3) + ¼D(T_2^4-T_1^4)$

$=241,3480(303,94412-313,5)+½2,3065(303,94412^2-313,5^2)+⅓(-,005066)$

$(303,94412^3-313,5^3) + ¼(4,7468E-06)(303,94412^4-313,5^4)$

$= -5831,1416$ Kj/Kmol °K

$Q_{Myristic\ Acid} = (Mol \times Cp_{Myristic\ Acid} \times \Delta T) + (Mol \times \lambda)$

$$= \left(\frac{19,4245}{228} \text{Kmol/batch} \times -5043,7192 \text{Kj/Kmol}^0\text{K} \times (303,94412 - 313,5)^0\text{K}\right) + \left(\frac{19,4245}{228} \text{Kmol/batch} \times -197,0399 \text{kJ/Kmol}\right)$$

= 979,9921 Kj/batch - 16,7868 kJ/batch

= 963,2052 kJ/batch

$Q_{Palmitic\ Acid} = (Mol \times Cp_{Palmitic\ Acid} \times \Delta T) + (Mol \times \lambda)$

$$= \left(\frac{64,7485}{256} \text{Kmol/batch} \times -6266,6017 \text{kJ/Kmol}^0\text{K} \times (303,94412 - 313,5)^0\text{K}\right) + \left(\frac{64,7485}{256} \text{Kmol/batch} \times -211,5828 \text{kJ/Kmol}\right)$$

= 3614,7520 kJ/batch - 53,5143 kJ/batch

= 3561,2377 kJ/batch

$Q_{Stearic\ Acid} = (Mol \times Cp_{Stearic\ Acid} \times \Delta T) + (Mol \times \lambda)$

$$= \left(\frac{19,4245}{284} \text{Kmol/batch} \times -6587,5662 \text{kJ/Kmol}^0\text{K} \times (303,94412 - 313,5)^0\text{K}\right) + \left(\frac{19,4245}{284} \text{Kmol/batch} \times -219,4811 \text{kJ/Kmol}\right)$$

= 1027,5741 kJ/batch - 15,0117 kJ/batch

= 1012,5625 kJ/batch

$$Q_{Oleic\ Acid} = (Mol \times Cp_{Oleic\ Acid} \times \Delta T) + (Mol \times \lambda)$$

$$= \left(\frac{323{,}7422}{282} Kmol/_{batch} \times -6423{,}1936\ ^{kJ}/_{Kmol\ ^oK} \times (303{,}94412 - 313{,}5)^oK\right) + 0$$

$= 16817{,}3625$ Kj/batch

$$Q_{Linoleic\ Acid} = (Mol \times Cp_{Linoleic\ Acid} \times \Delta T) + (Mol \times \lambda)$$

$$= \left(\frac{220{,}1447}{280} Kmol/_{batch} \times -5831{,}1416\ ^{kJ}/_{Kmol\ ^oK} \times (303{,}94412 - 313{,}5)^oK\right) + 0$$

$= 10455{,}8767$ Kj/batch

$$Q_{air} = \left(R \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT \times mol\right)$$

$$= \left(8{,}314\ ^{kJ}/_{Kmol\ K} \times -86{,}8800\ K \times 5{,}6286\ ^{Kmol}/_{batch}\right)$$

$= -4065{,}6232$ kJ/batch

$$QCO_2 = \left(R \int_{T_1}^{T} \frac{\langle C_p^{ig} \rangle_H}{R} dT \times mol\right) + H_2^R - H_1^R$$

$$= \left(8{,}314\ ^{kJ}/_{Kmol\ K} \times -44{,}4197\ K \times 102{,}3282\ ^{Kmol}/_{batch}\right) - 431{,}2572 + 8614{,}4680$$

$= -28744{,}6502$ kJ/batch

$$Q_{total} = Q_{Myristic\ Acid} + Q_{Palmitic\ Acid} + Q_{Stearic\ Acid} + Q_{Oleic\ Acid} + Q_{Linoleic\ Acid} + Q_{Air} + QCO_2$$

$= 963{,}2052 + 3561{,}2377 + 1012{,}5625 + 16817{,}3625 + 10455{,}8767 - 4065{,}6232 - 28744{,}6502$

$= -0{,}0288$ kJ/batch ≈ 0 (Trial dianggap benar)

$$|Q\ suplai| = |Q\ total| + |Q\ loss|$$

Dimana : Q loss = 0,1 Q suplai

Q suplai = 0,0288 + 0,1 Q suplai

0,9 Q suplai = 0,0288 kJ/batch

Q total = 0,0320 kJ/batch

Q loss = 0,1 x -0,0320 = 0,0032 kJ/batch

Neraca Panas di Expansion Valve 2

Panas yang dibutuhkan	kJ/batch	Panas yang diberikan	kJ/batch
Q total	0,0288	Q suplai	0,0320
Q loss	0,0032		
Total	**0,0320**	**Total**	**0,0320**

7. Compressor 2 (K-128)

Keterangan : - Massa air, myristic acid, palmitic acid, stearic acid, oleic acid, dan linoleic acid diabaikan karena massanya terlalu kecil sehingga pada piston pump neraca panas hanya dihitung untuk komponen CO_2 saja.

Bahan masuk :

❖ **Dari Separator I**

Suhu masuk = 313,5 K

Tekanan masuk = 100 bar

Tekanan keluar = 20 bar

Tc = 304,2 K Pc = 73,83 bar ω = 0,2240

$Tr_1 = \frac{T1}{Tc} = \frac{313,5}{304,2} = 1,0306$ $Pr_1 = \frac{P1}{Pc} = \frac{100}{73,83} = 1,0306$

$$\frac{S_1^R}{R} = -Pr_1\left(\frac{dB^0}{dTr_1} + \omega\frac{dB^1}{dTr_1}\right)$$

Dimana : $\frac{dB^0}{dTr_1} = \frac{0{,}675}{Tr_1^{\,2{,}6}} = \frac{0{,}675}{1{,}0306^{2{,}6}} = 0{,}6242$

$\frac{dB^1}{dTr_1} = \frac{0{,}722}{Tr_1^{\,5{,}2}} = \frac{0{,}722}{1{,}0306^{5{,}2}} = 0{,}6173$

Sehingga : S_1^R = {- 1,0306 (0,6242 + 0,2240 x 0,6173)} x 8,314

= - 8,5860 kJ/kmol K

❖ **Dari Separator II**

Suhu masuk = 303,94412 K

Tekanan masuk = 10 bar

Tekanan keluar = 20 bar

Tc = 304,2 K Pc = 73,83 bar ω = 0,2240

$Tr_1 = \frac{T1}{Tc} = \frac{303{,}94412}{304{,}2} = 0{,}9992$ $Pr_1 = \frac{P1}{Pc} = \frac{10}{73{,}83} = 0{,}1354$

$$\frac{S_1^R}{R} = -Pr_1\left(\frac{dB^0}{dTr_1} + \omega\frac{dB^1}{dTr_1}\right)$$

Dimana : $\frac{dB^0}{dTr_1} = \frac{0{,}675}{Tr_1^{\,2{,}6}} = \frac{0{,}675}{0{,}9992^{2{,}6}} = 0{,}6765$

$\frac{dB^1}{dTr_1} = \frac{0{,}722}{Tr_1^{\,5{,}2}} = \frac{0{,}722}{0{,}9992^{5{,}2}} = 0{,}7252$

Sehingga : S_1^R = {- 0,1354 (0,6765 + 0,2240 x 0,7252)} x 8,314

= - 0,9447 kJ/kmol K

$$\Delta S = n_A \times S^R_{1\,A} + n_B \times S^R_{1\,B} + n_A \times \Delta S^{ig}_A + n_B \times \Delta S^{ig}_B + (n_A + n_B) \times S^R_2$$

Untuk η = 100 % maka ΔS = 0

Trial T_2 teorities :

$T_2 = 246{,}5$ K

$$Tr_2 = \frac{T_2}{Tc} = \frac{246{,}5}{304{,}2} = 0{,}8087 \qquad Pr_2 = \frac{P_2}{Pc} = \frac{20}{73{,}83} = 0{,}2709$$

$$\frac{S_2^{\,R}}{R} = -\mathrm{Pr}_2\left(\frac{dB^0}{dTr_2} + \omega\frac{dB^1}{dTr_2}\right)$$

Dimana : $\dfrac{dB^0}{dTr_2} = \dfrac{0{,}675}{Tr_2^{\,2,6}} = \dfrac{0{,}675}{0{,}8087^{2,6}} = 1{,}1663$

$$\frac{dB^1}{dTr_2} = \frac{0{,}722}{Tr_2^{\,5,2}} = \frac{0{,}722}{0{,}8087^{5,2}} = 2{,}1553$$

Sehingga : $S_2^R = \{-0{,}2709\,(1{,}1663 + 0{,}2240 \times 2{,}1553)\} \times 8{,}314$

$= -3{,}7140$ kJ/kmol K

$$\int_{T_1}^{T_2}\frac{\langle C^{ig}_p\rangle_S}{R}\frac{dT}{T} = A\ln\tau + \left[BT_1 + \left(CT_1^2 + \frac{D}{\tau^2 T_1^2}\right)\left(\frac{\tau+1}{2}\right)\right](\tau-1)$$

Dimana : koefisien A, B, C, D untuk CO_2 diambil dari Smith, hal 638

A = 5,457 ; B = 0,00145; C = 0 , D = -115700

- **Dari Tangki Separator I**

$$\tau = \frac{T_2}{T_1} = \frac{246{,}5}{313{,}5} = 0{,}7863$$

$$\int_{T_1}^{T_2}\frac{\langle C^{ig}_p\rangle_S}{R}\frac{dT}{T} = 5{,}457\times\ln(0{,}7863) + \left[(0{,}00145\times 313{,}5) + \left(0 + \frac{-115700}{0{,}7863^2\times 313{,}5^2}\right)\left(\frac{0{,}7863+1}{2}\right)\right](0{,}7863-1)$$

$$\int_{T_1}^{T_2}\frac{\langle C^{ig}_p\rangle_S}{R}\frac{dT}{T} = -1{,}0186 \text{ K}$$

❖ **Dari Tangki Separator II**

$$\tau = \frac{T_2}{T_1} = \frac{246{,}5}{303{,}94412} = 0{,}8110$$

$$\int_{T_1}^{T_2} \frac{\left\langle C^{ig}_{P} \right\rangle_S}{R} \frac{dT}{T} =$$

$$5{,}457\ln(0{,}8110) + \left[\left(0{,}00145 \times 303{,}94412\right) + \left(0 + \frac{-115700}{0{,}8110 \times 303{,}94412^2}\right)\left(\frac{0{,}8110+1}{2}\right)\right]\left(0{,}8110 - 1\right)$$

$$\int_{T_1}^{T_2} \frac{\left\langle C^{ig}_{P} \right\rangle_S}{R} \frac{dT}{T} = -0{,}8773\ \mathrm{K}$$

$$\Delta S = n_A \times S^R_{1\,A} + n_B \times S^R_{1\,B} + n_A \times \Delta S^{ig}_A + n_B \times \Delta S^{ig}_B + \left(n_A + n_B\right) \times S^R_2$$

$$= \begin{array}{l} 1807{,}8990 \times -8{,}5860 + 10{,}2324 \times -0{,}9447 + 1807{,}8990 \times 12{,}3622 + \\ 10{,}2324 \times -6{,}6401 + (1807{,}8990 + 10{,}2324) \times -3{,}7140 \end{array}$$

= - 3,0328 kJ/batch

Trial dilakukan sampai $\Delta S = 0$ hasil trial mendapat T_2 teorities = **246,5292 K**.

Dari T_2 teorities dicari $\Delta H_{teorities}$

$$\Delta H_{teorities} = n_A \times H^R_{1\,A} + n_B \times H^R_{1\,B} + n_A \times \Delta H^{ig}_A + n_B \times \Delta H^{ig}_B + (n_A + n_B) \times H^R_2$$

Dimana :

❖ **Dari Tangki Separator I**

$$\int_{T_1}^{T_2} \frac{\left\langle C^{ig}_{P} \right\rangle_H}{R} dT = \left[A + \frac{B}{2} T_1(\tau + 1) + \frac{C}{3} T_1^2\left(\tau^2 + \tau + 1\right) + \frac{D}{\tau T_1^2} \right]\left(T_2 - T_1\right)$$

$$= \left[5{,}457 + \frac{0{,}001045}{2} 313{,}5(0{,}7864 + 1) + 0 + \frac{-115700}{0{,}7864 \times 313{,}5^2} \right](246{,}5252 - 313{,}5)$$

= - 284,8148 K

$$\frac{H^R}{R \times Tc} = Pr\left[B^0 - Tr\frac{dB^0}{dTr} + \omega\left(B^1 - Tr\frac{dB^1}{dTr}\right)\right]$$

Dimana : $\dfrac{dB^0}{dTr_1} = \dfrac{0{,}675}{Tr_1^{\,2,6}} = \dfrac{0{,}675}{1{,}0306^{2,6}} = 0{,}6242$

$$\frac{dB^1}{dTr_1} = \frac{0{,}722}{Tr_1^{\,5,2}} = \frac{0{,}722}{1{,}0306^{5,2}} = 0{,}6173$$

Sehingga :

$$\frac{H^R_{1\ A}}{8{,}314 \times 304{,}2} = \{1{,}3545[(-0{,}3191) - (1{,}0306 \times 0{,}6242) + 0{,}2240 \times ((-0{,}0126) - (1{,}0306 \times 0{,}6173))]\}$$

$$H^R_{1\ A} = -1{,}5004\ {}^{kJ}\!/_{kmol}$$

❖ **Dari Tangki Separator II**

$$\int_{T_1}^{T_2} \frac{\langle C^{ig}_p \rangle_{II}}{R} dT = \left[A + \frac{B}{2}T_1(\tau + 1) + \frac{C}{3}T_1^2\left(\tau^2 + \tau + 1\right) + \frac{D}{\tau T_1^{\,2}}\right]\left(T_2 - T_1\right)$$

$$= \left[5{,}457 + \frac{0{,}001045}{2}303{,}94412(0{,}8111 + 1) + 0 + \frac{-115700}{0{,}8111 \cdot 303{,}94412^2}\right](240{,}5252 - 303{,}94412)$$

$= -\ 241{,}1886$ K

$$\frac{H^R}{R \times Tc} = Pr\left[B^0 - Tr\frac{dB^0}{dTr} + \omega\left(B^1 - Tr\frac{dB^1}{dTr}\right)\right]$$

Dimana : $\dfrac{dB^0}{dTr_1} = \dfrac{0{,}675}{Tr_1^{\,2,6}} = \dfrac{0{,}675}{0{,}9992^{2,6}} = 0{,}6765$

$$\frac{dB^1}{dTr_1} = \frac{0{,}722}{Tr_1^{\,5,2}} = \frac{0{,}722}{0{,}9992^{5,2}} = 0{,}7252$$

Sehingga :

$$\frac{H^{R}_{1\,B}}{8{,}314\times 304{,}2}=0{,}1354\begin{bmatrix}(-0{,}3396)-(0{,}9992\times 0{,}6765)\\ +0{,}2240((-0{,}0336)-(0{,}9992\times 0{,}7252))\end{bmatrix}$$

$$H^{R}_{1\,B}=-0{,}1605\ \text{kJ}/\text{kmol}$$

$$\frac{H^{R}}{R\times Tc}=Pr\left[B^{0}-Tr\frac{dB^{0}}{dTr}+\omega\left(B^{1}-Tr\frac{dB^{1}}{dTr}\right)\right]$$

Dimana : $\frac{dB^{0}}{dTr_2}=\frac{0{,}675}{{Tr_2}^{2{,}6}}=\frac{0{,}675}{0{,}8104^{2{,}6}}=1{,}1659$

$$\frac{dB^{1}}{dTr_2}=\frac{0{,}722}{{Tr_2}^{5{,}2}}=\frac{0{,}722}{0{,}8104^{5{,}2}}=2{,}1542$$

Sehingga :

$$\frac{H^{R}_{2}}{8{,}314\times 304{,}2}=0{,}2709\begin{bmatrix}(-0{,}2542)-(0{,}8104\times 0{,}4687)+\\ 0{,}2240(0{,}0436-(0{,}8104\times 0{,}3482))\end{bmatrix}$$

$$H^{R}_{2}=-0{,}2366\ \text{kJ}/\text{kmol}$$

$$\Delta H_{teorities}=n_A\times H^{R}_{1\,A}+n_B\times H^{R}_{1\,B}+n_A\times \Delta H^{ig}_{A}+n_B\times \Delta H^{ig}_{B}+(n_A+n_B)\times H^{R}_{2}$$

$$=(1807{,}8990\times -1{,}5004)+(10{,}2324\times -0{,}1605)+(1807{,}8990\times -284{,}8148\times 8{,}314)+$$
$$(10{,}2324\times -241{,}1886\times 8{,}314)+\{(1807{,}8990+10{,}2324)\times -0{,}2366\}$$

= -4304678,2888 kJ/batch

$$Ws=\frac{\Delta H_{teorities}}{\eta}=\frac{-4304678{,}2888}{0{,}7}=-6149540{,}4126\ \text{kJ/batch};\ \eta=70\%\ \textbf{(Ulrich)}$$

$$\Delta H\ \text{aktual}=\frac{\Delta H\ \text{teorities}}{\eta}=-6149540{,}4126\ \text{kJ/batch}$$

Trial T_2 aktual = 297,25 K

❖ **Dari Tangki Separator I**

$$\int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT = \left[A + \frac{B}{2} T_1 (\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1 \right) + \frac{D}{\tau T_1^2} \right] (T_2 - T_1)$$

$$= \left[5{,}457 + \frac{0{,}001045}{2} 313{,}5(0{,}7864 + 1) + 0 + \frac{-115700}{0{,}7864 \times 313{,}5} \right] \times (297{,}25 - 313{,}5)$$

$$= -405{,}8289 \text{ K}$$

❖ **Dari Separator II**

$$\int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT = \left[A + \frac{B}{2} T_1 (\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1 \right) + \frac{D}{\tau T_1^2} \right] (T_2 - T_1)$$

$$= \left[5{,}457 + \frac{0{,}001045}{1} 303{,}94412(0{,}8111 + 1) + 0 + \frac{-115700}{0{,}8111 \times 303{,}94412} \right] \times (297{,}25 - 303{,}94412)$$

$$= -362{,}2027 \text{ K}$$

$$\frac{H^R}{R \times Tc} = Pr\left[B^0 - Tr \frac{dB^0}{dTr} + \omega \left(B^1 - Tr \frac{dB^1}{dTr} \right) \right]$$

Dimana : $\frac{dB^0}{dTr_2} = \frac{0{,}675}{Tr_2^{2.6}} = \frac{0{,}675}{0{,}9772^{2.6}} = 0{,}9417$

$$\frac{dB^1}{dTr_2} = \frac{0{,}722}{Tr_2^{5.2}} = \frac{0{,}722}{0{,}9772^{5.2}} = 0{,}8140$$

Sehingga :

$$\frac{H_2^R}{8{,}314 \times 304{,}2} = 0{,}2709 \left[\begin{array}{l} (-2{,}5336) - (0{,}9722 \times 0{,}9471) + \\ 0{,}2240((-20{,}5462) - (0{,}9722 \times 0{,}8140)) \end{array} \right]$$

H_2^R = - 8,3357 kJ/kmol

$$\Delta H_{aktual} = n_A \times H^R_{1A} + n_B \times H^R_{1B} + n_A \times \Delta H^{ig}_A + n_B \times \Delta H^{ig}_B + (n_A + n_B) \times H^R_2$$

$$= \begin{Bmatrix} (1807{,}8990 \times -1{,}5004) + (10{,}2324 \times -0{,}1605) + (1807{,}8990 \times -405{,}8289 \times 8{,}314) + \\ (10{,}2324 \times -362{,}2027) + ((1807{,}8990 + 10{,}2324) \times -8{,}3357) \end{Bmatrix}$$

= - 6148646,0164 kJ/batch

Melakukan trial T_2 sampai ΔH aktual = -6150266,6771 kJ/batch, dan dari hasil trial tersebut didapatkan T_2 = 297,2662 K

Q CO_2 keluar = ΔH aktual

$$= n_A \times H^R_{1A} + n_B \times H^R_{1B} + n_A \times \Delta H^{ig}_A + n_B \times \Delta H^{ig}_B + (n_A + n_B) \times H^R_2$$

$$= \begin{Bmatrix} (1807{,}8990 \times -1{,}5004) + (10{,}2324 \times -0{,}1605) + (1807{,}8990 \times -405{,}9368 \times 8{,}314) + \\ (10{,}2324 \times -362{,}3105) + ((1807{,}8990 + 10{,}2324) \times -8{,}3307) \end{Bmatrix}$$

= - 6150266,7717 kJ/batch

Q_{loss} = 0,3 x Q_{keluar}

= 0,3 x -6150266,7717 kJ/batch

= -1845080,0315 kJ/batch

Q suplai = Q CO_2 + Q_{loss}

= -6150266,7717 + (- 1845080,0315)

= - 7995346,8032 kJ/batch

Neraca Panas di Compressor II

Panas yang dibutuhkan	Kj/batch	Panas yang diberikan	Kj/batch
Dari Tangki Separator I dan II		Ke Tangki Penampungan CO_2	
Q suplai	- 7995346,8032	Q CO_2	-6150266,7717
		Q loss	-1845080,0310
Total	- 7995346,8032	**Total**	- 7995346,8032

8. Heater 1 (E-133)

Suhu minyak masuk HE = 30°C = 303 K

Suhu minyak keluar HE = 100 °C = 373K

Tabel data koefisien A, B, C, dan D untuk menghitung Cp masing – masing komponen.

Komponen	A	B	C	D
Myristic Acid	80,266	2,8162	-0,00601	5,1299E-06
Palmitic Acid	86,29	3,5237	-0,0073217	6,1001E-06
Stearic Acid	99,012	3,5874	-0,0072484	5,9035E-06
Oleic Acid	278,686	2,5434	-0,0051355	4,924E-06
Linoleic Acid	241,348	2,3065	-0,0050663	4,7468E-06
Air	8,712	0,00125	-1,8E-07	0
CO_2	5,457	0,001045	0	-115700

$$\int Cp_{\text{Myristic Acid}}\,dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 80{,}2660(373-303) + \frac{2{,}8162}{2}(373^2 - 303^2) + \frac{-0{,}00601}{3}(373^3 - 303^3) + \frac{5{,}1299E-06}{4}(373^4 - 303^4)$$

= 38030,5444 kJ/kmol

$$\int Cp_{\text{Palmitic Acid}}\,dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 86{,}2900(373-303) + \frac{3{,}5237}{2}(373^2 - 303^2) + \frac{-0{,}0073}{3}(373^3 - 303^3) + \frac{6{,}1001E-06}{4}(373^4 - 303^4)$$

= 47314,9949 kJ/kmol

$$\int Cp_{\text{Stearic Acid}}\,dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 99{,}0120(373-303) + \frac{3{,}5874}{2}(373^2 - 303^2) + \frac{-0{,}0072484}{3}(373^3 - 303^3) + \frac{5{,}9035E-06}{4}(373^4 - 303^4)$$

= 49763,8475 kJ/kmol

$$\int Cp_{\text{Oleic Acid}}\,dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 278{,}686(373-303) + \frac{2{,}5434}{2}(373^2 - 303^2) + \frac{-0{,}0051355}{3}(373^3 - 303^3) + \frac{4{,}924E-06}{4}(373^4 - 303^4)$$

= 49513,7219 kJ/kmol

$$\int Cp_{\text{Linoleic Acid}}\,dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 241,348(373-303)+\frac{2,3065}{2}(373^2-303^2)+\frac{-0,0050663}{3}(373^3-303^3)+\frac{4,7468E-06}{4}(373^4-303^4)$$

$= 43773,9730$ kJ/kmol

$$\int_{T_1}^{T_2}\frac{\langle C_p^{ig}\rangle_H}{R}dT=\left[A+\frac{B}{2}T_1(\tau+1)+\frac{C}{3}T_1^2(\tau^2+\tau+1)+\frac{D}{\tau T_1^2}\right](T_2-T_1)$$

$$=\left[8,712+\frac{0,00125}{2}303(1,2310+1)+\frac{-1,8E-07}{3}303^2(1,2310^2+1,2310+1)+0\right](373-303)$$

$= 637,9704$ K

$$\int_{T_1}^{T_2}\frac{\langle C_p^{ig}\rangle_H}{R}dT=\left[A+\frac{B}{2}T_1(\tau+1)+\frac{C}{3}T_1^2(\tau^2+\tau+1)+\frac{D}{\tau T_1^2}\right](T_2-T_1)$$

$$=\left[5,457+\frac{0,001045}{2}303(1,2310+1)+0+\frac{-115700}{1,2310\times 303^2}\right](373-303)$$

$= 335,0542$ K

$Q_{Myristic\ Acid} = mol \times \int Cp\, dT$

$= 0,0847\ kmol/batch \times 38030,5444\ kJ/kmol$

$= 3220,0862$ kJ/batch

$Q_{Palmitic\ Acid} = mol \times \int Cp\, dT$

$= 0,2514\ kmol/batch \times 47314,9949\ kJ/kmol$

$= 11893,4372$ kJ/batch

$Q_{Stearic\ Acid} = mol \times \int Cp\, dT$

$= 0,0680\ kmol/batch \times 49763,8475\ kJ/kmol$

$= 3382,7151$ kJ/batch

$Q_{Oleic\ Acid} = mol \times \int Cp\, dT$

$$= 1{,}1410\ \text{kmol}/\text{batch} \times 49513{,}7219\ \text{kJ}/\text{kmol}$$

$$= 56493{,}0497\ \text{kJ/batch}$$

$$Q_{\text{Linoleic Acid}} = \text{mol} \times \int Cp\ dT$$

$$= 0{,}7814\ \text{kmol}/\text{batch} \times 43773{,}9730\ \text{kJ}/\text{kmol}$$

$$= 34204{,}6699\ \text{kJ/batch}$$

$$Q_{air} = \text{mol} \times R \times \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT$$

$$= 0{,}0234\ kmol/batch \times 8{,}314\ kJ/kmol\ K \times 637{,}9704\ K$$

$$= 124{,}1745\ \text{kJ/batch}$$

$$Q\ CO_2 = \text{mol} \times R \times \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT$$

$$= 0{,}0001\ kmol/batch \times 8{,}314\ kJ/kmol\ K \times 335{,}0542\ K$$

$$= 0{,}3166\ \text{kJ/batch}$$

$$Q_{Minyak} = Q_{MyristicAcid} + Q_{PalmiticAcid} + Q_{StearicAcid} + Q_{OleicAcid} + Q_{Linoleic\ Acid} + Q_{air} + QCO_2$$

$$= 3220{,}0862 + 11893{,}4372 + 3382{,}7151 + 56493{,}0497 + 34204{,}6699 + 124{,}1745 + 0{,}3166$$

$$= 109318{,}4492\ \text{kJ/batch}$$

$$|Q_{steam}| = |Q_{larutan}| + |Q_{loss}|$$

$$|Q_{steam}| = 109318{,}4492 + 0{,}05\ |Q_{steam}|$$

$$|Q_{steam}| = 115072{,}0519\ \text{kJ/batch};\ |Q_{loss}| = 5753{,}6026\ \text{kJ/batch}$$

Menggunakan superheated steam dengan suhu steam masuk = 220°C, **λ pada suhu** 220°C = 2914,8781 kJ/kg (Geankoplis).

$$\left|Q_{steam}\right| = \text{massa} \times \lambda$$

$$115072{,}0517 \text{ kJ/batch} = \text{massa} \times 2914{,}8781 \, ^{kJ}/_{kg}$$

Massa steam = 39,4775 kg/batch

Neraca Panas di Heater I

Panas yang dibutuhkan	**kJ/batch**	**Panas yang diberikan**	**kJ/batch**
Q myristic acid	3220,0862	Q steam	**115072,0517**
Q palmitic acid	11893,4372		
Q stearic acid	3382,7151		
Q oleic acid	56493,0497		
Q linoleic acid	34204,6699		
Q air	124,1745		
Q CO_2	0,3166		
Q loss	5753,6026		
Total	**115072,0517**	**Total**	**115072,0517**

9. Tangki Pemucat (F-130)

Suhu minyak masuk tangki pemucat = 100°C = 373 K

Suhu karbon aktif dan bleaching earth masuk tangki pemucat = 30° **C = 303 K**

Suhu minyak, karbon aktif dan bleaching earth keluar tangki **pemucat = 80°C =** 353 K

Tabel data koefisien A, B, C, dan D untuk menghitung Cp **masing – masing** komponen.

Komponen	A	B	C	D
Myristic Acid	80,266	2,8162	-0,00601	5,1299E-06
Palmitic Acid	86,29	3,5237	-0,0073217	6,1001E-06
Stearic Acid	99,012	3,5874	-0,0072484	5,9035E-06
Oleic Acid	278,686	2,5434	-0,0054355	4,924E-06
Linoleic Acid	241,348	2,3065	-0,0050663	4,7468E-06
Air	8,712	0,00125	-1,8E-07	0
CO_2	5,457	0,001045	0	-115700

Bleaching earth	35,791	0,071963	0,00044	0
Karbon aktif	1,771	0,000771	0	-3,02E-06

$$\int Cp_{\text{Myristic Acid}}\, dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 80{,}2660(323 - 373) + \frac{2{,}8162}{2}(323^2 - 373^2) + \frac{-0{,}006601}{3}(323^3 - 373^3) + \frac{5{,}1299E-06}{4}(323^4 - 373^4)$$

= - 11119,4985 kJ/kmol

$$\int Cp_{\text{Palmitic Acid}}\, dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 86{,}29(353 - 373) + \frac{3{,}5237}{2}(353^2 - 373^2) + \frac{-0{,}0073217}{3}(353^3 - 373^3) + \frac{6{,}1001E-06}{4}(353^4 - 373^4)$$

= - 13847,5654 kJ/kmol

$$\int Cp_{\text{Stearic Acid}}\, dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 99{,}012(353 - 373) + \frac{3{,}5874}{2}(353^2 - 373^2) + \frac{-0{,}0072481}{2}(353^3 - 373^3) + \frac{5{,}9013E-06}{4}(353^4 - 373^4)$$

= - 14569,4709 kJ/kmol

$$\int Cp_{\text{Oleic Acid}}\, dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 278{,}686(353 - 373) + \frac{2{,}5434}{2}(353^2 - 373^2) + \frac{-0{,}0051355}{3}(353^3 - 373^3) + \frac{4{,}924E-06}{4}(353^4 - 373^4)$$

= - 14424,6570 kJ/kmol K

$$\int Cp_{\text{Limoleic Acid}}\, dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 241{,}348(353 - 373) + \frac{2{,}3065}{2}(353^2 - 373^2) + \frac{-0{,}0050663}{3}(353^3 - 373^3) + \frac{4{,}7468E-06}{4}(353^4 - 373^4)$$

= - 12761,5857 kJ/kmol

$$\int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT = \left[A + \frac{B}{2} T_1(\tau + 1) + \frac{C}{3} T_1^2(\tau^2 + \tau + 1) + \frac{D}{\tau T_1^2} \right](T_2 - T_1)$$

$$= \left[8{,}712 + \frac{0{,}00125}{2} 373(0{,}9464) + \frac{-1{,}8E-06}{3} 373^2\left(0{,}9464^2 + 0{,}9464 + 1\right) + 0\right](353 - 373)$$

= - 182,8405 K

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT = \left[A + \frac{B}{2} T_1(\tau + 1) + \frac{C}{3} T_1^2\left(\tau^2 + \tau + 1\right) + \frac{D}{\tau T_1^2}\right](T_2 - T_1)$$

$$= \left[5{,}457 + \frac{0{,}001045}{2} 373(0{,}9464 + 1) + 0 + \frac{-115700}{0{,}9464 \times 373^2}\right](353 - 373)$$

= - 99,1523 K

$$\int Cp_{\text{Bleaching Earth}}\, dT = A(T_2 - T_1) + \frac{B}{2}\left(T_2^2 - T_1^2\right) + \frac{C}{3}\left(T_2^3 - T_1^3\right) + \frac{D}{4}\left(T_2^4 - T_1^4\right)$$

$$= 35{,}791(353 - 303) + \frac{0{,}071963}{2}\left(353^2 - 303^2\right) + \frac{0{,}00044}{3}\left(353^3 - 303^3\right) + 0$$

= 5341,1745 kJ/kmol

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT = \left[A + \frac{B}{2} T_1(\tau + 1) + \frac{C}{3} T_1^2\left(\tau^2 + \tau + 1\right) + \frac{D}{\tau T_1^2}\right](T_2 - T_1)$$

$$= \left[1{,}771 + \frac{0{,}000771}{2} 303(1{,}1650 + 1) + 0 + \frac{-0{,}302E-05}{1{,}1650 \times 303^2}\right](353 - 303) = 101{,}1944$$

K

$$Q_{\text{Myristic Acid}} = \text{mol} \times \int Cp\, dT$$

$$= 0{,}0847 \,{}^{\text{kmol}}\!/_{\text{batch}} \times -11119{,}4985 \,{}^{\text{kJ}}\!/_{\text{kmol}} = -941{,}4996 \text{ kJ/batch}$$

$$Q_{\text{Palmitic Acid}} = \text{mol} \times \int Cp\, dT$$

$$= 0{,}2514 \,{}^{\text{kmol}}\!/_{\text{batch}} \times -13847{,}5654 \,{}^{\text{kJ}}\!/_{\text{kmol}} = -3480{,}8236 \text{ kJ/batch}$$

$Q_{Stearic\ Acid} = mol \times \int Cp\ dT$

$= 0{,}0680\ ^{kmol}/_{batch} \times -14569{,}4709\ ^{kJ}/_{kmol}$ = -990,3649 kJ/batch

$Q_{Oleic\ Acid} = mol \times \int Cp\ dT$

$= 1{,}1410\ ^{kmol}/_{batch} \times -14424{,}6570\ ^{kJ}/_{kmol}$ = -16457,9198 kJ/batch

$Q_{Linoleic\ Acid} = mol \times \int Cp\ dT$

$= 0{,}7814\ ^{kmol}/_{batch} \times -12761{,}5857\ ^{kJ}/_{kmol}$ = -9971,8119 kJ/batch

$$Q_{air} = mol \times R \times \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT$$

$= 0{,}0234\ ^{kmol}/_{batch} \times 8{,}314\ ^{kJ}/_{kmol\ K} \times -182{,}8405\ K$ = - 35,5881 kJ/batch

$$Q\ CO_2 = mol \times R \times \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT$$

$= 0{,}0001\ ^{kmol}/_{batch} \times 8{,}314\ ^{kJ}/_{kmol\ K} \times -99{,}1523\ K$

= - 0,0937 kJ/batch

$Q_{Bleaching\ Earth} = mol \times \int Cp\ dT$

$= 0{,}0858\ ^{kmol}/_{batch} \times 5341{,}1748\ ^{kJ}/_{kmol}$

= 458,2728 kJ/batch

$$Q_{Karbon\ Aktif} = mol \times R \times \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT$$

$= 0{,}0536\ ^{kmol}/_{batch} \times 101{,}1944\ ^{kJ}/_{kmol\ K} \times (353 - 303)\ K$

$= 45{,}1163$ kJ/batch

$Q_{Pemberi\ Panas} = Q_{Myristic\ Acid} + Q_{Palmitic\ Acid} + Q_{Stearic\ Acid} + Q_{Oleic\ Acid} + Q_{Linoleic\ Acid}$

$+Q_{air} + QCO_2$

$$= \begin{matrix}(-941{,}4996)+(-3480{,}8236)+(-990{,}3649)+(-16457{,}9198)+(-9971{,}8119)+\\(-35{,}5881)+(-0{,}0937)\end{matrix}$$

$= -31878{,}1016$ kJ/batch

$Q_{Penerima\ Panas} = Q_{Bleaching\ Earth} + Q_{Karbon\ Aktif}$

$= 458{,}2728 + 45{,}1163$

$= 503{,}3891$ kJ/batch

$Q_{Pemberi\ Panas} = Q_{Penerima\ Panas} + Q_{loss}$

$-31878{,}1016 = 503{,}3891 + Q_{loss}$

$Q_{loss} = -32381{,}4907$ kJ/batch

Neraca Panas di Tangki Pemucat

Panas yang dibutuhkan	**kJ/batch**	**Panas yang diberikan**	**kJ/batch**
Qbleaching earth	458,272775	Q myristic acid	-941,4996392
Qkarbon aktif	45,11633421	Q palmitic acid	-3480,823566
Qloss	-32381,49068	Q stearic acid	-990,3649131
		Q oleic acid	-16457,91983
		Q linoleic acid	-9971,811878
		Q air	-35,58807311
		Q CO2	-0,093676415
Total	**-31878,10157**	**Total**	**-31878,10157**

10. Heater 2 (E-138)

Suhu minyak masuk HE = 75°C = 348 K

Suhu minyak keluar HE = 190 °C = 463 K

Tabel data koefisien A, B, C, dan D untuk menghitung Cp masing – masing komponen.

Komponen	A	B	C	D
Myristic Acid	80,266	2,8162	-0,00601	5,1299E-06
Palmitic Acid	86,29	3,5237	-0,0073217	6,1001E-06
Stearic Acid	99,012	3,5874	-0,0072484	5,9035E-06
Oleic Acid	278,686	2,5434	-0,0054355	4,924E-06
Linoleic Acid	241,348	2,3065	-0,0050663	4,7468E-06
Air	8,712	0,00125	-1,8E-0[illegible]	0
CO_2	5,457	0,001045	0	-115700

$$\int Cp_{\text{Myristic Acid}}\,dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 80{,}2660(463 - 348) + \frac{2{,}8162}{2}(463^2 - 348^2) + \frac{-0{,}00601}{3}(463^3 - 348^3) + \frac{5{,}1299E-06}{4}(463^4 - 348^4)$$

$= 66275{,}3002$ kJ/kmol

$$\int Cp_{\text{Palmitic Acid}}\,dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 86{,}2900(463 - 348) + \frac{3{,}5237}{2}(463^2 - 348^2) + \frac{-0{,}0073217}{3}(463^3 - 348^3) + \frac{6{,}1001E-06}{2}(463^4 - 348^4)$$

$= 82579{,}6239$ kJ/kmol

$$\int Cp_{\text{Stearic Acid}}\,dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 99{,}0120(463 - 348) + \frac{3{,}5874}{2}(463^2 - 348^2) + \frac{-0{,}0072484}{3}(463^3 - 348^3) + \frac{5{,}9035E-06}{4}(463^4 - 348^4)$$

$= 86870{,}6992$ kJ/kmol

$$\int Cp_{\text{Oleic Acid}}\,dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 278{,}686(463 - 348) + \frac{2{,}5434}{2}(463^2 - 348^2) + \frac{-0{,}0054355}{3}(463^3 - 348^3) + \frac{4{,}924E-06}{4}(463^4 - 348^4)$$

$= 85698{,}0175$ kJ/kmol

$$\int Cp_{\text{Linoleic Acid}}\,dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 241{,}3480(463 - 348) + \frac{2{,}3062}{2}(463^2 - 348^2) + \frac{-0{,}0054355}{3}(463^3 - 348^3) + \frac{4{,}7468E-06}{4}(463^4 - 348^4$$

$= 75999{,}0266$ kJ/kmol

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT = \left[A + \frac{B}{2} T_1 (\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1 \right) + \frac{D}{\tau T_1^2} \right] (T_2 - T_1)$$

$$= \left[8{,}712 + \frac{0{,}00125}{2} 348(1{,}3305 + 1) + \frac{1{,}8E - 07}{3} 348^2 \left(1{,}3305^2 + 1{,}3305 + 1\right) + 0 \right] (463 - 348)$$

$= 1056{,}7441$ K

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT = \left[A + \frac{B}{2} T_1 (\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1 \right) + \frac{D}{\tau T_1^2} \right] (T_2 - T_1)$$

$$= \left[5{,}457 + \frac{0{,}001045}{2} 348(1{,}3305 + 1) + 0 + \frac{-115700}{1{,}3305 \times 348^2} \right] (463 - 348)$$

$= 593{,}7067$ K

$Q_{\text{Myristic Acid}} = \text{mol} \times \int Cp\, dT$

$= 0{,}0593 \; \text{kmol}/\text{batch} \times 66275{,}3002 \; \text{kJ}/\text{kmol}$

$= 3928{,}1196$ kJ/batch

$Q_{\text{Palmitic Acid}} = \text{mol} \times \int Cp\, dT$

$= 0{,}1760 \; \text{kmol}/\text{batch} \times 82579{,}6239 \; \text{kJ}/\text{kmol}$

$= 14530{,}4546$ kJ/batch

$Q_{\text{Stearic Acid}} = \text{mol} \times \int Cp\, dT$

$= 0{,}0476 \; \text{kmol}/\text{batch} \times 86870{,}6992 \; \text{kJ}/\text{kmol}$

$= 4133{,}5457$ kJ/batch

$$Q_{Oleic\ Acid} = mol \times \int Cp\ dT$$

$$= 0{,}7987\ {}^{kmol}/_{batch} \times 85698{,}0175\ {}^{kJ}/_{kmol}$$

$$= 68444{,}4502\ kJ/batch$$

$$Q_{Linoleic\ Acid} = mol \times \int Cp\ dT$$

$$= 0{,}5470\ {}^{kmol}/_{batch} \times 75999{,}0266\ {}^{kJ}/_{kmol}$$

$$= 41569{,}5734\ kJ/batch$$

$$Q_{air} = mol \times R \times \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT$$

$$= 0{,}0164\ {}^{kmol}/_{batch} \times 8{,}314\ {}^{kJ}/_{kmol\ K} \times 1056{,}7441\ K$$

$$= 143{,}9793\ kJ/batch$$

$$Q\ CO_2 = mol \times R \times \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT$$

$$= 0{,}0001\ {}^{kmol}/_{batch} \times 8{,}314\ {}^{kJ}/_{kmol\ K} \times 593{,}7067\ K$$

$$= 0{,}3926\ kJ/batch$$

$$Q_{Minyak} = Q_{Myristic\ Acid} + Q_{Palmitic\ Acid} + Q_{Stearic\ Acid} + Q_{Oleic\ Acid} + Q_{Linoleic\ Acid} + Q_{air} + QCO_2$$

$$= 3928{,}1196 + 14530{,}4546 + 4133{,}5457 + 68444{,}4502 + 41569{,}5734 + 143{,}9793 + 0{,}3926$$

$$= 132750{,}5153\ kJ/batch$$

$$|Q_{steam}| = |Q_{larutan}| + |Q_{loss}|$$

$$|Q_{steam}| = 132750{,}5153 + 0{,}05\ |Q_{steam}|$$

$|Q_{steam}| = 139737{,}3845$ kJ/batch

$|Q_{loss}| = 6986{,}8692$ kJ/batch

Menggunakan superheated steam dengan suhu steam masuk = 220°C, λ pada suhu 220°C = 2914,8781 kJ/kg (Geankoplis).

$|Q_{steam}| \quad = \text{massa} \times \lambda$

$139737{,}3845 \text{ kJ/batch} = \text{massa} \times 1856{,}2 \, {}^{kJ}/_{kg}$

Massa steam = 47,9394 kg/batch

Neraca Panas di Heater II

Panas yang dibutuhkan	kJ/batch	Panas yang diberikan	kJ/batch
Q myristic acid	3928,1196	Q steam	139737,3845
Q palmitic acid	14530,4546		
Q stearic acid	4133,5457		
Q oleic acid	68444,4502		
Q linoleic acid	41569,5734		
Q air	143,9793		
Q CO_2	0,3926		
Q loss	6986,8692		
Total	**139737,3845**	**Total**	**139737,3845**

11. Tangki Deodorizer (F-140)

Suhu minyak masuk tangki deodorisasi = 190°C = 463 K

Suhu minyak keluar tangki deodorisasi = 170°C = 443 K

Tabel data koefisien A, B, C, dan D untuk menghitung Cp masing – masing komponen.

Komponen	A	B	C	D
Myristic Acid	80,266	2,8162	-0,00601	5,1299E-06
Palmitic Acid	86,29	3,5237	-0,0073217	6,1001E-06
Stearic Acid	99,012	3,5874	-0,0072484	5,9035E-06
Oleic Acid	278,686	2,5434	-0,0054355	4,924E-06
Linoleic Acid	241,348	2,3065	-0,0050663	4,7468E-06

Air	8,712	0,00125	-1,8E-07	0
CO_2	5,457	0,001045	0	-115700

$$\int Cp_{\text{Myristic Acid}}\, dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 80{,}2660(443 - 463) + \frac{2{,}8162}{2}(443^2 - 463^2) + \frac{-0{,}00601}{3}(443^3 - 463^3) + \frac{5{,}13E-06}{4}(443^4 - 463^4)$$

= - 11992,0882 kJ/kmol

$$\int Cp_{\text{Palmitic Acid}}\, dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 86{,}2900(443 - 463) + \frac{3{,}5237}{2}(443^2 - 463^2) + \frac{-0{,}0073217}{3}(443^3 - 463^3) + \frac{6{,}1E-06}{4}(443^4 - 463^4)$$

= - 14942,8594 kJ/kmol

$$\int Cp_{\text{Stearic Acid}}\, dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 99{,}0120(443 - 463) + \frac{3{,}5874}{2}(443^2 - 463^2) + \frac{-0{,}0072484}{3}(443^3 - 463^3) + \frac{5{,}904E-06}{4}(443^4 - 463^4)$$

= - 15709,6111 kJ/kmol

$$\int Cp_{\text{Oleic Acid}}\, dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 278{,}686(443 - 463) + \frac{2{,}5434}{2}(443^2 - 463^2) + \frac{-0{,}0054355}{3}(443^3 - 463^3) + \frac{4{,}924E-06}{4}(443^4 - 463^4)$$

= - 15464,1601 kJ/kmol K

$$\int Cp_{\text{Linoleic Acid}}\, dT = A(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) + \frac{D}{4}(T_2^4 - T_1^4)$$

$$= 241{,}348(443 - 463) + \frac{2{,}3065}{2}(443^2 - 463^2) + \frac{-0{,}0050663}{3}(443^3 - 463^3) + \frac{4{,}747E-06}{4}(443^4 - 463^4)$$

= - 13756,9858 kJ/kmol

$$\int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT \text{ air} = \left[A + \frac{B}{2} T_1(\tau + 1) + \frac{C}{3} T_1^2 \left(\tau^2 + \tau + 1\right) + \frac{D}{\tau T_1^2} \right] (T_2 - T_1)$$

$$= \left[8{,}712 + \frac{0{,}00125}{2} 463(0{,}9568+1) + \frac{-1{,}8E-07}{3} 463^2 \left(0{,}9568^2 + 0{,}9568 + 1\right) + 0\right](443-463)$$

= - 184,8261 K

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT \; CO_2 = \left[A + \frac{B}{2} T_1(\tau+1) + \frac{C}{3} T_1^2\left(\tau^2+\tau+1\right) + \frac{D}{\tau T_1^2}\right](T_2 - T_1)$$

$$= \left[5{,}457 + \frac{0{,}001045}{2} 463(0{,}9568+1) + 0 + \frac{-115700}{0{,}9568 \times 463^2}\right](443-463) = -107{,}3259 \text{ K}$$

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT \; \text{steam} = \left[A + \frac{B}{2} T_1(\tau+1) + \frac{C}{3} T_1^2\left(\tau^2+\tau+1\right) + \frac{D}{\tau T_1^2}\right](T_2 - T_1)$$

$$= \left[8{,}712 + \frac{0{,}00125}{2} 393(1{,}1272+1) + \frac{-1{,}8E-07}{3} 393^2 \left(1{,}1272^2 + 1{,}1272 + 1\right) + 0\right](443-393)$$

= 460,1506 K

$Q_{\text{Myristic Acid}} = \text{mol} \times \int Cp \, dT$

$= 0{,}0593 \text{ kmol/batch} \times -11992{,}0882 \text{ kJ/kmol} = -710{,}7679$ kJ/batch

$Q_{\text{Palmitic Acid}} = \text{mol} \times \int Cp \, dT$

$= 0{,}1760 \text{ kmol/batch} \times -14942{,}8594 \text{ kJ/kmol} = -2629{,}3012$ kJ/batch

$Q_{\text{Stearic Acid}} = \text{mol} \times \int Cp \, dT$

$= 0{,}0476 \text{ kmol/batch} \times -15709{,}6111 \text{ kJ/kmol} = -747{,}5064$ kJ/batch

$Q_{\text{Oleic Acid}} = \text{mol} \times \int Cp \, dT$

$$= 0{,}7987\,{}^{kmol}\!/_{batch} \times -15464{,}1601\,{}^{kJ}\!/_{kmol} = \text{-}12350{,}7640 \text{ kJ/batch}$$

$$Q_{Linoleic\ Acid} = mol \times \int Cp\, dT$$

$$= 0{,}5470\,{}^{kmol}\!/_{batch} \times -13756{,}9858\,{}^{kJ}\!/_{kmol} = \text{-}7524{,}7273 \text{ kJ/batch}$$

$$Q_{air} = mol \times R \times \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT$$

$$= 0{,}0164\,{}^{kmol}\!/_{batch} \times 8{,}314\,{}^{kJ}\!/_{kmol\ K} \times -184{,}8261\text{ K} = \text{- }3{,}0291 \text{ kJ/batch}$$

$$Q\ CO_2 = mol \times R \times \int_{T_1}^{T_2} \frac{\langle C_p^{ig} \rangle_H}{R} dT$$

$$= 0{,}0001\,{}^{kmol}\!/_{bacth} \times 8{,}314\,{}^{kJ}\!/_{kmol\ K} \times -107{,}3259\text{ K} = \text{- }0{,}0085 \text{ kJ/batch}$$

$$Q_{Larutan} = Q_{Myristic\ Acid} + Q_{Palmitic\ Acid} + Q_{Stearic\ Acid} + Q_{Oleic\ Acid} + Q_{Linoleic\ Acid} + Q_{air} + QCO_2$$

$$= \begin{array}{l}(-710{,}7679) + (-2629{,}3012) + (-747{,}5064) + (-12350{,}7640) + (-7524{,}7273) \\ + (-3{,}0291) + (-0{,}0085)\end{array}$$

$= \text{-}23966{,}1045$ kJ/batch

$$Q_{steam} = mol \times \left\{ \left(R \times \int_{T_1}^{T_2} \frac{\langle Cp^{ig} \rangle_H}{R} \right) + H_2 - H_1 \right\}$$

Dimana data H_2 dan H_1 diperoleh dari steam tabel untuk superheated steam.

$$= 1{,}2513\,{}^{kmol}\!/_{batch} \times \left(\left(8{,}314\,{}^{kJ}\!/_{kmol\ K} \times 460{,}1506\text{ K} \right) + 2822{,}1456\,{}^{kJ}\!/_{kmol} - 2726{,}5954\,{}^{kJ}\!/_{kmol} \right)$$

$= 4913{,}7082$

Neraca Panas di Tangki Deodorisasi

Panas yang dibutuhkan	kJ/batch	Panas yang diberikan	kJ/batch
Q myristic acid	-710,7679	Q steam	4913,7082
Q palmitic acid	-2629,3012		
Q stearic acid	-747,5064		
Q oleic acid	-12350,7640		
Q linoleic acid	-7524,7273		
Q air	-3,0291		
Q CO_2	-0,0085		
Q loss	28879,8127		
Total	**4913,7082**	**Total**	**4913,7082**

12. Cooler 2 (E-143)

Suhu minyak masuk Cooler = 170°C = 443 K

Suhu minyak keluar Cooler = 35 °C = 308 K

Tabel data koefisien A, B, C, dan D untuk menghitung Cp masing – masing komponen.

Komponen	A	B	C	D
Myristic Acid	80,266	2,8162	-0,00601	5,1299E-06
Palmitic Acid	86,29	3,5237	-0,0073217	6,1001E-06
Stearic Acid	99,012	3,5874	-0,0072484	5,9035E-06
Oleic Acid	278,686	2,5434	-0,0054355	4,924E-06
Linoleic Acid	241,348	2,3065	-0,0050663	4,7468E-06
Air	8,712	0,00125	-1,8E-07	0
CO_2	5,457	0,001045	0	-115700

Cp untuk masing – masing komponen dihitung dengan cara yang sama seperti pada perhitungan Cp di neraca panas Heater I.

$\int Cp_{Myristic\ Acid}\, dT$ = - 75814,9353 kJ/kmol

$\int Cp_{Palmitic\ Acid}\, dT$ = - 94414,6657 kJ/kmol

$\int Cp_{Stearic\ Acid}\, dT$ = - 99320,9075 kJ/kmol

$\int Cp_{Oleic\ Acid}\, dT$ = - 98306,8802 kJ/kmol

$\int Cp_{Linoleic\ Acid}\, dT$ = - 87053,1370 kJ/kmol

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT \text{ air} = -1236{,}0224 \text{ K}$$

$$\int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT \text{ } CO_2 = -675{,}1931 \text{ K}$$

$$Q_{\text{Myristic Acid}} = \text{mol} \times \int Cp \, dT$$

$$= 0{,}0041 \text{ kmol/batch} \times -75814{,}9353 \text{ kJ/kmol} = -314{,}5322 \text{ kJ/batch}$$

$$Q_{\text{Palmitic Acid}} = \text{mol} \times \int Cp \, dT$$

$$= 0{,}0123 \text{ kmol/batch} \times -94414{,}6657 \text{ kJ/kmol} = -1162{,}9231 \text{ kJ/batch}$$

$$Q_{\text{Stearic Acid}} = \text{mol} \times \int Cp \, dT$$

$$= 0{,}0033 \text{ kmol/batch} \times -99320{,}9075 \text{ kJ/kmol} = -330{,}8016 \text{ kJ/batch}$$

$$Q_{\text{Oleic Acid}} = \text{mol} \times \int Cp \, dT$$

$$= 0{,}7971 \text{ kmol/batch} \times -98306{,}9075 \text{ kJ/kmol} = -78357{,}9043 \text{ kJ/batch}$$

$$Q_{\text{Linoleic Acid}} = \text{mol} \times \int Cp \, dT$$

$$= 0{,}5459 \text{ kmol/batch} \times -87053{,}1370 \text{ kJ/kmol} = -47520{,}7530 \text{ kJ/batch}$$

$$Q_{\text{air}} = \text{mol} \times R \times \int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT$$

$$= 0{,}0131 \text{ kmol/batch} \times 8{,}314 \text{ kJ/kmol K} \times -1236{,}0224 \text{ K} = -134{,}7336 \text{ kJ/batch}$$

$$Q \text{ } CO_2 = \text{mol} \times R \times \int_{T_1}^{T_2} \frac{\left\langle C_p^{ig} \right\rangle_H}{R} dT$$

$$0,0001 \,\text{kmol/batch} \times 8,314 \,\text{kJ/kmol K} \times -675,1931 \,\text{K} = -0,3572 \,\text{kJ/batch}$$

$$Q_{Masuk} = Q_{Myristic\ Acid} + Q_{Palmitic\ Acid} + Q_{Stearic\ Acid} + Q_{Oleic\ Acid} + Q_{Linoleic\ Acid} + Q_{air} + QCO_2$$

$$= \begin{Bmatrix} (-314,5322) + (-1162,9231) + (-330,8016) + (-78357,9043) + \\ (-47520,7530) + (-134,7336) + (-0,3572) \end{Bmatrix}$$

$$= -127822,0050 \,\text{kJ/batch}$$

$$|Q_{air\ pendingin}| = |Q_{Masuk}| + |Q_{loss}|$$

$$|Q_{air\ pendingin}| = 127822,0050 + 0,05\,|Q_{air\ pendingin}|$$

$$|Q_{air\ pendingin}| = 134549,4789 \,\text{kJ/batch}$$

$$|Q_{loss}| = 6727,4739 \,\text{kJ/batch}$$

$$|Q_{air\ pendingin}| = \text{mol} \times R \times \int_{T_1}^{T_2} \left(\frac{C_p^{ig}}{R}\right)_H dT$$

$$134549,4789 \,\text{kJ/batch} = \text{mol} \times 8,314 \,\text{kJ/kmol K} \times 363,8779 \,\text{K}$$

Mol air pendingin = 44,4750 kmol/batch

Massa air pendingin = 800,5507 kg/batch

Neraca Panas di Cooler II

Panas dibutuhkan	kJ/batch	Panas diberikan	kJ/batch
Q air pendingin	134549,4789	Q myristic acid	314,5322
		Q palmitic acid	1162,9231
		Q stearic acid	330,8016
		Q oleic acid	78357,9043
		Q linoleic acid	47520,7530
		Q air	134,7336
		Q CO_2	0,3572
		Q loss	6727,4739
Total	**134549,4789**	**Total**	**134549,4789**

APPENDIKS C

PERHITUNGAN SPESIFIKASI ALAT

LAMPIRAN C

PERHITUNGAN SPESIFIKASI ALAT

Bucket Elevator (J – 111)

Fungsi : Memindahkan biji jagung kotor secara vertikal dari truk menuju ke silo (F-112)

Bahan konstruksi : Driving head and boat : Carbon steel

Roda : Carbon steel

Bucket : Cast iron

Belt : Karet

Tipe : Spaced-Bucket Centrifugal-Discharge Elevators

Dasar pemilihan : Efektif untuk memindahkan material dengan sudut kemiringan mencapai 90°

Kapasitas : $\frac{60000 \text{ kg/hari}}{6 \text{ jam/hari}} = 10000 \text{ kg/jam}$

Untuk kecepatan putaran 14000 kg/jam, maka kecepatan bucket elevator = 225 ft/min dan kecepatan head shaft = 43 rpm (Perry 6th ed; tabel 7 – 8).

Tinggi elevasi : 75 ft

Kecepatan bucket elevator $= \frac{10000 \text{ kg/jam}}{14000 \text{ kg/jam}} \times 225 \text{ ft/min}$

$= 160{,}7143 \text{ ft/min} \approx 160 \text{ ft/min}$

Kecepatan head shaft $= \dfrac{10000\ \text{kg/jam}}{14000\ \text{kg/jam}} \times 43\ \text{rpm}$

$= 30{,}7143\ \text{rpm} \approx 30\ \text{rpm}$

Power teoritis $= \dfrac{\text{Kapasitas (ton/jam)} \times 2 \times \text{tinggi elevasi}}{1000}$

Power teoritis $= \dfrac{10\ \text{ton/jam} \times 2 \times 75\ \text{ft}}{1000} = 1{,}5\ \text{hp}$

Efisiensi = 78 % (Peters; fig. 14 – 38)

Power aktual $= \dfrac{1{,}5\ \text{hp}}{0{,}78} = 1{,}9231\ \text{hp} \approx 2\ \text{hp}$

Silo (F – 112)

Fungsi : Menampung biji jagung sementara sebelum masuk ke grinder (C-110)

Bahan Konstruksi : SA-240 grade C

Tipe : Silinder tegak dengan tutup atas berbentuk flat dan tutup bawah berbentuk konis

Ukuran : Bawah : konis 60^0

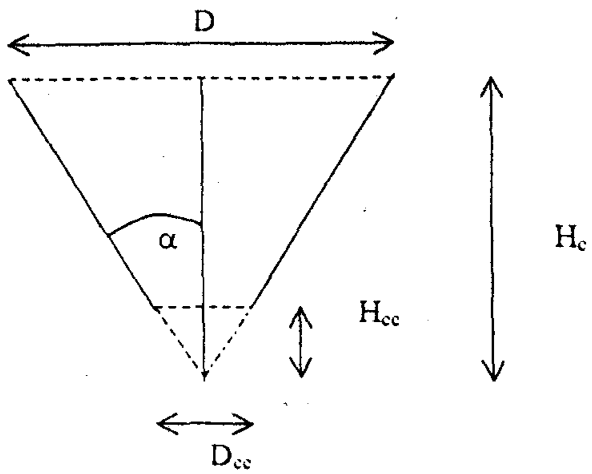
Dasar pemilihan : Cocok untuk menyimpan padatan kering

Kapasitas $= 420000\ \dfrac{\text{kg}}{\text{minggu}}$

$= 925940{,}4\ \dfrac{\text{lb}}{\text{minggu}}$

Bulk densitas biji jagung : 20,295 lb/ ft^3

Kondisi operasi : T = 30 °C



H = D (Ulrich, Tabel 4.27)

α = 60°

D_{cc} = 4,026 in (4 in schedule 40) = 0,3333 ft

$$\text{Volume biji jagung dalam silo / minggu} = \frac{\text{kapasitas}}{\text{densitas biji jagung}}$$

$$= \frac{925940{,}4 \text{ lb/minggu}}{20{,}295 \text{ lb/ft}^3}$$

$$= 45624{,}0650 \text{ ft}^3$$

$$\text{Volume silo} = \text{Volume biji jagung dalam silo} \times \frac{100}{80}$$

$$= 45624{,}0650 \times \frac{100}{80} \text{ ft}$$

$$= 57030{,}0813 \text{ ft}^3$$

Volume silo = volume shell + volume konis

$$57030{,}0813 = (0{,}25 \times \pi \times D^2 \times H) + \frac{\pi \times (D^3 - D^3_{cc})}{24 \times tg\alpha}$$

$$57030{,}0813 = (0{,}7854 \times D^2 \times D) + (0{,}2267 \times (D^3 - 0{,}3333^3))$$

$$57030{,}0813 = 0{,}7854 \times D^3 + 0{,}2267 \times D^3 - 0{,}0252$$

$$57044{,}5901 = 1{,}0121\ D^3$$

$$D = 38{,}0543\ ft \approx 38\ ft$$

$$H_c = \frac{\frac{1}{2} \times D}{tg\ \alpha} = \frac{\frac{1}{2} \times 38}{tg\ 60}$$

$$= 10{,}9697\ ft$$

$$H_{cc} = \frac{\frac{1}{2} \times D_{cc}}{tg\alpha} = \frac{\frac{1}{2} \times 0{,}3333}{tg\ 60}$$

$$= 0{,}0962\ ft$$

Tinggi konis terpancung $= (10{,}9697 - 0{,}0962)\ ft$

$= 10{,}8735\ ft$

Volume konis terpancung $= \frac{\pi}{12} \times (D^2 \times H_c - D_{cc}^2 \times H_{cc})$

$= \frac{\pi}{12} \times (38^2 \times 10{,}9697 - 0{,}3333^2 \times 0{,}0962)$

$= 4146{,}9641\ ft^3$

Tinggi shell = diameter silinder

$= 38 \text{ ft}$

Volume shell $= \frac{1}{4} \times \pi \times D^2 \times H$

$= \frac{1}{4} \times \pi \times 38^2 \times 38$

$= 43096{,}3680 \text{ ft}^3$

Tinggi silo = Tinggi shell + tinggi konis terpancung

= 38 + 10,8735

= 48,8735 ft

$$P_{ops} = \frac{r \times \rho_b \times (g/g_c) \times (1 - e^{(-2 \times \mu' \times Z_T \times K')/r})}{2 \times \mu' \times K'}$$ (McCabe 4th ed; pers. 26. 24)

Dimana : r = diameter dalam tangki = D / 2

Z_T = tinggi padatan dalam tangki

ρ_b = bulk density

μ' = koefisien friksi (untuk granular solid, μ' = 0.35 – 0.55)

μ' = 0,4 (asumsi)

K' = ratio tekanan (untuk granular solid, K' = 0.35 – 0.6)

K' = 0,5 (asumsi)

$$P_{ops} = \frac{19 \times 20{,}295 \times (32{,}174/32{,}174) \times (1 - e^{-2 \times 0{,}4 \times 0{,}5 \times 48{,}8735)/19})}{2 \times 0{,}4 \times 0{,}5}$$

$$= 619{,}4800 \frac{\text{lbf}}{\text{ft}^2} = 4{,}3019 \frac{\text{lb}}{\text{in}^2}$$

$= 4{,}3019 \text{ psia} + 14{,}696 \text{ psia} = 18{,}9979 \text{ psia}$

$P_{design} = 1{,}2 \times P_{ops}$

$= 1{,}2 \times 18{,}9979$

$= 22{,}7975 \dfrac{lb}{in^2}$

Tebal shell :

$$t_{shell} = \frac{P_{design} \times D}{2 \times \{(f \times E) - (0{,}6 \times P_{design})\}} + c \quad \text{(Brownell; pers. 13.1)}$$

f = stress max yang diijinkan

= 18750 psi (Brownell; hal 251 untuk SA-240 grade C)

E = 0,8 (tabel 13.2 untuk double welded butt joint)

c = 0,1250 in (asumsi)

$$t_{shell} = \frac{22{,}7975 \text{ psi} \times 38 \text{ ft} \times 12 \frac{in}{ft}}{2 \times \{(18750 \text{ psi} \times 0{,}8) - (0{,}6 \times 22{,}7975 \text{ psi})\}} + 0{,}1250$$

$t_{shell} = 0{,}4717 \text{ in}$

Tebal shell yang digunakan : $\frac{1}{2}$ in

Tebal konis :

$$t_{konis} = \frac{P_{design} \times D}{\{2 \times \cos\alpha \times (f \times E) - (0{,}6 \times P_{design})\}} + c \quad \text{(Brownell; pers. 6.154)}$$

$$t_{kons} = \frac{22,7975 \text{ psi} \times 38 \text{ ft} \times 12 \frac{\text{in}}{\text{ft}}}{\{2 \times \cos 60° \times (18750 \text{ psi} \times 0,8) - (0,6 \times 22,7975 \text{ psia})\}} + 0,1250$$

t_{konis} = 0,8187 in

Tebal konis yang digunakan : 1 in

Screw Conveyor I (J – 113)

Fungsi	: Memindahkan biji jagung kotor dari bin menuju ke rol mill
Tipe	: Standard pitch screw conveyor
Dasar pemilihan	: Membutuhkan ruangan sedikit, murah, pemeliharaan mudah
Kondisi operasi	: T masuk = 30 °C ; P = 1 atm
Kapasitas	: 2500 kg/jam = 2,5 ton/jam
Panjang	: 10 ft (asumsi)

Untuk kecepatan putaran 5 ton/jam maka kecepatan putaran screw conveyor = 40 rpm ; dan untuk panjang maksimum screw conveyor = 15 ft, power yang dibutuhkan = 0,43 hp (Perry 6th ed; tabel 7 – 6).

$$\text{Kecepatan screw conveyor} = \frac{2,5 \text{ ton/jam}}{5 \text{ ton/jam}} \times 40 \text{ rpm}$$

$$= 20 \text{ rpm}$$

Power teoritis $= \frac{10\ \text{ft}}{15\ \text{ft}} \times 0{,}43\ \text{hp} = 0{,}2867\ \text{hp}$

Efisiensi = 78 % (Peters; fig. 14 – 38)

Power aktual $= \frac{0{,}2867\ \text{hp}}{0{,}78} = 0{,}3675\ \text{hp} \approx 0{,}5\ \text{hp}$

Grinder (C-110)

Fungsi : menghancurkan atau mengecilkan biji jagung dari 0,25 in menjadi 0,125 in

Bahan konstruksi : SA-240 grade C

Tipe : roll mill

Kapasitas : 2500 kg/jam= 2,5 ton/jam

Dasar pemilihan : konstruksi sederhana, cocok untuk ukuran partikel 1,5 – 0,25 in

Kondisi operasi : T masuk = 30 °C, P = 1 atm

Grinder bekerja selama 24 jam/ hari

Power : 20 hp (Perry 6-ed, hal 8-55, tabel 8.38)

Ukuran : $(24 \times 18)\ \text{in}^2$ (Perry 6-ed, hal 8-55, tabel 8.38)

Screw Conveyor II (J – 114)

Fungsi : Memindahkan biji jagung kotor dari roll mill menuju ke bin

Tipe : Standard pitch screw conveyor

Dasar pemilihan : Membutuhkan ruangan sedikit, murah, pemeliharaan mudah

Kondisi operasi : T masuk = 30 °C ; P = 1 atm

Kapasitas : $60000 \frac{kg}{hari} \times \frac{1}{24} \frac{hari}{jam} = 2500 \frac{kg}{jam} = 2{,}5 \frac{ton}{jam}$

Panjang : 10 ft (asumsi)

Dengan perhitungan yang sama dari screw conveyor I (J-113), maka mendapatkan:

Kecepatan = 20 rpm

Power teoritis = 0,2867 hp

Efisiensi = 78 % (Peters; fig. 14 – 38)

Power aktual = 0,3675 hp ≈ 0,5 hp

Bin (F – 115)

Fungsi : Menampung biji jagung sebelum diekstraksi

Bahan Konstruksi : SA-240 grade C

Tipe : Silinder tegak dengan tutup atas berbentuk flat dan tutup bawah berbentuk konis

Kapasitas $= 60000 \frac{kg}{hari}$

$= 132277{,}2 \frac{lb}{hari}$

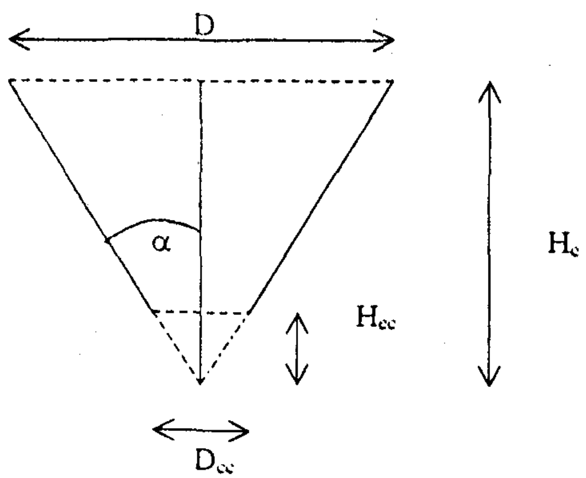
Bulk densitas biji jagung = 22,6925 lb/ft^3

Waktu tinggal = 4 jam = 0,1667 hari

Volume biji jagung dalam bin $= \dfrac{\text{kapasitas}}{\text{densitas biji jagung}} \times \text{waktu tinggal}$

$$= \frac{132277{,}2 \text{ lb/hari}}{22{,}6925 \text{ lb/ft}^3} \times 0{,}1667 \text{ hari}$$

$$= 971{,}7135 \text{ ft}^3$$



H = 3 D (Ulrich; Tabel 4. 27)

α = 30°

D_{cc} = 4,026 in (4 in schedule 40) (asumsi) = 0,3333 ft

Volume bin = Volume biji jagung dalam bin x $\dfrac{100}{80}$

$$= 971{,}7135 \times \frac{100}{80} \text{ ft}$$

$$= 1214{,}6419 \text{ ft}^3$$

Dengan perhitungan yang sama dari silo (F-112), maka mendapatkan :

D = 7,7765 ft ≈ 8 ft

H_c = 6,9282 ft

H_{cc} = 0,2887 ft

Tinggi konis terpancung = 6,6395 ft

Volume konis terpancung = 116,0747 ft^3

Tinggi shell = 24 ft

Volume shell = 18,1791 ft

Tinggi bin = 30,6395 ft

$P_{operasi}$ = 16,2719 psia

P_{design} = $19,5263 \frac{lb}{in^2}$

Tebal shell = 0,1875 in ≈ $\frac{1}{4}$ in

Tebal konis = 0,1972 in ≈ $\frac{1}{4}$ in

Screw Conveyor III (J – 116)

Fungsi : Memindahkan biji jagung kotor dari tangki penampungan sementara menuju ke tangki ekstraksi

Tipe : Standard pitch screw conveyor

Dasar pemilihan : Membutuhkan ruangan sedikit, murah, pemeliharaan mudah

Kondisi operasi : T masuk = 30 °C ; P = 1 atm

Kapasitas : $\frac{60000 \text{ kg/hari}}{18 \text{ jam/hari}} = 3333{,}3333$ kg/jam = 3,3333 ton/jam

Panjang : 10 ft (asumsi)

Dengan perhitungan yang sama dari screw conveyor I (J-113), maka mendapatkan:

Kecepatan = 26,67 rpm

Power teoritis = 0,2867 hp

Efisiensi = 78 % (Peters, fig. 14 – 38)

Power aktual = 0,3675 hp ≈ 0,5 hp

Tangki Penampungan CO_2 (F-121)

Fungsi : Menyimpan CO_2 pada keadaan gas

Bahan konstruksi : SA-240 grade C

Tipe : Tangki bertekanan dengan hemispherical head

Dasar pemilihan : Didesain untuk beroperasi pada tekanan tinggi

Kondisi operasi : T = 40°C ; P = 20 bar

Waktu tinggal : $1\frac{1}{2}$ jam

Kapasitas : Gas CO_2 = 80387,0130 kg/batch = 26795,67 kg/jam

Dengan perhitungan yang sama dari tangki separator I (H-125), maka mendapatkan:

$Z = 0,9149$

Densitas gas CO_2 = 36,9618 kg/m^3

$$\text{Volume gas } CO_2 = \frac{Z \times R \times T}{P} \times \text{mol} \times 1\frac{1}{2}\ \text{jam}$$

$$= \frac{0,9149 \times 83,14 \dfrac{\text{bar} \times \text{cm}^3}{\text{mol} \times \text{K}} \times 313\ \text{K}}{20\ \text{bar}} \times 608992,5 \frac{\text{mol}}{\text{jam}} \times 1\frac{1}{2}\ \text{jam}$$

Volume gas CO_2 = 1087434115,8198 cm^3 = 1087,4341 m^3

Asumsi : L = 4 D

Dengan perhitungan yang sama dari tangki separator I (H-125), maka mendapatkan:

D = 23,57137 ft ≈ 24 ft

L = 4 D

L = 4 x 24 = 96 ft

P_{ops} = 293,92 psia

P_{design} = 352,7040 psia

Tebal shell = 3,5350 in

Tebal head = 1,8220 in

Tinggi head = 148 in = 12,3333 ft

Lebar tangki = 120,6667 ft

Compresor I (K-122)

Fungsi : Mengalirkan dan menaikkan tekanan CO_2 ke tangki ekstraksi superkritis (F-120) dari 20 bar menjadi 200 bar.

Tipe : Single stage compressor

Dasar pemilihan : Mampu beroperasi pada tekanan yang sangat tinggi

Kondisi Operasi : T masuk = 40 °C ; P masuk = 20 bar ; P keluar = 200 bar

Dari perhitungan neraca panas di kompresor 1 menghasilkan kerja kompresor (Ws) = 26691,7467 KJ/kmol = 6025,8297 hp

Cooler I (E-123)

Fungsi : Mendinginkan gas CO_2 dari suhu 452,7451 °C ke 163,15114 °C

Tipe : Shell and Tube Heat Exchanger

Kondisi operasi : T masuk = 163,15114 °C ; P = 1 atm

Bahan Konstruksi : Stainless steel

Jumlah : 2 buah

Cara perhitungan diambil dari Kern, 1965

Perhitungan:

1. Dari neraca panas memperoleh :

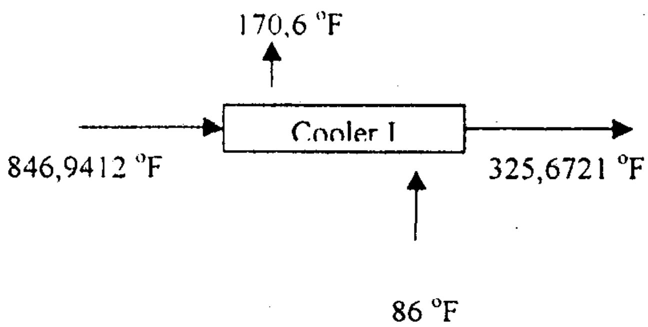
   Qc = 30549937,1524 kJ/batch = 14477819,82 btu/jam.

   Rate gas CO_2 = 80000 kg/batch = 58789,3333 lb/jam.

Jumlah air yang dibutuhkan = 40695,1404 kg/batch = 44858,2533 lb/jam.

Menggunakan 2 buah cooler, masing-masing Qc = 7238909,91 btu/jam, rate gas CO_2 = 29394,6667 lb/jam, jumlah air yang dibutuhkan = 22429,1267 lb/jam.

2. ΔT LMTD



ΔT_1 = 676,3412 °F ΔT_2 = 239,6721 °F

$$\Delta T\ LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} = \frac{676{,}3412 - 239{,}6721}{\ln\left(\frac{676{,}3412}{239{,}6721}\right)} = 420{,}9159\ ^{\circ}F$$

$$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{846{,}9412 - 325{,}6721}{170{,}6 - 86} = 6{,}1616$$

$$S = \frac{t_2 - t_1}{T_1 - t_1} = \frac{170{,}6 - 86}{846{,}9412 - 86} = 0{,}1112$$

Dari fig. 19 Kern untuk 2-4 Exchanger mendapat : Ft = 0,99

ΔT = ΔT LMTD x Ft (Kern, hal 229)

ΔT = 420,9159 x 0,99

ΔT = 416,7067 °F

3. Suhu caloric

$$T_c = \frac{T_1 + T_2}{2} = \frac{846,9412 - 325,6721}{2} = 586,3067\ ^\circ F$$

$$t_c = \frac{t_1 + t_2}{2} = \frac{86 + 170,6}{2} = 128,3\ ^\circ F$$

Trial UD

Dari Kern table 8 memperoleh harga UD = 2-50 btu/j.ft^2.°F

UD trial = 40 btu/j.ft^2.°F

Asumsi :

1 in OD, 16 BWG, 1¼ in square pitch

L = 13 ft

a" = 0,2618 ft^2/lin.ft (Kern, table 10)

Q = UD x A x ΔT (Kern, hal 86)

$$A = \frac{Q}{UD \times \Delta T} = \frac{7238909,91\ \text{btu/jam}}{40\ \text{btu/j.ft}^2.^\circ F \times 416,7067^\circ F} = 434,2929\ ft^2$$

A = Nt x a" x L

434,2929 = Nt x 0,2618 x 13

Nt perhitungan = 127,6056 tube

Dari table 9 memperoleh : ID shell = 19¼ inch

Nt = 128 tube

Digunakan HE 2-4

$$\text{UD koreksi} = \frac{\text{Nt perhitungan}}{\text{Nt}} \times \text{UD trial}$$

$$= \frac{127{,}6056}{128} \times 40$$

$$= 39{,}87$$

Kesimpulan sementara rancangan HE :

Type HE = 2-4

Shell	Tube
IDs = 19¼ in	Nt = 128
B = $\frac{19\frac{1}{4}}{5}$ = 3,85 in	Panjang = 13 ft
Passes = 2	OD = 1 in
	BWG = 16
	Pitch = 1¼ in
	Susunan = square pitch
	Passes = 4

Shell side (Gas CO_2, Fluida Panas)	Tube side (Air,Fluida Dingin)
4. $a_s = \frac{ID \times C' \times B}{144 \times Pt \times n}$ (Kern, pers 7.1) $B = ID/5 = \frac{19\frac{1}{4}}{5} = 3{,}85$ in $a_s = \frac{19\frac{1}{4} \times \frac{1}{4} \times 3{,}85}{144 \times 1{,}25 \times 2} = 0{,}0515\ ft^2$ 5. Gs = 29394,6667 / 0,0515	4. Flow area, a't =0,594 (table 10) $a_s = \frac{Nt \times a't}{144 \times n}$ $a_s = \frac{128 \times 0{,}594}{144 \times 4} = 0{,}132\ ft^2$ 5. Gt = 22429,1267 / 0,132 = 169917,6265 lb/j.ft^2

$= 570770{,}2272 \text{ lb/j.ft}^2$

6. Pada Ta = 586,3067°F maka didapat :

μ campuran = 0,0275 lb/ft.j (fig.15)

De = 0,99 in / 12 = 0,0825 ft (fig. 28)

$$Res = \frac{De \times Gs}{\mu \times 2{,}42}$$

$$= \frac{0{,}0825 \times 570770{,}2272}{0{,}025 \times 2{,}42}$$

$$= 778323{,}037$$

7. j_H = 580 (Kern fig. 28)

8. Pada Ta = 586,3067°F, didapat :

k campuran = 0,0232 btu/hr.ft².°F (table 5)

Cp campuran = 0,34 btu/lb.°F (Kern, fig. 3)

$$\left(\frac{Cp \times \mu}{k}\right)^{\frac{1}{3}} = \left(\frac{0{,}34 \times 0{,}0275}{0{,}0232}\right)^{\frac{1}{3}}$$

$$\left(\frac{Cp \times \mu}{k}\right)^{\frac{1}{3}} = 0{,}7387$$

9. $$ho = j_H \text{ x } \frac{k}{De} \times \left(\frac{Cp \times \mu}{k}\right)^{\frac{1}{3}}$$

$$= 580 \text{ x } \frac{0{,}0232}{0{,}0825} \text{ x } 0{,}7387$$

$$= 120{,}4842 \text{ btu/hr.ft}^2.^{\circ}F$$

6. Pada ta = 128,3°F. maka didapat:

μ air = 0,55 cps = 1,331 lb/ft.j (fig.14)

D = Diameter dalam tube (tabel 10) /12

D = 0,87 /12 = 0,0725 ft

$$Ret = \frac{D \times Gt}{\mu \times 2{,}42}$$

$$= \frac{0{,}0725 \times 169917{,}6265}{1{,}1331 \times 2{,}42}$$

$$= 4492{,}5491$$

7. $$v = \frac{Gt}{3600 \text{ x } \rho}$$

$$= \frac{169917{,}6265}{3600 \text{ x } 62{,}5}$$

$$= 0{,}7552 \text{ fps} \approx 1 \text{ fps}$$

8. hi = 380 Btu/j.ft² (°F/ft) (Kern ,fig.25)

9. $$hio = hi \text{ x } \frac{ID}{OD} = 380 \text{ x } \frac{0{,}870}{1}$$

hio = 330,6

10. $Uc = \dfrac{hio \times ho}{hio + ho} = \dfrac{330{,}6 \times 120{,}4842}{330{,}6 + 120{,}4842} = 88{,}3030$ btu/hr.ft^2.°F

11. $Rd = \dfrac{Uc - Ud}{Uc \times Ud} = \dfrac{88{,}3030 - 39{,}87}{88{,}3030 \times 39{,}87} = 0{,}0138 > 0{,}003$ (memenuhi)

Pressure drop

Shell Side	Tube Side
1. Res = 778323,037 f = 0,0009 (Kern, fig 29) 2. $D_s = \dfrac{19\frac{1}{4}}{12} = 1{,}6042$ ft s = 1,26 (Kern, hal 808) $N + 1 = 12\dfrac{L}{B} = 12 \times \dfrac{13}{3{,}85} = 40{,}52$ $\Delta Ps = \dfrac{f \times G_s^{\,2} \times D_s \times (N+1)}{5{,}22 \times 10^{10} \times D_e s}$ (Pers. 7.45) $= \dfrac{0{,}0009 \times (570770{,}2272^2) \times 1{,}6042 \times 40{,}52}{5{,}22 \times 10^{10} \times (0{,}99/12) \times 1{,}6042}$ = 2,7587 psi <10 psi (memenuhi)	1. Ret = 4492,5491 f = 0,00035 (Kern, fig 26) 2. $\Delta Pt = \dfrac{f \times G_t^{\,2} \times Ln}{5{,}22 \times 10^{10} \times Ds}$ (Pers 7.45) $= \dfrac{0{,}00035 \times 169917{,}6265^2 \times 13 \times 4}{5{,}22 \times 10^{10} \times (0{,}87/12)}$ = 0,1388 psi 3. $\Delta Pn = \left(\dfrac{4n}{s}\right) \times \left(\dfrac{V^2}{2g}\right)$ (Pers 7.46) $\left(\dfrac{V^2}{2g}\right)$ (Kern, fig 27) $\Delta Pn = \left(\dfrac{4 \times 4}{1}\right) \times 0{,}0038$ ΔPn = 0,0608 psi ΔPT = ΔPt + ΔPτ ΔPT = 0,1388 + 0,0608 ΔPT = 0,1996 psi < 10 psi (memenuhi)

Compresor II (K-128)

Fungsi : Mengalirkan tekanan CO_2 ke tangki penampungan CO_2 (F-121) dari 100 bar menjadi 20 bar, dari 10 bar menjadi 20 bar

Tipe : Single stage compressor

Dasar pemilihan : Mampu beroperasi pada tekanan yang sangat tinggi

Kondisi Operasi : P = 20 bar

Dari perhitungan neraca panas di compresor II menghasilkan kerja kompresor (Ws) = 6149540,4126 kJ/batch = 763,5635 hp

Tangki Ekstraksi Superkritis (F-120)

Fungsi : Mengekstrak komponen-komponen minyak dalam biji jagung dengan menggunakan CO_2 superkritis

Bahan konstruksi : SA-240 grade C

Tipe : Vertical Supercritical Extractor dengan hemispherical head

Dasar pemilihan : Dapat beroperasi pada tekanan tinggi

Jumlah : 2 buah

Kapasitas : Umpan masuk ekstraktor = 10000 kg/batch = 3333,3333 kg/jam, CO_2 masuk ekstraktor = 80000 kg/batch untuk 2 jam operasi.

Kondisi operasi : T = 50 °C ; P = 200 bar

Densitas minyak jagung : 922,299 kg/m^3 = 57,5792 lb/ft^3

Waktu tinggal : 15 menit = $\frac{1}{4}$ jam

Volume biji jagung $= \dfrac{3333{,}3333\ \text{kg/jam}}{922{,}299\ \text{kg/m}^3} \times \dfrac{1}{4}\ \text{jam}$

$= 0{,}9035\ \text{m}^3$

Densitas CO_2 sebagai fluida superkritis = 500 kg/m^3 (Reverchon, 1997)

Volume CO_2 sebagai fluida superkritis = $\dfrac{1}{8}\ \text{jam} \times 60000\ \dfrac{\text{kg}}{\text{jam}} \times \dfrac{1}{500}\ \dfrac{\text{m}^3}{\text{kg}}$

$= 15\ \text{m}^3$

Volume ekstraktor CO_2 yang harus dirancang = (0,9035 +15)m^3

$= 15{,}9035\ \text{m}^3 \approx 20\ \text{m}^3$

Digunakan 2 buah ekstraktor, masing-masing volumenya 10 m^3 = 353,134 ft^3

Persamaan tangki silinder dengan hemispherical head

$$D = \left(\frac{4 \times v \times M_g}{\pi \times G}\right)^{\frac{1}{2}} \quad \text{(Ulrich,hal 199)}$$

Dimana : v = kecepatan gas masuk (mol/s)

M_g = berat molekul gas (mol)

G = superficial gas mass flux (kg/s.m^2)

$$v = \frac{80000}{44}\frac{mol}{batch} \times \frac{1}{2}\frac{batch}{jam} \times \frac{1}{3600}\frac{jam}{detik} = 0{,}2525\ \frac{mol}{detik}$$

$$G = 80000\ \frac{kg}{batch} \times \frac{1}{2}\frac{batch}{jam} \times \frac{1}{3600}\frac{jam}{detik} \times \frac{4}{\pi \times D^2}\frac{1}{m^2} = \frac{14{,}1471}{D^2}\frac{kg}{s.m^2}$$

$$D = \left(\frac{4 \times v \times M_g}{\pi \times G}\right)^{\frac{1}{2}}$$

$$D = \left(\frac{4 \times 0{,}2525 \times 44}{\pi \times \dfrac{14{,}1471}{D^2}}\right)^{\frac{1}{2}}$$

$$D = \sqrt{\left(\frac{0{,}9999}{D^2}\right)}$$

$$D = \frac{\sqrt{1}}{D}$$

$$D^2 = 1$$

$$D = 1\ m = 3{,}2808\ ft \approx 4\ ft$$

$$V = (0{,}25 \times \pi \times D^2 \times H) + 2\left[0{,}5 \times \left(\frac{1}{6}\right) \times \pi \times (D)^3\right]$$

$$353{,}134 = (0{,}7854 \times 16 \times H) + 2\ (0{,}5 \times \left(\frac{1}{6}\right) \times \pi \times 64)$$

$$353{,}134 = (12{,}5664 \times H) + 33{,}5103$$

$$319{,}6237 = 12{,}5664 \times H$$

$$Hs = 25{,}4348\ ft \approx 30\ ft$$

$$P_{ops} = \frac{r \times \rho_b \times (g/g_c) \times (1 - e^{(-2 \times \mu' \times K' \times Z_T)/r})}{2 \times \mu' \times K'}$$ (McCabe 4th ed; pers. 26. 24)

Dimana : r = diameter dalam tangki = D / 2

Z_T = tinggi padatan dalam tangki

ρ_b = bulk density

μ' = koefisien friksi (untuk granular solid, μ' = 0.35 – 0.55)

μ' = 0,4 (asumsi)

K' = ratio tekanan (untuk granular solid, K' = 0.35 – 0.6)

K' = 0,5 (asumsi)

$$P_{ops} = \frac{2 \times 57{,}5792 \times (32{,}174/32{,}174) \times (1 - e^{-2 \times 0{,}4 \times 0{,}5 \times 30)/2})}{2 \times 0{,}4 \times 0{,}5}$$

$$= 287{,}1824 \frac{lbf}{ft^2} = 1{,}9943 \frac{lb}{in^2}$$

= 1,9943 psia +14,696 psia = 16,6903 psia

P_{design} = 1,2 x P_{ops}

= 1,2 x 16,6903

$$= 20{,}0284 \frac{lb}{in^2}$$

Tebal shell :

$$t_{shell} = \frac{P_{design} \times D}{2 \times \{(f \times E) - (0{,}6 \times P_{design})\}} + c$$ (Brownell; pers. 13.1)

f = stress max yang diijinkan

= 18750 psi (Brownell; hal 251 untuk SA-240 grade C)

E = 0,8 (tabel 13.2 untuk double welded butt joint)

c = 0,1250 in (asumsi)

$$t_{shell} = \frac{20{,}0284 \text{ psi} \times 4 \text{ ft} \times 12 \frac{\text{in}}{\text{ft}}}{2 \times \{(18750 \text{ psi} \times 0{,}8) - (0{,}6 \times 20{,}0284 \text{ psi})\}} + 0{,}1250$$

t_{shell} = 0,1571 in

Tebal shell yang digunakan : $\frac{1}{5}$ in

Tebal head :

Tipe head : Hemispherical

Bahan : Stainless steel

$$t_h = \frac{P \times \text{Din}}{(4 \times f \times E) - (0{,}4 \times P)} + C \quad \text{(Brownell, hal 140)}$$

$$= \frac{20{,}0284 \text{ psi} \times 4 \text{ ft} \times 12 \frac{\text{in}}{\text{ft}}}{(4 \times 18750 \times 0{,}8) - (0{,}4 \times 20{,}0284)} + 0{,}1250$$

$$= 0{,}1410 \text{ in}$$

Tebal head yang digunakan : $\frac{1}{5}$ in

Tinggi head :

Untuk tebal head $\frac{1}{5}$ in, direncanakan Sf = 2 in (Brownell; hal 96)

$H_h = t_h + Sf + D/2$

$= \frac{1}{5} + 2 + (4x12) / 2$

$= 26,2$ in $\approx 2,1833$ ft

Tinggi tangki :

$H = 2 \times H_h + H_s$

$= 2 \times 2,1833 + 30$

$= 34,3666$ ft

Tangki Separator I (F-125)

Fungsi	: Memisahkan minyak dan air dari CO_2
Bahan konstruksi	: SA-240 grade C
Tipe	: Vertical drum
Dasar pemilihan	: Cocok untuk memisahkan berdasarkan perbedaan volatilitas
Kondisi operasi	: T = 40,5 °C ; P = 100 bar
Waktu tinggal	: $\frac{1}{2}$ jam
Kapasitas	: Minyak jagung = 1036,3427 kg/batch = 345,4476 kg/jam, Gas CO_2 = 80000 kg/batch = 40000 kg/jam untuk 2 jam operasi.

Densitas minyak jagung : 922,299 kg/m^3 = 57,5792 lb/ft^3

Volume minyak jagung $= \dfrac{345,4476\ \text{kg/jam}}{922,299\ \text{kg/m}^3} \times \dfrac{1}{2}\ \text{jam}$

$= 0,1873\ \text{m}^3$

Diketahui data CO_2 : $\omega = 0,2240$

$Pc = 73,83$ bar ; $Tc = 304,2$ K ,

$Pr = \dfrac{100}{73,83} = 1,3545$; $Tr = \dfrac{313,5}{304,2} = 1,0306$

$B^0 = 0,083 - \dfrac{0,422}{Tr^{1,6}} = 0,083 - \dfrac{0,422}{1,0306^{1,6}} = -0,3191$

$B^1 = 0,139 - \dfrac{0,172}{Tr^{4,2}} = 0,139 - \dfrac{0,172}{1,0306^{4,2}} = -0,0126$

$Z^0 = 1 + B^0 \dfrac{Pr}{Tr} = 1 + (-0,3191 \times (1,3545/1,0306))$

$Z^0 = 0,5805$

$Z^1 = B^1 \dfrac{Pr}{Tr} = -0,0126 \times (1,3545/1,0306)$

$Z^1 = -0,0165$

$Z = Z^0 + \omega Z^1 = 0,5805 + (0,2240 \times (-0,0165))$

$Z = 0,5768$

Densitas CO_2 $= \dfrac{P \times BM}{Z \times RT} = \dfrac{100\ \text{bar} \times 44\ \dfrac{\text{gr}}{\text{mol}}}{0,5768 \times 83,14\ \dfrac{\text{bar} \times \text{cm}^3}{\text{mol} \times \text{K}} \times 313,5\ \text{K}}$

$= 0,2926\ \dfrac{\text{gr}}{\text{cm}^3} = 292,6464\ \dfrac{\text{kg}}{\text{m}^3}$

Volume CO_2 $= \frac{1}{4}\text{jam} \times 40000\ \frac{\text{kg}}{\text{jam}} \times \frac{1}{292{,}6464}\frac{\text{m}^3}{\text{kg}}$

$= 34{,}1709\ \text{m}^3$

Volume minyak + CO_2 = (0,1873 + 34,1709)m^3

$= 34{,}3582\ \text{m}^3 \approx 35\ \text{m}^3 = 1235{,}969\ \text{ft}^3$

Asumsi : Tangki berisi 80% (minyak + CO_2) , maka

Volume tangki = Volume (minyak + CO_2) x $\frac{100}{80}$

$= 1235{,}969 \times \frac{100}{80}$

$= 1544{,}9613\ \text{ft}^3$

Asumsi : H = 2 D

$$V\ \text{tangki} = (0{,}25 \times \pi \times D^2 \times H) + 2\left[0{,}5 \times \left(\frac{1}{6}\right) \times \pi \times (D)^3\right]$$

$1544{,}9613 = (0{,}7854 \times D^2 \times 2D) + 2\ (0{,}2618 \times D^3)$

$1544{,}9613 = (0{,}7854 \times 2D^3) + (0{,}5236 \times 2D^3)$

$1544{,}9613 = 1{,}309 \times 2D^3$

$D^3 = 590{,}1303$

$D = 8{,}3878\ \text{ft} \approx 9\ \text{ft}$

H = 2 D

H = 2 x 9 = 18 ft

$$P\ operasi = (100\ \times 14{,}696\ psia) + \left(\frac{\rho \times h \times \frac{g}{gc}}{144}\right) psia$$

$$= 1469{,}6\ psia + \left(\frac{57{,}5792 \times 14 \times \frac{32{,}174}{32{,}1740}}{144}\right) psia$$

P operasi = 1476,7974 psia

P design = 1,2 x P operasi

= 1,2 x 1476,7974

P design = 1772,1569 psia

Tebal shell :

$$t_{shell} = \frac{P_{design}\ x\ D}{2\ x\ \{(f\ x\ E) - (0{,}6\ x\ P_{design})\}} + c \quad \text{(Brownell; pers. 13.1)}$$

f = stress max yang diijinkan

= 18750 psi (Brownell; hal 251 untuk SA-240 grade C)

E = 0,8 (tabel 13.2 untuk double welded butt joint)

c = 0,1250 in (asumsi)

$$t_{shell} = \frac{1772{,}1569\ psi\ x\ 9\ ft\ x\ 12\ \frac{in}{ft}}{2\ x\ \{(18750\ psi\ x\ 0{,}8) - (0{,}6\ x\ 1772{,}1569\ psi)\}} + 0{,}1250$$

t_{shell} = 6,9915 in = 0,1776 m

<u>Tebal head :</u>

Tipe head : Hemispherical

Bahan : Stainless steel

- Untuk head bagian atas

$$t_h = \frac{P \times D}{(4 \times f \times E) - (0{,}4 \times P)} + C \quad \text{(Brownell, hal 140)}$$

$$= \frac{1772{,}1569 \text{ psi} \times 9 \text{ ft} \times 12 \frac{\text{in}}{\text{ft}}}{(4 \times 18750 \times 0{,}8) - (0{,}4 \times 1772{,}1569)} + 0{,}1250$$

= 3,3530 in = 0,0852 m

- Untuk head bagian bawah

$$t_h = \frac{P \times D}{(4 \times f \times E) - (0{,}4 \times P)} + C \quad \text{(Brownell, hal 140)}$$

$$= \frac{1772{,}1569 \text{ psi} \times 9 \text{ ft} \times 12 \frac{\text{in}}{\text{ft}}}{(4 \times 18750 \times 0{,}8) - (0{,}4 \times 1772{,}1569)} + 0{,}1250$$

= 3,3530 in = 0,0852 m

<u>Tinggi head :</u>

Untuk tebal head 3,3530 in, direncanakan Sf = 2 in (Brownell; hal 96)

$H_h = t_h + Sf + D/2$

= 3,3530 + 2 + (9x12) / 2

= 59,3530 in ≈ 4,9460 ft

Tinggi tangki :

$H = 2 \times H_h + H_s$

$= 2 \times 4{,}9460 + 18$

$= 27{,}8920 \text{ ft} = 8{,}5016 \text{ m}$

Tangki Separator II (F-127)

Fungsi	: Memisahkan minyak dan air dari CO_2
Bahan konstruksi	: SA-240 grade C
Tipe	: Vertical drum
Dasar pemilihan	: Cocok untuk memisahkan berdasarkan perbedaan volatilitas
Kondisi operasi	: T = 30,9441 °C ; P = 10 bar
Waktu tinggal	: $\frac{1}{2}$ jam
Kapasitas	: Minyak jagung = 845,0166 kg/batch = 281,6722 kg/jam Gas CO_2 = 450,2315 kg/batch = 225,1158 kg/jam untuk 2 jam operasi.

Dengan perhitungan yang sama dari tangki separator I (F-125), maka mendapatkan:

$D = 4{,}0705 \text{ ft} \approx 5 \text{ ft}$

$H = 2\,D$

$H = 2 \times 5 = 10 \text{ ft}$

P_{ops} = 150,9586 psia

P_{design} = 181,1503 psia

Tebal shell = 0,4899 in $\approx \frac{1}{2}$ in

Tebal head = 0,3064 in ≈ 0,3 in

Tinggi head = 32,2 in = 2,6833 ft

Tinggi tangki = 15,3666 ft

Tangki Penampungan Sementara (F-132)

Fungsi	: Menampung minyak jagung sebelum dibawa ke tangki pemucat
Bahan konstruks	: SA-240 grade C
Tipe	: Silinder tegak dengan tutup atas berbentuk hemispherical head dan tutup bawah berbentuk flat
Dasar pemilihan	: Cocok untuk menampung bahan
Kondisi operasi	: T = 30 °C ; P = 1,3 bar
Waktu tinggal	: 7 jam
Kapasitas	: Minyak jagung = 643,9264 kg/batch = 214,6421 kg/jam

Densitas minyak jagung : 922,299 kg/m³ = 57,5792 lb/ft³

$$\text{Volume minyak jagung dalam t.p.s} = \frac{214{,}6421\ \text{kg/jam}}{922{,}299\ \text{kg/m}^3} \times 7\text{jam}$$

$= 1{,}6291\ m^3$

Asumsi : Tangki berisi 80% cairan, maka :

$$\text{Volume t.p.s} = \text{Volume minyak jagung dalam t.p.s} \times \frac{100}{80}$$

$$= 1{,}6921\ m^3 \times \frac{100}{80}$$

$$= 2{,}0363\ m^3$$

Asumsi : H = 1 D

$$\text{Volume t.p.s} = \left(\frac{\pi}{4} \times D^2 \times H\right) + \left[0{,}5 \times \left(\frac{1}{6}\right) \times \pi \times (D)^3\right]$$

$$2{,}0363 = \left(\frac{\pi}{4} \times D^2 \times D\right) + \left[0{,}5 \times \left(\frac{1}{6}\right) \times \pi \times (D)^3\right]$$

$$2{,}0363 = 1{,}0472 \times D^3$$

$$D^3 = 1{,}9446\ m$$

$$D = 1{,}2482\ m = 4{,}0950\ ft \approx 5\ ft$$

H = D

H = 5 ft

$$P\ \text{operasi} = (1{,}3 \times 14{,}696\ \text{psia}) + \left(\frac{\rho \times h \times \frac{g}{gc}}{144}\right) \text{psia}$$

$$= 19{,}1048 \text{ psia} + \left(\frac{57{,}5792 \times 5 \times \dfrac{32{,}174}{32{,}1740}}{144} \right) \text{psia}$$

P operasi = 21,1041 psia

P design = 1,2 x P operasi

= 1,2 x 21,1041

P design = 25,3249 psia

Tebal shell :

$$t_{shell} = \frac{P_{design} \times D}{2 \times \{(f \times E) - (0{,}6 \times P_{design})\}} + c \quad \text{(Brownell; pers. 13.1)}$$

f = stress max yang diijinkan

= 18750 psi (Brownell; hal 251 untuk SA-240 grade C)

E = 0,8 (tabel 13.2 untuk double welded butt joint)

c = 0,1250 in (asumsi)

$$t_{shell} = \frac{25{,}3249 \text{ psi} \times 5 \text{ ft} \times 12 \dfrac{\text{in}}{\text{ft}}}{2 \times \{(18750 \text{ psi} \times 0{,}8) - (0{,}6 \times 25{,}3249 \text{ psi})\}} + 0{,}1250$$

t_{shell} = 0,1757 in

Tebal head :

Tipe head : Hemispherical

Bahan : Stainless steel

- Untuk head bagian atas

$$t_h = \frac{P \times D}{(4 \times f \times E) - (0{,}4 \times P)} + C \quad \text{(Brownell, hal 140)}$$

$$= \frac{21{,}1041 \text{ psi} \times 5 \text{ ft} \times 12 \frac{\text{in}}{\text{ft}}}{(4 \times 18750 \times 0{,}8) - (0{,}4 \times 21{,}1041)} + 0{,}1250$$

$$= 0{,}1503 \text{ in } \frac{1}{5} \text{ in}$$

- Untuk head bagian bawah

$$t_h = \frac{P \times D}{(4 \times f \times E) - (0{,}4 \times P)} + C \quad \text{(Brownell, hal 140)}$$

$$= \frac{21{,}1041 \text{ psi} \times 5 \text{ ft} \times 12 \frac{\text{in}}{\text{ft}}}{(4 \times 18750 \times 0{,}8) - (0{,}4 \times 21{,}1041)} + 0{,}1250$$

$$= 0{,}1503 \text{ in} \approx \frac{1}{5} \text{ in}$$

Tinggi head :

Untuk tebal head $\frac{1}{5}$ in, direncanakan Sf = 2 in (Brownell; hal 96)

$H_h = t_h + Sf + D/2$

$= \frac{1}{5} + 2 + (5 \times 12) / 2$

$= 32{,}2$ in $= 2{,}6833$ ft

Tinggi tangki :

$H = H_h + H_s$

= 2,6833 + 5

= 7,6833 ft = 2,3419 m

Heater I (E-133)

Fungsi : Menaikan suhu dari 30 °C ke 100 °C untuk menyesuaikan dengan kondisi tangki pemucat (F-130)

Tipe : Shell and Tube Heat Exchanger

Bahan Konstruksi : Stainless steel

Cara perhitungan mengambil dari Kern, 1965

Perhitungan:

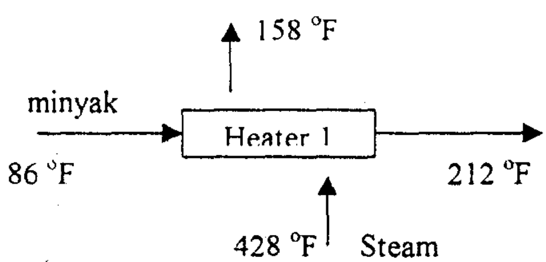
1) Dari neraca panas memperoleh :

   Qc = 115072,0519 kJ/batch = 36355,6107 btu/jam.

   Kapasitas minyak jagung = 643,9264 kg/batch = 473,2043 lb/jam.

   Jumlah steam yang dibutuhkan = 52,2509 kg/batch = 38,3978 lb/jam.

2) ΔT LMTD



Fluida Panas		Fluida Dingin	Beda Suhu
428 °F	Suhu tinggi	212 °F	216 °F
158 °F	Suhu rendah	86 °F	72 °F
270 °F	Beda suhu	126 °F	144 °F

$$\Delta T\ LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} = \frac{216 - 72}{\ln\left(\frac{216}{72}\right)} = 131{,}0744\ ^{o}F$$

$$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{270}{126} = 2{,}1428$$

$$S = \frac{t_2 - t_1}{T_1 - t_1} = \frac{126}{428 - 86} = 0{,}3684$$

Dari fig. 19 Kern untuk 2-4 Exchanger mendapat : Ft = 0,8

$\Delta T = \Delta T$ LMTD x Ft (Kern, hal 229)

$\Delta T = 131{,}0744 \times 0{,}8$

$\Delta T = 104{,}8595\ ^{o}F$

3) Suhu caloric

$$T_c = \frac{T_1 + T_2}{2} = 293\ ^{o}F$$

$$t_c = \frac{t_1 + t_2}{2} = \frac{212 + 86}{2} = 149^{o}F$$

Trial UD

Dari Kern table 8 memperoleh harga UD = 50-100 btu/j.ft^2.°F (untuk sistem steam-medium organic)

UD trial = 50 btu/j.ft^2.°F

Asumsi :

1 in OD, 16 BWG, 1¼ in square pitch

L = 5 ft

a" = 0,2618 ft^2/lin.ft (Kern, table 10)

Q = UD x A x ΔT (Kern, hal 86)

$$A = \frac{Q}{UD \times \Delta T} = \frac{36355{,}6107 \text{ btu/jam}}{50 \text{ btu/j.ft}^2.^\circ F \times 104{,}8595\ ^\circ F} = 17{,}4999 \text{ ft}^2$$

A = Nt x a" x L

17,4999 = Nt x 0,2618 x 5

Nt perhitungan = 13,3689 tube

Dari table 9 memperoleh : ID shell = 8 inch

Nt = 14 tube

Menggunakan HE 2-4

$$\text{UD koreksi} = \frac{\text{Nt perhitungan}}{\text{Nt}} \times \text{UD trial}$$

$$= \frac{13{,}3689}{14} \times 50$$

$$= 47{,}7461$$

Kesimpulan sementara rancangan HE :

Type HE = 2-4

Shell Tube

IDs = 8 in

$B = \frac{8}{5} = 1{,}6$ in

Passes = 2

Nt = 14 tube

Panjang = 5 ft

OD = 1 in

BWG = 16

Pitch = 1¼ in

Susunan = square pitch

Passes = 4

Shell side (Fluida Panas)	Tube side (Fluida Dingin)
4. $a_s = \frac{ID \times C' \times B}{144 \times Pt \times n}$ (Kern, pers 7.1) B = 1,6 in $a_s = \frac{8 \times {}^{1}\!/_{4} \times 1{,}6}{144 \times 1{,}25 \times 2} = 0{,}0178\ ft^2$ 5. Gs = 38,3978 / 0,0178 = 2157,1798 lb/j.ft² 6. Pada Ta = 203°F maka mendapat : μ (fig.14) = 1,35 lb/ft.j De = 0,99 in / 12 = 0,0825 ft (fig. 28) $Res = \frac{De \times Gs}{\mu \times 2{,}42}$ $= \frac{0{,}0825 \times 2157{,}1798}{1{,}35 \times 2{,}42}$	4. Flow area, a't =0,594 (table 10) $a_s = \frac{Nt \times a't}{144 \times n}$ $a_s = \frac{14 \times 0{,}594}{144 \times 4} = 0{,}0144\ ft^2$ 5. Gt = 473,2043 / 0,0144 = 32861,4097 lb/j.ft² 6. Pada ta = 149°F maka mendapat: μ = 4,5358 lb/ft.j D = Diameter dalam tube (tabel 10) /12 D = 0,87 /12 = 0,0725 ft $Ret = \frac{D \times Gt}{\mu \times 2{,}42}$ $= \frac{0{,}0725 \times 32861{,}4097}{4{,}5358 \times 2{,}42}$ = 217,0476

$= 544{,}7420$ 7. $j_H = 12$ (Kern fig. 28) 8. Pada Ta = 203°F, mendapat : k (tabel 4) = 0,3363 btu/hr.ft².°F Cp = 1 btu/lb.°F (Kern, fig. 2) $\left(\frac{Cp \times \mu}{k}\right)^{\frac{1}{3}} = \left(\frac{1 \times 1{,}35}{0{,}3363}\right)^{\frac{1}{3}}$ $\left(\frac{Cp \times \mu}{k}\right)^{\frac{1}{3}} = 1{,}5893$ 9. $ho = j_H \times \frac{k}{De} \times \left(\frac{Cp \times \mu}{k}\right)^{\frac{1}{3}}$ $= 12 \times \frac{0{,}3363}{0{,}0825} \times 1{,}5893$ $= 77{,}7428$ btu/hr.ft².°F	7. $j_H = 4$ (Kern fig. 24) 8. Pada Ta = 149°F, mendapat : k (tabel 5) = 0,712 btu/hr.ft².°F Cp = 0,6098 btu/lb.°F $\left(\frac{Cp \times \mu}{k}\right)^{\frac{1}{3}} = \left(\frac{0{,}6098 \times 4{,}5358}{0{,}712}\right)^{\frac{1}{3}}$ $\left(\frac{Cp \times \mu}{k}\right)^{\frac{1}{3}} = 1{,}572$ 9. $hi = j_H \times \frac{k}{De} \times \left(\frac{Cp \times \mu}{k}\right)^{\frac{1}{3}}$ $= 4 \times \frac{0{,}712}{0{,}0825} \times 1{,}572$ $= 61{,}7525$ btu/hr.ft².°F 10. $hio = hi \times \frac{ID}{OD}$ $= 61{,}7525 \times 8 = 494{,}02$

12. $Uc = \frac{hio \times ho}{hio + ho} = \frac{494{,}02 \times 77{,}7428}{494{,}02 + 77{,}7428} = 67{,}1721$ btu/hr.ft².°F

13. $Rd = \frac{Uc - Ud}{Uc \times Ud} = \frac{67{,}1721 - 47{,}7461}{67{,}1721 \times 47{,}7461} = 0{,}006 > 0{,}003$ (memenuhi)

Pressure drop

Shell Side	Tube Side
1. Res = 544,7420 f = 0,0035 (Kern, fig 29)	1. Ret = 217,0476 f = 0,0025 (Kern, fig 26)

<table>
<tr>
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2. $D_s = \dfrac{8}{12} = 0,67$ ft

s = 1,26 (Kern, hal 808)

$N + 1 = 12\ \dfrac{L}{B} = 12 \times \dfrac{5}{1,6} = 37,5$

$\Delta Ps = \dfrac{f \times G_s^{\,2} \times D_s \times (N+1)}{5,22 \times 10^{10} \times D_e s}$

(Pers. 7.45)

$= \dfrac{0,0035 \times \left(2157,1798^{2}\right) \times 0,67 \times 37,5}{5,22 \times 10^{10} \times (0,99/12) \times 0,67}$

= 0,1418 psi <10 psi (memenuhi)

</td>
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2. $\Delta Pt = \dfrac{f \times G_t^{\,2} \times Ln}{5,22 \times 10^{10} \times Ds}$

(Pers 7.45)

$= \dfrac{0,0025 \times 32861,4097^{2} \times 5 \times 4}{5,22 \times 10^{10} \times (0,8/12)}$

= 1,5515 psi

3. $\Delta Pn = \left(\dfrac{4n}{s}\right) \times \left(\dfrac{V^2}{2g}\right)$ (Pers 7.46)

$\left(\dfrac{V^2}{2g}\right)$ (Kern, fig 27)

$\Delta Pn = \left(\dfrac{4 \times 4}{1}\right) \times 0,001$

$\Delta Pn = 0,016$ psi

$\Delta PT = \Delta Pt + \Delta Pn$

$\Delta PT = 1,5515 + 0,016$

$\Delta PT = 1,5675$ psi < 10 psi

(memenuhi)

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Tangki Pemucat (F-130)

Fungsi : Untuk memucatkan warna minyak.

Tipe : Silinder tegak dengan tutup atas berbentuk dished head dan tutup bawah berbentuk konis yang dilengkapi batang pengaduk.

Dasar pemilihan : Mudah dalam pengeluaran

Kondisi operasi : T = 80 °C , P = 1,3 bar

Kapasitas : Minyak jagung = 643,9264 kg/batch = 64,3926 kg/menit

Bleaching earth = 5,7915 kg/batch = 0,5792 kg/menit

Karbon aktif = 0,6435 kg/batch = 0,0644 kg/menit

Densitas masuk rata-rata :

Komponen	Massa (kg/menit)	Fraksi (x)	Densitas (kg/m3)	x/densitas (m3/kg)
Bleaching earth	0,5792	0,008905	2610	3,4119E-06
Karbon aktif	0,0644	0,0009894	2000	4,94725E-07
Minyak jagung	64,3926	0,9901055	922,299	0,001073519
	65,0361		TOTAL	0,001077426

$$\rho \text{ campuran} = \frac{1}{0,0010774266} = 928,1383 \text{ kg/m}^3 = 57,9442 \text{ lb/ft}^3$$

Waktu tinggal = 30 menit (Bernardini, 1983, p.177)

$$\text{Volume slurry} = \frac{65,0361 \text{ kg/menit}}{928,1383 \text{ kg/m}^3} \times 30 \text{ menit} = 2,1021 \text{ m}^3 = 74,2340 \text{ ft}^3$$

$$\text{Volume tangki pemucat} = \text{volume cairan x } \frac{100}{80}$$

$$= 2,1021 \text{ m}^3 \text{ x } \frac{100}{80}$$

$$= 2,6277 \text{ m}^3 = 92,7925 \text{ ft}^3$$

Volume tangki pemucat = volume shell + volume konis

$$\text{Volume shell} = \frac{\pi}{4} \text{x } D^2 \text{ x H}$$

$$\text{Volume konis} = \left(\frac{1}{3} \times \frac{\pi}{4} \times D^2 \times H\right) - \left(\frac{1}{3} \times \frac{\pi}{4} \times Dn^2 \times Hn\right)$$

$$= \left(\frac{1}{3}\times\frac{\pi}{4}\times D^2\times\frac{D}{2\,tg\alpha}\right)-\left(\frac{1}{3}\times\frac{\pi}{4}\times Dn^2\times\frac{Dn}{2\,tg\alpha}\right)$$

$$= \frac{\pi}{24\times tg\,\alpha}\,(D^3\text{-}Dn^3)\quad \text{(Brownel, pers. 5.14)}$$

dimana : D_n = diameter lubang pengeluaran cairan

D = diameter konis bagian atas = diameter shell

H_t = tinggi konis

H_n = tinggi konis terpancung

Asumsi : $H_{shell} = D_{shell}$ (Ulrich, tabel 4-27)

$\alpha = 30\,^{o}$

Volume tangki pemucat = $(\frac{\pi}{4}\times D^2\times H) + (\frac{\pi}{24\times tg\,\alpha}(D^3\text{-}Dn^3))$

$92,7925\ ft^3 \quad = 1,0121 \times D^3$

$D^3 \quad = 91,6831$ ft

$D \quad = 4,5092\ ft \approx 4,5\ ft = 54$ in

$$q_f = \frac{65,0361\ kg/menit}{928,1383\ kg/m^3}\times\frac{1\ menit}{60\ detik} = 0,0012\ m^3/detik = 0,0412\ ft^3/detik$$

Di opt = $3,9 \times q_f^{\,0,45} \times \rho_m^{\,0.13}$ (Peter, hal 496)

$$Di\ opt = 3,9\times(0,0412\frac{ft^3}{s})^{0,45}\times(57,9442\frac{lb}{ft^3})^{0.13} = 1,5745\ in$$

Memilih pipa dengan diameter 2" sch 80, dari Geankoplis App A.5. didapat Di = 1,9390 in

$$N_{Re} = \frac{Di.v.\rho}{\mu} = \frac{q_f.\rho}{\pi.\mu.Di} = \frac{0{,}0412\ ft^3/s \times 57{,}9442\ lb/ft^3}{3{,}14 \times 0{,}00126\ lb/ft.s \times 0{,}1616\ ft}$$

N_{Re} = 3733,9254 (laminar)

Jadi lubang pengeluaran liquid (D_n) = 1,9390 in = 0,1616 ft

Volume cairan dalam konis = $\frac{\pi}{24 \times tg\ 30^o}(4{,}5^3 - 0{,}1616^3) = 20{,}6471\ ft^3$

Volume cairan dalam shell = $(74{,}2340 - 20{,}6471) ft^3 = 53{,}5869\ ft^3$

Tinggi cairan dalam shell (H_s) = $\frac{53{,}5869}{0{,}25 \times 3{,}14 \times 4{,}5^2} = 3{,}3710\ ft \approx 3{,}5\ ft$

Tinggi konis terpancung (H_n) = $\frac{D}{2 \times tg\alpha} - \frac{D_n}{2 \times tg\alpha} = \frac{4{,}5}{2 \times tg30^o} - \frac{0{,}1616}{2 \times tg30^o}$

$= 3{,}7569\ ft$

Tinggi cairan dalam tangki $= H_s + H_n = (3{,}5 + 3{,}7569)\ ft = 7{,}2569\ ft$

$$P\ operasi = \left(1{,}3\ bar \times \frac{14{,}696\ psia}{1\ bar}\right) + \left(\frac{\rho \times H \times \frac{g}{gc}}{144}\right)$$

$$P\ operasi = 19{,}1048 + \left(\frac{57{,}9442 \times 7{,}2569 \times \frac{32{,}174}{32{,}1740}}{144}\right)$$

P operasi = 22,0249 psia

P design = 1,2 × P operasi = 1,2 × 22,0249 = 26,4299 psia

Tebal shell :

$$t_s = \frac{P_{design} \times D}{2 \times (f \times E - 0,6 \times P_{design})} + c \qquad \text{(Brownell, pers. 13.1)}$$

$$t_s = \frac{26,1561 \times 4,5 ft \times 12 \frac{in}{ft}}{2 \times (18750 \times 0,8 - 0,6 \times 24299)} + 0,125 = 0,1726 \text{ in} = 3/16"$$

OD = ID + (2 x t_s) = 54 + (2 x 3/16") = 54,3750 in

Dari Brownell and Young, 1959, tabel 5.7 memperoleh OD standar = 60 in

ID = OD – 2 × t_s = 60 – (2 × 3/16") = 59,6250 in = 4,9688 ft

$$\text{Volume cairan dalam konis} = \frac{\pi}{24 \times tg\, 30^o}(5^3 - 0,1616^3) = 28,3229 \text{ ft}^3$$

Volume cairan dalam shell = (74,2340 – 28,3229)ft^3 = 45,9111 ft^3

$$\text{Tinggi cairan dalam shell } (H_s) = \frac{45,9111}{0,25 \times 3,14 \times 5^2} = 2,3394 \text{ ft} \approx 2,5 \text{ ft}$$

$$\text{Tinggi konis terpancung } (H_n) = \frac{D}{2 \times tg\alpha} - \frac{D_n}{2 \times tg\alpha} = \frac{5}{2 \times tg30^o} - \frac{0,1616}{2 \times tg30^o}$$

$$= 4,1898 \text{ ft}$$

Tinggi cairan dalam tangki $= H_s + H_n = (2,5 + 4,1898)$ ft = 6,6898 ft

$$\text{P operasi} = \left(1,3 \text{ bar} \times \frac{14,696 \text{ psia}}{1 \text{ bar}}\right) + \left(\frac{\rho \times H \times \frac{g}{gc}}{144}\right)$$

$$P\ operasi = 19{,}1048 + \left(\frac{57{,}94 \times 6{,}6898 \times \dfrac{32{,}174}{32{,}1740}}{144} \right)$$

P operasi = 21,7967 psia

P design = 1,2 × P operasi = 1,2 × 21,7967 = 26,1561 psia

Tebal dish (torispherical dished head)

t_s = 3/16"

Dari table 5.7 B& Y memperoleh OD standart = 60, r (crown rádius of dish) = 60 in dan icr (inside corner radius knucle radius) = 3 5/8 in.

$$W = \frac{1}{4} \times \left(3 + \sqrt{\frac{rc}{icr}} \right) \quad \text{(Brownell, pers. 7.76)}$$

$$W = \frac{1}{4} \times \left(3 + \sqrt{\frac{60}{3{,}625}} \right) = 1{,}7671$$

A = ID/2 = 59,6250 /2 = 29,8125 in

AB = ID/2 – icr = 26,1875 in

BC = r – icr = 56,3750 in

$$b = r - \sqrt{(BC)^2 - (AB)^2} = 60 - \sqrt{(56{,}3750)^2 - (26{,}1875)^2} = 10{,}0765 \text{ in}$$

$$t_d = \frac{P \times r_c \times W}{2 \times f \times E - 0{,}2 \times P} + c$$

$$t_d = \frac{26{,}1561 \times 60 \times 1{,}7671}{2 \times 18750 \times 0{,}8 - 0{,}2 \times 26{,}1561} + 0{,}125 = 0{,}2175 \text{ in}$$

tebal dish standar = ¼ in (Brownell, tabel 5.7)

Memilih panjang straight flange (sf) = 3 in (Brownell, tabel 5.8)

OA = t + b + sf = 3/16" + 10,0765 + 3 = 13,2640 in = 1,1053 ft

Tinggi tangki keseluruhan = tinggi shell + tinggi dish + tinggi konis

= 4,5 + 1,1053 + 4,1898 = 9,7952 ft

Tebal konis

$$t_c = \frac{P_{design} \times D}{2 \times \cos\alpha \times \left(f \times E - 0{,}6 \times P_{design}\right)} + c \qquad \text{(Brownell, hal 118)}$$

$$t_c = \frac{26{,}1561 \times 60\,\text{in}}{2 \times \cos 30 \times \left(18750 \times 0{,}8 - 0{,}6 \times 26{,}1561\right)} + 0{,}1250 = 0{,}1855\ \text{in} \approx 1/4\ \text{in}$$

Perhitungan impeller : (Geankoplis, hal 144)

$$\frac{D_a}{D_t} = \frac{1}{2} \rightarrow D_a = \frac{1}{2} \times 4{,}5\ \text{ft} = 2{,}25\ \text{ft} = 0{,}6858\ \text{m}$$

$$\frac{W}{D_a} = \frac{1}{5} \rightarrow W = \frac{1}{5} \times 2{,}25\ \text{ft} = 0{,}45\ \text{ft}$$

$$\frac{H}{D_t} = 1 \rightarrow H = 4{,}5\ \text{ft}$$

$$\frac{L}{D_a} = \frac{1}{4} \rightarrow L = \frac{1}{4} \times 2{,}25\ \text{ft} = 0{,}5625\ \text{ft}$$

$$\frac{C}{D_t} = \frac{1}{3} \rightarrow C = \frac{1}{3} \times 4{,}5\ \text{ft} = 1{,}5\ \text{ft}$$

$$\frac{J}{D_t} = \frac{1}{12} \rightarrow J = \frac{1}{12} \times 4{,}5\ \text{ft} = 0{,}375\ \text{ft}$$

Dimana : D_a = diameter pengaduk

D_t = diameter tangki

L = panjang blade

W = lebar blade

C = jarak dari dasar tangki

J = lebar baffle

Kecepatan impeller antara 20-150 rpm (McCabe edisi 5, hal 238), menggunakan kecepatan impeller 100 rpm = 1,6667 rps.

Kecepatan putar impeller = 200-250 m/min (MV. Joshi, hal 389)

$= \pi \times D_a \times N$

$= \pi \times 0{,}6858 \text{ m} \times 100 \text{ rpm}$

= 215,4504 m/min (cocok)

$$N_{Re} = \frac{N \times D_a^2 \times \rho}{\mu}$$

Dimana : N = kecepatan agitasi

D_a = diameter impeller

ρ = densitas cairan

μ = viscositas cairan

$$N_{Re} = \frac{1{,}6667 \text{ rps} \times (0{,}6858 \text{ m})^2 \times 928{,}1383 \text{ kg/m}^3}{1{,}8750 \times 10^{-3} \text{ kg/m.s}} = 388037{,}1572$$

Menggunakan flat-six blade disk turbine

Dari gambar 3.4-4, geankoplis hal 145 mendapatkan harga Np = 5

Jumlah impeller = $\frac{sg \times H}{Dt}$ (MV. Joshi, hal 389)

Jumlah impeller = $\frac{\frac{57{,}9442}{61{,}2964} \times 4{,}5}{4{,}5}$ = 0,9453 = 1 buah

Power untuk 1 buah pengaduk :

Power = Np x ρ x N^3 x D_a^5

Dimana : Np = power number

N = kecepatan agitasi

ρ = densitas cairan

D_a = diameter impeller

Power = 5 x 928,1383 kg/m^3 x (1,6667 rps)^3 x (0,6858 m)^5

Power = 3259,4357 J/s = 3,2594 kW = 4,3710 hp (teoritis)

Efisiensi = 84 % (Peter, fig. 14-38)

Power actual = $\frac{4{,}3710 \text{ hp}}{0{,}84}$ = 5,2036 hp ≈ 5,5 h

Filter Press (H-136)

Fungsi : Untuk memisahkan antara minyak jagung dengan bleaching earth dan karbon aktif

Bahan konstruksi : Metal (Perry 5^{th} ed; tabel 19-17)

Tipe : Plate and frame

Dasar pemilihan : Cocok untuk memisahkan minyak jagung dengan bleaching earth dan karbon aktif, pengerjaan mudah, cara pengoperasian alat sederhana.

Waktu tinggal : 2 jam (terdiri dari 1 jam bongkar pasang dan 1 jam operasi)

Jumlah batch dalam 1 hari = 24 jam / 2 jam = 12 batch

Kapasitas :

- Bahan masuk

Komponen	Massa (kg/batch)	Fraksi (x)	Densitas (kg/m3)	x/densitas (m3/kg)
Minyak jagung	643,9264	9,9011E-01	922,299	1,0735E-03
Bleaching earth	5,7915	8,9050E-03	2610	3,4119E-06
Karbon aktif	0,6435	9,8945E-04	2000	4,9472E-07
	650,3614		TOTAL	1,0774E-03

$$\rho \text{ feed} = \frac{1}{1{,}0774E-03} = 928{,}1383 \text{ kg/m}^3$$

- Cake

Komponen	Massa (kg/batch)	Fraksi (x)	Densitas (kg/m3)	x/densitas (m3/kg)
Minyak jagung	193,1779	9,6776E-01	922,299	1,0493E-03
Bleaching earth	5,7915	2,9014E-02	2610	1,1116E-05
Karbon aktif	0,6435	3,2237E-03	2000	1,6119E-06
	199,6129		TOTAL	1,0620E-03

$$\rho \text{ cake} = \frac{1}{1{,}0620E-03} = 941{,}6001 \text{ kg/m}^3$$

Kecepatan bahan masuk $= \dfrac{650{,}3614\ \text{kg}/\text{batch}}{928{,}1383\ \text{kg}/\text{m}^3} \times \dfrac{12\ \text{batch}}{24\ \text{jam}} \times \dfrac{264{,}17\ \text{gal}}{1\ \text{m}^3}$

$$= 92{,}5541\ \frac{\text{gal}}{\text{jam}}$$

Volume cake $= \dfrac{199{,}6129\ \frac{\text{kg}}{\text{batch}}}{941{,}6001\ \frac{\text{kg}}{\text{m}^3}}$

$$= 0{,}2120\ \frac{\text{m}^3}{\text{batch}} = 7{,}4862\ \frac{\text{ft}^3}{\text{batch}}$$

Kecepatan filtrasi $= 10\ \dfrac{\text{gal}}{\text{ft}^2\,.\text{jam}}$ (Perry 5th ed; Tabel 19 – 18)

Luas filtrasi $= \dfrac{\text{kecepatan bahan masuk}}{\text{kecepatan filtrasi}}$

$$= \frac{92{,}5541}{10}$$

$$= 9{,}2554\ \text{ft}^2$$

Ukuran plate nominal yang digunakan 18 in x 18 in dan luas plate efektif = 3.9 ft^2

(Perry 5th ed; Tabel 19 – 17)

Jumlah plate $= \dfrac{9{,}2554}{3{,}9} = 2{,}3732$

Total frame yang digunakan = jumlah plate = 3

Volume 1 frame $= \dfrac{\text{volume cake}}{\text{total frame}}$

$$= \frac{7{,}4862}{3}$$

$= 2{,}4954\ ft^3$

Tebal 1 frame $= \dfrac{\text{volume 1 frame}}{\text{luas efektif}}$

$= \dfrac{2{,}4954}{3{,}9/2}$

$= 0{,}3199\ ft = 3{,}84\ in \approx 4\ in$

Tebal frame berkisar antara 0,125 – 8 in (Perry 5th ed; hal 19 – 66)

Dari perhitungan diatas, tebal frame adalah 3,8 in yang terletak diantara 0,125 dan 8 in. Berarti hasil perhitungan diatas benar.

Jumlah plate dan frame = (2 x 3) + 1 = 7 buah

Panjang plate dan frame filter press = 7 x 0,3199

= 2,2395 ft

= 0,68 m ≈ 1 m

Panjang plate dan frame filter press adalah 0,5 – 20 m (Ulrich; Tabel 4 – 23)

Dari perhitungan diatas 1 m terletak diantara 0,5 and 20 m, jadi hasil perhitungan benar.

Bak Penampung Cake (F-137)

Fungsi : Menampung cake dari filter press (H-136)

Jumlah : 1 buah

Tipe : bak persegi

Kapasitas bak adalah terisi 90 % dari kapasitas cake dan direncanakan untuk menampung selama 7 hari

Kapasitas : 0,2112 m^3/batch = 15 m^3

Ukuran : 4m x 2,5m x 1,5m

Bahan konstruksi : beton

Heater II (E-138)

Fungsi : Menaikan suhu dari 75 °C ke 190 °C

Tipe : Shell and Tube Heat Exchanger

Bahan Konstruksi : Stainless steel

Cara perhitungan mengambil dari Kern, 1965

Perhitungan:

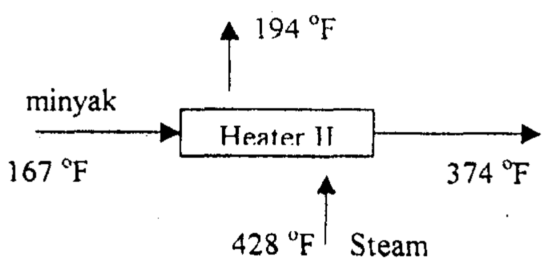
1. Dari neraca panas memperoleh :

   Qc = 139737,3845 kJ/batch = 44148,3216 btu/jam.

   Kapasitas minyak jagung = 450,7485 kg/batch = 331,2431 lb/jam.

   Jumlah steam yang dibutuhkan = 75,2814 kg/batch = 55,3223 lb/jam.

2. ΔT LMTD



Fluida Panas		Fluida Dingin	Beda Suhu
428 °F	Suhu tinggi	374 °F	54 °F
194 °F	Suhu rendah	167 °F	27 °F
234 °F	Beda suhu	207 °F	27 °F

$$\Delta T\ LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} = \frac{54 - 27}{\ln\left(\frac{54}{27}\right)} = 42{,}4536\ ^oF$$

$$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{234}{207} = 1{,}13$$

$$S = \frac{t_2 - t_1}{T_1 - t_1} = \frac{207}{428 - 167} = 0{,}6931$$

Dari fig. 19 Kern untuk 2-4 Exchanger mendapat : Ft = 0,8

$\Delta T = \Delta T\ LMTD \times Ft$ (Kern, hal 229)

$\Delta T = 42{,}4536 \times 0{,}8$

$\Delta T = 33{,}9629\ ^oF$

3. Suhu caloric

$$T_c = \frac{T_1 + T_2}{2} = 311\ ^oF$$

$$t_c = \frac{t_1 + t_2}{2} = 270{,}5\ ^oF$$

Trial UD

Dari Kern table 8 memperoleh harga UD = 50-100 btu/j.ft^2.°F (untuk sistem steam-medium organic)

UD trial = 50 btu/j.ft^2.°F

Asumsi :

1 in OD, 16 BWG, 1¼ in square pitch

L = 5 ft

a" = 0,2618 ft^2/lin.ft (Kern, table 10)

Q = UD x A x ΔT (Kern, hal 86)

$$A = \frac{Q}{UD \times \Delta T} = \frac{44148{,}3216\ \text{btu/jam}}{50\ \text{btu/j.ft}^2.^\circ F \times 33{,}9629\ ^\circ F} = 28{,}3345\ \text{ft}^2$$

A = Nt x a" x L

28,3345= Nt x 0,2618 x 5

Nt perhitungan = 21,6459 tube

Dari table 9 memperoleh : ID shell = 10 inch

Nt = 26 tube

Menggunakan HE 2-4

$$UD\ \text{koreksi} = \frac{\text{Nt perhitungan}}{\text{Nt}} \times UD\ \text{trial}$$

$$= \frac{21{,}6459}{26} \times 50$$

$$= 41{,}6267$$

Dengan perhitungan yang sama dari heater I (F-133), maka mendapatkan :

Shell	Tube
IDs = 10 in	Nt = 26 tube

B $= \frac{10}{5} = 2$ in

Passes = 2

Panjang = 5 ft

OD = 1 in

BWG = 16

Pitch = 1¼ in

Susunan = square pitch

Passes = 4

$$Rd = \frac{Uc - Ud}{Uc \times Ud} = \frac{53,1548 - 41,6267}{53,1548 \times 41,6267} = 0,005 > 0,003 \text{ (memenuhi)}$$

$$\Delta Ps = \frac{f \times G_s^{\ 2} \times D_s \times (N+1)}{5,22 \times 10^{10} \times D_e s} = 0,1357 \text{ psi} < 10 \text{ psi (memenuhi)}$$

$$\Delta Pn = \left(\frac{4n}{s}\right) \times \left(\frac{V^2}{2g}\right) = 0,016 \text{ psi}$$

$\Delta PT = \Delta Pt + \Delta Pn$

$\Delta PT = 0,4214 + 0,016$

$\Delta PT = 0,4374$ psi < 10 psi (memenuhi)

Kolom Deodorizer (F-140)

Fungsi : Untuk menghilangkan bau dari minyak yang tidak dikehendaki dengan tekanan vakum sehingga bau (FFA) itu dapat teruapkan dari minyak

Bahan konstruksi : SA-240 grade C

Tipe : Bubble cap plate tower

Dasar pemilihan : Cocok untuk menghilangkan bau dari minyak

Kondisi operasi : T = 170 °C ; P = 1 atm

Perhitungan berdasarkan beban liquid dan uap yang terbesar yaitu bagian atas kolom :

- Beban liquid (L) = 378,6765 kg/batch = 126,2255 kg/jam

Beban uap (V) = FFA = 72,072 kg/batch

Steam = 22,5225 kg/batch +

94,5945 kg/batch = 31,5315 kg/jam

= 69,5150 lb/jam

Densitas liquid = 57,5792 lb/ft^3

Densitas uap = 0,0414 lb/ft^3

Laju alir uap (Vm) = 1679,1063 ft^3/jam

1. Seleksi Bubble cap

Memilih diameter cap = 3"

Memperoleh slope shape (trapezium) $Rs = \dfrac{\text{lebar slot atas}}{\text{lebar slot bawah}} = \dfrac{0{,}167}{0{,}333} = 0{,}5$

Tinggi slot ; Hs = 1,0 in

Luas slot ; As = 5,0 in^2

Luas cap ; Ac = 7,5 in^2

2. Luas slot (As)

$$Vm = Cs\sqrt{Hs\left(\frac{\rho_L - \rho_V}{\rho_V}\right)} \times As$$

$$1679,1063 = 0,74\sqrt{1\left(\frac{57,5792 - 0,0414}{0,0414}\right)} \times As$$

$$1679,1063 = 27,5872 \times As$$

$$As = 60,8654 \text{ ft}^2$$

3. Cap spacing = 25 %
4. Luas cap/active area yang diperlukan

Diameter cap = 3"

$\gamma = 0,25$

$$\frac{\text{luas slot}}{\text{luas active area}} = 0,39$$

Jadi luas active area yang dibutuhkan = $\frac{60,8654}{0,39} = 156,0651 \text{ ft}^2$

5. Diameter menara

Mengambil : allocated cap area = 60 % dari luas tray

$$At = \frac{156,0651}{60\%} = 260,1085 \text{ ft}^2$$

Diameter menara = $\sqrt{\frac{4 \times A_t}{\pi}} = \sqrt{\frac{4 \times 260,1085}{\pi}} = 18,1984 \text{ ft} = 18,5 \text{ ft}$

6. Macam tray

D = 18,5 ft

L = 126,2255 kg/jam

Dari data diatas dipilih jenis cross flow

7. Seleksi ukuran cap

   Untuk diameter tray 10-20 ft, dia cap = 3"

   Untuk diameter tray $\geq$16 ft, dia cap = 3"

   Jadi diameter cap 3" telah memenuhi syarat

8. Pembagian luas daerah tray

   Mengambil L/D = 0,6

   Down flow = 10-20 %

   Liquid distribusi area = 2-10 %

   Wastage area = 2-8 %

   Sehingga diambil :

Luas side down flow (1 buah)	=	5 %
Luas side down flow (2 buah)	=	10 %
Luas liquid distribusi	=	10 %
Luas end wastage	=	5 %
Luas allocated cap	=	75 %+
Total	=	100 %

Aa/At = 0,746

At = 264,3474 ft^2

9. Penaksiran kembali diameter menara

$264{,}3474 = \pi/4 \times D^2$

$D = 18{,}3460 \text{ ft} \approx 18{,}5 \text{ ft}$

10. Tray spacing untuk diameter 18,5 ft adalah 24 in

11. Lay out dari tray

<u>Tinggi weir :</u>

Skirt height = 1"

Shroud ring = 0,25"

Tinggi slot = 1,00"

Static seal = 0,5"

Tinggi outlet weir = 2,75"

Seal pada down flow baffle ditetapkan = 0,5" (untuk diameter < 6 ft)

Luas daerah down comer baffle adalah :

Clearence dibawah baffle = 2,75-0,5 = 2,25"

Luas dibawah baffle = 0,6 x 3,5 x 2,25/12 = 0,39375 ft

12. Penentuan jumlah cap

Panjang tray untuk dibagi = 3,5 ft = 42 in

Distribusi liquid = 2 x 3 = 6"

Diameter cap = 3"

Lebar down comer = 2 x H = 2 x H/D x D = 2 x 0,1 x 42 = 8,4" +

Jumlah total = 6 +3 + 8,4" = 17,4"

Sisa panjang untuk penentuan banyaknya row = 42-17,4 = 24,6"

Jarak antar row = 3,75 x sin 60° = 3,248"

Jumlah baris = 24,6"/3,248"+1 = 7,57 + 1 = 8

Sisa = 0,5719" x 3,248" = 1,86"

Sehingga diperoleh banyaknya cap = 78 buah

	Luas per cap, ft^2	Luas per tray, ft^2	% jenis luas thd luas tray
Luas riser	2,65	78 x 2,65/144 = 1,435	14,915 %
Luas slot	5	78 x 5/144 = 2,708	28,147 %
Luas down flow		1,001	10,40 %
Luas dibawah baffle		0,39375	
Luas menara		268,8025	100 %

13. Menentukan jumlah plate

Tebal efisiensi plate = 60 %

Jumlah plate teoritis = 8 plate (Geankoplis, fig 11.7-3)

Jumlah plate actual = 8/0,6 = 14 plate

14. Pengecekan floading

$$\frac{L}{V}\left(\frac{\rho_V}{\rho_L}\right)^{1/2} = \frac{126,2255}{69,5150}\left(\frac{0,0414}{57,5792}\right)^{1/2} = 0,0487$$

Spasi tray = 18"

Dari gambar 1-28, mendapat $U_{vn}\left(\dfrac{\rho_V}{\rho_L - \rho_V}\right)^{1/2} = 0,25$

$$U_{vn} = \frac{0,25}{\left(\frac{0,0414}{57,5792 - 0,0414}\right)^{1/2}} = 9,32 \text{ ft/s}$$

Kecepatan aliran yang sebenarnya :

Luas tray		$= 268,8025 \text{ ft}^2$
Luas down comer		$= 1 \text{ ft}^2$ –
	Total	$= 267,8025 \text{ ft}^2$

$$\text{Kecepatan aliran uap} = \frac{V}{A} = \frac{1679,1063 \text{ ft}^3\text{/s}}{267,8025 \text{ ft}^2} = 6,2699 \text{ ft/s}$$

$$\text{Kecepatan aliran uap yang sesungguhnya} = \frac{6,2699}{9,32} \times 100\% = 67,27\ \%$$

Karena : 67,27 % < 70 % mk non foaming

Penentuan tinggi kolom

Ditetapkan

Rongga atas		= 4 ft
Rongga bawah + hold up liquid		= 10 ft
Tinggi spacing (14-1) x 2		= 26 ft +
	Total	= 40 ft

Jadi tinggi total kolom = 40 ft

Steam Jet Ejector (E – 141)

Fungsi : Menvacumkan tekanan dalam kolom deodorizer

Bahan konstruksi : SA-240 grade C

Tekanan kolom deodorizer (P_{ob}) = 0,2113 atm = 3,1053 psia

Tekanan discharge (P_{o3}) = 1 atm = 14,696 psia

$$\frac{P_{o3}}{P_{ob}} = \frac{3,1053}{14,696} = 4,7326$$

Tekanan steam yang digunakan (P_{oa}) = 6 atm = 88,1760 psia

$$\frac{P_{ob}}{P_{oa}} = \frac{3,1053}{88,1760} = 0,0352$$

Dari Perry 6th ed; fig. 6 – 72; memperoleh entrainment ratio $\frac{W_b}{W_a} = 1,7$

Dimana : Wa = berat steam (lb/jam) = 16,5512

Wb = berat distilat (lb/jam)

$$\left(\frac{W_b}{W_a}\right)_{actual} = \left(\frac{W_b}{W_a}\right) x \left[\left(\frac{t_a \times M_b}{t_b \times M_a}\right)\right]^{0,5} \quad \text{(Perry 6}^{th}\text{ ed; pers. 6 – 36)}$$

Dimana :

t_a = Suhu steam (°F) = 338

t_b = Suhu uap yang diserap (°F) = 338

M_a = Berat molekul steam (kg/kmole) = 18,02

M_b = Berat molekul uap (kg/kmole)

Komponen	Massa (kg/batch)	Fraksi massa (x)	BM	x/BM
Myristic acid	12,5676	0,1391	228	0,0006
Palmitic acid	41,8918	0,4636	256	0,0018
Stearic acid	12,5676	0,1391	284	0,0005
Oleic acid	0,4504	0,0050	282	1,7674E-05
Linoleic acid	0,3063	0,0034	278	1,2193E-05
CO_2	0,0007	0,0000	44	1,7605E-07
Air	0,0590	0,0007	18,02	3,6232E-05
Steam	22,5225	0,2492	18,02	0,0138
TOTAL	90,3659	1,0000		0,0168

$$M_b = \frac{1}{x/BM} = \frac{1}{0{,}0168} = 59{,}4957$$

$$(W_b)_{actual} = 1{,}7 \times \left[\left(\frac{338 \times 59{,}4957}{338 \times 18{,}02}\right)\right]^{0,5} \times 16{,}5512 \text{ lb/jam}$$

$$= 438{,}0420 \text{ lb/jam}$$

Pompa (L-142)

Fungsi : Mengalirkan minyak jagung menuju ke cooler II (E-144)

Tipe : Centrifugal pump

Dasar pemilihan : Harga alat murah, konstruksi sederhana .

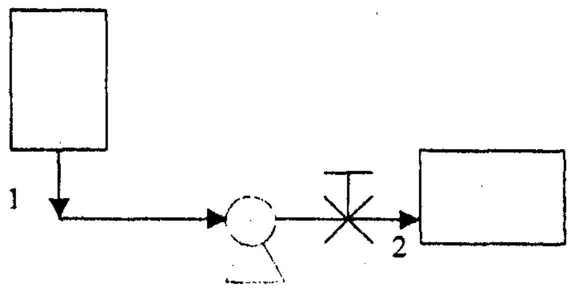
Kondisi operasi : T = 170 °C ; P = 1 atm

Asumsi : direncanakan beda elevasi kolom deodorizer dengan cooler II = 3 ft dengan panjang pipa = 10 ft

Rancangan perpipaan dilengkapi dengan :

- 1 buah elbow 90 °

- 1 buah globe valve
- 1 buah sudden contraction
- 1 buah sudden enlargement



Rate minyak jagung yang keluar dari kolom deodorizer (F-140) = 382,9049 kg/batch

= 281,3866 lb/jam

ρ minyak jagung = 922,299 kg/m^3 = 57,5792 lb/ft^3

μ minyak jagung = 1,0952 x 10^{-3} kg/m.s = 0,000736 lb/ft.s

Kecepatan bahan masuk = $\dfrac{281{,}3866 \text{ lb/jam}}{57{,}5792 \text{ lb/ft}^3}$ = 4,8869 ft^3/jam = 1,3575 x 10^{-3} ft^3/s

Diasumsikan aliran turbulen sehingga :

Di opt = 3,9 × (qf)^{0,45} × (ρ)^{0,13} (Peter and Temmerhaus, 4th ed.. pp. 496)

= 3,9 × (0,0013)^{0,45} × (57,5792)^{0,13}

= 0,3320 in

Menggunakan pipa standart 3/8 in schedule 80.

Dari geankoplis Appendix A.5 memperoleh :

- D out = 0,675 in

- ID = 0,423 in = 0,20575 ft
- Cross section area = 0,00098 ft^2

Kecepatan linear (V) = $\dfrac{qf}{A} = \dfrac{0,0013}{0,00098} = 1,3265\ ft/s$

<u>Menentukan bilangan Reynolds :</u>

$$N_{re} = \frac{Di \times V \times \rho}{\mu} = \frac{0,20575\ ft \times 1,3265\ ft/detik \times 57,5792\ lb/ft^3}{0,000736\ lb/ft.detik}$$

= 21351,8205 (turbulen → trial benar)

Dengan mempergunakan neraca tenaga :

$$-Ws = \frac{\Delta V^2}{2 \times \alpha \times gc} + \frac{g}{gc} \times \Delta Z + \frac{\Delta P}{\rho} + \Sigma F$$ (Geankoplis 3rd ed., per 2.7-28, hal 275)

Dimana ΣF merupakan total fraksional losses, meliputi :

1. Losses karena kontraksi pada outlet centrifuge 1, hc
2. Losses karena friksi pada pipa lurus, Ft
3. Losses karena friksi pada elbow dan valve, Hf
4. Losses karena ekspansi pada inlet cooler II
5. Losses karena pressure drop di cooler II

Perhitungan ΣF :

1. Losses karena kontraksi pada outlet centrifuge 1, hc

$$Kc = 0,55 \times \left(1 - \frac{A_2}{A_1}\right)$$

Dimana : A_1 = luas penampang kolom deodorizer

A_2 = luas penampang pipa

Karena A_1 >>> A_2 maka (A_2/A_1) diabaikan

Kc = 0,55 x (1-0) = 0,55

$$Hc = Kc \times \left(\frac{v^2}{2 \times \alpha \times gc} \right) = 0,55 \times \left(\frac{1,3265^2}{2 \times 1 \times 32,174} \right) = 0,0150$$

2. Losses karena friksi pada pipa lurus, Ft

Menggunakan pipa commercial steel ε = 0,00015 ft (didapat dari insert fig 2.10-3 hal 88 Geankoplis kemudian dari m dikonversi ke ft)

Relative roughness = $\frac{\varepsilon}{D}$ = 0,00015 ft/0,03525 ft = 4,2553 x 10^{-3}

Dari fig. 2.10-3 Geankoplis 3rd ed., hal 88, memperoleh f = 0,008

Panjang pipa = 10 ft

$$Ft = 4f \times \frac{\Delta L}{D} \times \left(\frac{v^2}{2 \times \alpha \times gc} \right)$$

$$= 4 \times 0,008 \times \frac{10}{0,03525} \times \left(\frac{1,3265^2}{2 \times 1 \times 32,174} \right) = 0,2482 \text{ ft.lbf/lbm}$$

3. Losses karena friksi pada elbow dan valve, Hf

Terdapat 1 elbow 90° ,1 globe valve

Dari geankoplis tabel 2.10-2

$Kf = 0{,}75 + 6 = 6{,}75$

$$hf = Kf \times \left(\frac{v^2}{2 \times \alpha \times gc} \right)$$

$$= 6{,}75 \times \left(\frac{1{,}3265^2}{2 \times 1 \times 32{,}174} \right) = 0{,}1846 \text{ ft.lbf/lbm}$$

4. Losses karena ekspansi pada inlet cooler II

Dimana : A_1 = luas penampang pipa

A_2 = luas penampang cooler II

Karena A_1 <<< A_2 maka (A_1/A_2) diabaikan

$$K_{ex} = \left(1 - \frac{A_1}{A_2} \right)^2 = (1\text{-}0)^2 = 1$$

$$K_{ex} = K_{ex} \times \left(\frac{v^2}{2 \times \alpha \times gc} \right) = 1 \times \left(\frac{1{,}3265^2}{2 \times 1 \times 32{,}174} \right) = 0{,}0273 \text{ ft.lbf/lbm}$$

5. Losses karena pressure drop di cooler II

$P_1 = 0{,}2113$ atm = 447,1590 lbf/ft^2

$P_2 = 1$ atm = 2116,2281 lbf/ft^2

ΔP = (2116,2281-447,1590) lbf/ft^2

= 1669,0691 lbf/ft^2

ΣF = 0,0150 + 0,2482 + 0,1846 + 0,0273 + 1669,0691 = 1669,5442 ft.lbf/lbm

$$-Ws = \frac{\Delta V^2}{2 \times \alpha \times gc} + \frac{g}{gc} \times \Delta Z + \frac{\Delta P}{\rho} + \Sigma F$$

Dimana : $\Delta V = 0$

$\Delta P = 1669{,}0691$

$\Delta Z = 3$ ft

$\alpha = 1$ (turbulen)

$$-Ws = 0 + \frac{32{,}174}{32{,}174} \times (3) + \frac{1669{,}0691}{57{,}5792} + 1669{,}5442 = 1701{,}5316 \text{ ft.lbf/lbm}$$

Effisiensi pompa (η) = 50% (Ulrich, hal 206)

Brake hp = $\frac{-Ws \times m}{\eta \times 550}$ (Geankoplis, pers. 3.3-2)

m = 281,3866 lb/j = 0,0782 lb/dtk

Brake hp = $\frac{1701{,}5316 \times 0{,}0782}{0{,}5 \times 550} = 0{,}4839$ hp $\approx 0{,}5$ hp

Effisiensi motor = 80% (Peter 5th ed., Fig.12-18, hal 516)

Sehingga memakai pompa dengan motor = $\frac{0{,}5}{0{,}8} = 0{,}625$ hp $\approx 0{,}75$ hp

Cooler II (E-143)

Fungsi	: Menurunkan suhu dari 170 °C menjadi 35 °C
Tipe	: Shell and Tube Heat Exchanger
Bahan Konstruksi	: Stainless steel

Cara perhitungan mengambil dari Kern, 1965

Perhitungan:

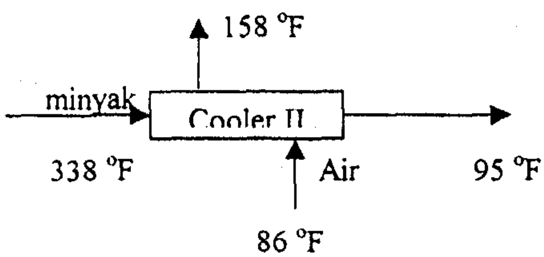
1. Dari neraca panas memperoleh :

   Qc = 134549,4789 kJ/batch = 42509,2661 btu/jam.

   Kapasitas minyak jagung = 382,9049 kg/batch = 281,3866 lb/jam.

   Jumlah air yang dibutuhkan = 800,5507 kg/batch = 588,3034lb/jam.

2. ΔT LMTD



Fluida Panas		Fluida Dingin	Beda Suhu
338 °F	Suhu tinggi	158 °F	180 °F
95 °F	Suhu rendah	86 °F	9 °F
243 °F	Beda suhu	72 °F	171 °F

$$\Delta T\ LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} = \frac{171}{\ln\left(\frac{180}{9}\right)} = 57{,}0812\ ^\circ F$$

$$R = \frac{T_1 - T_2}{t_2 - t_1} = 3{,}375$$

$$S = \frac{t_2 - t_1}{T_1 - t_1} = 0{,}2857$$

Dari fig. 19 Kern untuk 2-4 Exchanger mendapat : Ft = 0,75

Dengan perhitungan yang sama dari cooler I (E-123), maka mendapatkan :

$\Delta T = 42{,}8109\,^{\circ}F$

UD koreksi = 52,5155

Shell	Tube
IDs = 10 in	Nt = 26 tube
B $= \frac{10}{5} = 2$ in	Panjang = 5 ft
Passes = 2	OD = 1 in
	BWG = 16
	Pitch = 1¼ in
	Susunan = square pitch
	Passes = 4

$$Rd = \frac{Uc - Ud}{Uc \times Ud} = \frac{72{,}9559 - 52{,}5155}{72{,}9559 \times 52{,}5155} = 0{,}005 > 0{,}003 \text{ (memenuhi)}$$

$$\Delta Ps = \frac{f \times G_s^{\,2} \times D_s \times (N+1)}{5{,}22 \times 10^{10} \times D_e s} = 0{,}0114 \text{ psi} < 10 \text{ psi (memenuhi)}$$

$$\Delta Pn = \left(\frac{4n}{s}\right) \times \left(\frac{V^2}{2g}\right) = 0{,}016 \text{ psi}$$

$\Delta PT = \Delta Pt + \Delta Pn$

$\Delta PT = 0{,}089 + 0{,}016$

$\Delta PT = 0{,}105$ psi < 10 psi (memenuhi)

APPENDIKS D

ANALISA EKONOMI

LAMPIRAN D

ANALISA EKONOMI

Harga alat akan berubah setiap saat tergantung pda kondisi ekonomi dan politik, untuk itu dibutuhkan suatu metode yang dapat mengkonversikan harga alat pada beberapa tahun yang lalu, supaya dapat diperoleh harga yang ekuivalen pada saat ini. Ekuivalensi iut dihitung dengan menggunakan persamaan :

$$\text{Harga alat tahun 2007} = \frac{\text{indeks harga tahun 2007}}{\text{indeks harga tahun 1990}} \times \text{harga alat tahun 1990}$$

Harga alat pada tahun A yang digunakan dalam pra rencana ini didasarkan pada harga alat yang terdapat pada pustaka Peters dan Timmerhaus dengan menggunakan Marshall & Swift Cost Index.

Dalam perhitunagn ini digunakan indeks harga tahun 1990 = 924 (Timmerhaus hal 158). Dengan extrapolasi dan linearisasi dari data tahun sebelumnya diperoleh cost indeks untuk tahun 2007 = 1324,77.

Kapasitas : 925940,4 $\frac{lb}{minggu}$

Harga tahun 1990 : Rp. 32.000.000,00

Harga alat saat ini : $\frac{1324,77}{924} \times$ Rp.32.000.000,00 = Rp. 45.879.481,00

Dengan cara yang sama untuk mendapatkan harga alat yang lain seperti pada tabel D-1.

Tabel D-1. Harga Peralatan Proses

1 $ dolar = Rp. 9300,00

No	Nama Alat	Jumlah	Harga per satuan Tahun 1990	Harga (Rp)
1	Bucket elevator	1	Rp. 20.000.000,00	28.674.675,32
2	Silo	1	Rp. 32.000.000,00	45.879.480,52
3	Screw	3	Rp. 25.000.000,00	107.530.032,47
4	Grinder	1	Rp. 18.500.000,00	26.524.074,68
5	Bin	4	Rp. 27.000.000,00	154.843.246,75
6	Tangki Penampungan CO_2	1	Rp. 1.200.000.000,00	1.720.480.519,48
7	Kompresor	2	Rp. 40.000.000,00	114.698.701,30
8	Coller	3	Rp. 90.000.000,00	387.108.116,88
9	Tangki Ekstraksi Superkritis	2	$ 222.580,65	5.935.657.792,21
10	Tangki Separator I	1	$ 102.150,54	1.362.047.077,92
11	Tangki Separator II	1	Rp. 80.000.000,00	114.698.701,30
12	Tangki Penampungan Sementara	1	Rp. 30.000.000,00	43.012.012,99
13	Heater	2	Rp. 700.000.000,00	2.007.227.272,73
14	Tangki Pemucat	1	Rp. 149.227.800,00	213.952.935,72
15	Filter Press	1	Rp. 15.000.000,00	21.506.006,49
16	Kolom Deodorizer	1	$ 167.741,94	2.236.624.675,32
17	Pompa	1	Rp. 18.255.900,00	26.174.100,26
18	Steam Jet	1	Rp. 69.750.000,00	100.002.930,19
	TOTAL	28		14.646.642.352,54

B. Perhitungan Harga Tanah dan Bangunan

Luas tanah = 3393 m^2

Luas pabrik dan gudang = 582,5 m^2

Luas bangunan kantor = 200 m^2

Luas bangunan lain - lain = 632 m^2

Harga tanah = Rp. 15.000,00/m^2

Harga bangunan pabrik dan gudang = Rp. 950.000,00/m^2

Harga bangunan kantor = Rp. 950,000/m^2

Harga bangunan lain - lain = Rp. 750.000,00/m^2

Jadi :

Harga tanah = 3393 m^2 x Rp. 15.000,00/m^2 = Rp. 50.895.000,00

Harga bangunan pabrik dan gudang = 582,5 m2 x Rp 950.000,00/m^2

= Rp. 553.375.000,00

Harga bangunan kantor = 200 m^2 x Rp. 950.000/m^2 = Rp. 237.500.000,00

Harga bangunan lain – lain = 632 m^2 x Rp. 750.000,00/m^2 = Rp. 600.400.000,00

Total harga tanah dan bangunan = Rp. 1.442.170.000,00

C. Perhitungan Harga Bahan Baku dan Harga Jual Produk

❖ **Harga Bahan Baku**

1. Biji Jagung Bersih

   Harga : Rp. 2750/kg

   Kebutuhan : 19.800.000 kg/tahun

   Total harga : Rp. 54.450.000.000,00

2. Karbon Aktif

   Harga : Rp. 20000/kg

   Kebutuhan : 1274,13 kg/tahun

   Total harga : Rp. 25.482.600,00

3. Bleaching Earth

   Harga : Rp 500/kg

   Kebutuhan : 11 467,17 kg/tahun

   Total harga : Rp. 50.733.585,00

Total Bahan Baku per tahun = Rp. 54.526.216.190,00

- **Harga Jual Produk**

1. Minyak Jagung

   Harga : Rp 20 000/L

   Produksi : 822.024,2004 L/tahun

   Total harga : Rp. 16.440.484.010,00

2. Ampas Jagung

   Harga : Rp. 750/kg

   Produksi : 18.137.790 kg/tahun

   Total Harga : Rp. 13.603.342.500,00

Total = Rp. 30.043.826.510,00

D. Perhitungan Gaji Karyawan

Perincian gaji karyawan disajikan pada tabel D-2 berikut ini :

Tabel D-2. Gaji Karyawan

No	Jabatan	Jumlah	Gaji/bulan (Rp)	Total/bulan (Rp)
1	Direktur utama	1	10.000.000,00	10.000.000,00
2	Direktur teknik & produksi	1	5.000.000,00	5.000.000,00
3	Direktur administrasi & keuangan	1	5.000.000,00	5.000.000,00
4	Sekretaris	2	1.500.000,00	3.000.000,00
5	Kabag produksi	1	4.000.000,00	4.000.000,00
6	Kabag keuangan	1	4.500.000,00	4.500.000,00
7	Kasie proses & util	1	3.000.000,00	3.000.000,00
8	Kasie R&D dan QC	8	3.000.000,00	24.000.000,00
9	Kasie keuangan	8	3.000.000,00	24.000.000,00
10	Kasie pemeliharaan & perbaikan dan gudang	1	3.000.000,00	3.000.000,00
11	Kasie personalia dan keamanan	8	3.000.000,00	24.000.000,00
12	Karyawan proses	80	800.000,00	64.000.000,00
13	Karyawan utilitas	12	800.000,00	9.600.000,00
14	Karyawan QC	12	800.000,00	9.600.000,00
15	Karyawan R&D	4	800.000,00	3.200.000,00
16	Karyawan keuangan	4	800.000,00	3.200.000,00
17	Karyawan pemeliharaan & perbaikan	8	800.000,00	6.400.000,00
18	Karyawan personalia	2	800.000,00	1.600.000,00
19	Karyawan keamanan	16	800.000,00	12.800.000,00
20	Karyawan gudang	16	750.000,00	12.000.000,00
21	Sopir & pesuruh	12	750.000,00	9.000.000,00
	TOTAL	**199**		**240.900.000,00**

Total gaji karyawan per bulan = Rp. 240.900.000,00

Ditetapkan 1 tahun produksi adalah 12 bulan + 1 bulan tunjangan.

Gaji karyawan per tahun = Rp. 240.900.000,00 x 13 bulan = Rp. 3.131.700.000,00

E. Perhitungan Biaya Utilitas

1. Kebutuhan air PDAM

Kebutuhan air PDAM = 44,3496 m^3/hari

Harga air PDAM 10 m^3 pertama = Rp. 2.500

Untuk harga 10 m^3 berikutnya, tiap kenaikkan 10 m^3 harga naik Rp. 450, sehingga diperoleh perhitungan air PDAM :

(10 m^3 x Rp. 2.500) + (34,3496 m^3 x Rp. 2950) = Rp. 126.331,32 / hari

≈ Rp. 126.350,00 / hari

Rp 41.695.500,00 / tahun

2. Kebutuhan Listrik

Kebutuhan listrik untuk penerangan = 9,370 kW/hari

Kebutuhan listrik untuk proses dan utilitas =

= (6799,1434 + 0,018) x 0,7457 kw/hari

= 5070,1344 kW/hari

Total kebutuhan listrik = 5079,5044 kW

Beban listrik terpasang = 1,25 x 5079,5044 kW

= 6349,3805 kW

Biaya beban per bulan = Rp 35.000,00 /kW/bulan

Biaya beban per tahun = Rp 2.666.739.810,00 /tahun

Biaya pemakaian listrik :

WBP = Rp 702,00/kwh (pk.18.00-22.00)

LWBP = Rp 468,00/kwh (pk. 22.00-18.00)

Biaya pemakaian listrik per tahun = biaya (toal pemakaian listrik – lampu mati)

= [((4 jam x 5079,5044 kw x Rp 702/kwh) + (20 jam x 5079,5044 kw x Rp 468/kwh)) x 330 hr/tahun] + [((4 jam x 9,370 kw x Rp 702/kwh) + (20 jam x 9,370 kw x Rp 468/kwh)) x 35 hari/tahun] - [((4 jam x 5079,5044 kw x Rp 702/kwh) + (20 jam x 5079,5044 kw x Rp 468/kwh) + (4 jam x 9,370 kw x Rp 702/kwh) + (20 jam x 9,370 kw x Rp 468/kwh)) x 3 hari/tahun]

= Rp 20.214.671.380,00

Biaya listrik total per tahun = biaya beban + biaya pemakaian listrik

= Rp 2.666.739.810,00 + Rp 20.214.671.380,00

= Rp 22.881.411.190,00

3 Kebutuhan Bahan Bakar

Kebutuhan solar = 3070,1340 kg/bln = 41817,6395 L/tahun

Harga solar = Rp 2.500,00/L

Biaya solar per tahun = 41817,6395 L/tahun x Rp 2.500,00/L

= Rp 104.544.100,00/tahun

F. Pembagian Shift Kerja

Pabrik direncanakan beroperasi 330 hari dalam setahun, 24 jam sehari, sedangkan sisa hari yang ada dipergunakan shut down dan perbaikan peralatan pabrik disamping hari libur besar yang ada. Pembagian jam kerja karyawan adalah sebagai berikut :

a) Untuk karyawan non shift

Dalam seminggu bekerja selama 5 hari, sedangkan hari sabtu, minggu dan hari besar libur.

Ketentuan jam kerja adalah sebagai berikut:

- Senin sampai Jumat : 08.00 – 17.00 WIB

Dalam seminggu bekerja selama 5 hari, sedangkan hari sabtu, minggu dan hari besar libur.

Ketentuan jam kerja adalah sebagai berikut:

- Senin sampai Jumat : 08.00 – 17.00 WIB

Waktu istirahat:

- Senin sampai Kamis : 12.00 – 13.00 WIB
- Jumat : 11.00 – 13.00 WIB

b) Untuk karyawan shift

Untuk karyawan proses, pengemasan, dan keamanan dibagi menjadi 3 shift dengan 4 grup dalam pembagian kerja

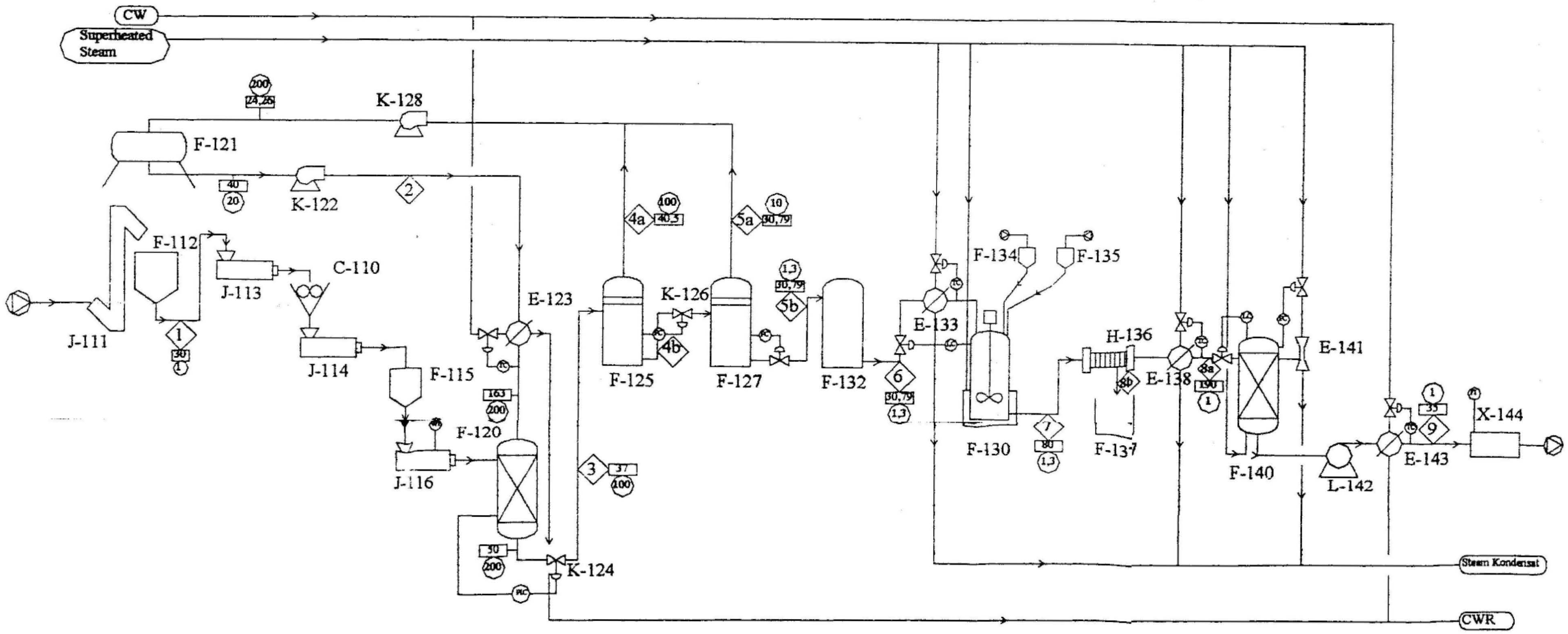
Tabel D-3. Shift Pergantian Karyawan

Grup	**Hari**							
	Senin	**Selasa**	**Rabu**	**Kamis**	**Jumat**	**Sabtu**	**Minggu**	**Senin**
1	P	P	L	L	M	M	L	L
2	S	S	P	P	L	L	P	P
3	M	M	S	S	P	P	S	S
4	L	L	M	M	S	S	M	M

Keterangan : P = Pagi ; S = Siang ; M = Malam ; L = Libur

Pergantian shift untuk bagian proses, pengemasan, dan keamanan :

- Shift 1 : 07.00 – 15.00 WIB
- Shift 2 : 15.00 – 23.00 WIB
- Shift 3 : 23.00 – 07.00 WIB



Simbol
- ◇ Nomor aliran massa
- ○ Kondisi tekanan (bar)
- ▭ Kondisi suhu (°C)

Instrumentasi.
- WI : Weight Indicator
- FI : FlowIndicator
- LC : Level Control
- TC : Temperature Control
- PC : Pressure Control
- PIC : Pressure Indicator Controller

aliran massa / komponen	1	2	3	4a	4b	5a	5b	6	7	8a	8b	9
Karbohidrat	7800.0000											
Protein	1000.0000											
Myristic Acid	19.5000	0.0015	19.3065	2.94E-06	19.3065	0.0015	19.3050	19.3050	19.3050	13.5135	5.7915	0.9459
Palmitic Acid	65.0000	0.0243	64.3743	0.0000483	64.3743	0.0241	64.3501	64.3501	64.3501	45.0450	19.3050	3.1531
Stearic Acid	19.5000	0.0004	19.3054	8.06E-07	19.3054	0.0004	19.3050	19.3050	19.3050	13.5135	5.7915	0.9459
Oleic Acid	325.0000	0.0022	321.7522	4.43E-06	321.7522	0.0022	321.7500	321.7500	321.7500	225.2250	96.5250	224.7745
Linoleic Acid	221.0000	0.0023	218.7923	4.53E-06	218.7923	0.0023	218.7900	218.7900	218.7900	153.1530	65.6370	152.8467
Air	200.0000	196.8120	392.8120	191.3260	201.4860	200.0793	0.4214	0.4214	0.4214	0.2950	0.1264	0.2360
Inert	350.0000											
CO2		79997.7885	79997.7885	79547.5570	450.2315	448.0201	0.0050	0.0050	0.0050	0.0035	0.0015	0.0028
Karbon Aktif									5.7915		5.7915	
Bleaching Earth									0.6435		0.6435	

No	Kode	Nama Alat
1	G-110	Grinder
2	J-111	Bucket elevator
3	F-112	Silo
4	J-113	Screw conveyor I
5	J-114	Screw conveyor II
6	F-115	Bin
7	J-116	Screw conveyor III
8	F-120	Tangki Ekstraksi Superkritis
9	F-121	Tangki Penampungan CO_2
10	K-122	Compresor I
11	E-123	Cooler I
13	F-125	Tangki Separator I
15	F-127	Tangki Separator II
16	K-128	Compresor II
18	F-132	Tangki Penampungan Sementara
19	E-133	Heater I
20	F-130	Tangki Pemucat
21	F-134	Bin Bleaching Earth
22	F-135	Bin Karbon aktif
24	H-136	Filter Press
25	F-137	Bin Penampung Cake
25	E-138	Heater II
26	F-140	Kolom deodorisasi
27	E-141	Steam jet ejector
28	L-142	Pompa
29	E-143	Cooler II
30	X-144	Unit Pengemasan

Digambar oleh :

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Flowsheet Pabrik Minyak Goreng dari Biji Jagung

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