APPENDIX A
PERHITUNGAN NERACA MASSA

Satuan Massa	:	Kilogram			
Basis Operasi	:	1 jam operasi			
1 Tahun Kerja	:	330	hari		
1 Hari Kerja	:	24	jam		
Kapasitas produksi	:	70000	ton / tahun		
	:	212.1212121	ton / hari	(asumsi 1 tahun = 330 hari)	
	:	8.838383838	ton / jam		
	:	8838.383838	Kg/ jam	736.532	

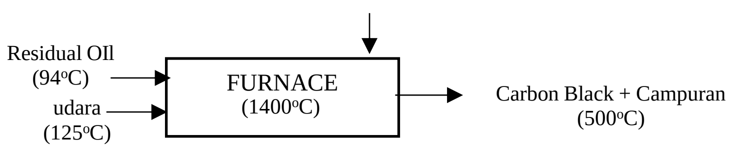
Komposisi Bahan Baku:

Komposisi Residual Oil: = Scale up 18827.2386

Komponen	% Berat
C	87.75
S	0.84
H2	10.49
O2	0.64
N2	0.28
Total	100

1. FURNACE

Fungsi : Pembakaran residual oil menjadi carbon black



Kondisi Operasi:

Tekanan Operasi	:	5	atm	(karakteristik alat)		
Suhu operasi	:	1400	^oC	=	2552	^oF
Yield Reaksi	:	47	%			
Feed Masuk	:	18882.00184	Kg/jam			

Reaksi cracking $C_{20}H_{42} \longrightarrow 20\ C_{(amorph)} + 21\ H_{2(g)}$ (terkonversi 55%)

	$C_{20}H_{42}$	$C_{(amorph)}$	$H_{2(g)}$	
M	66.9575			
R	36.8266	736.5320	773.359	
S	30.1309	736.5320	773.359	(kmol)

Reaksi Pembakara $C_{20}H_{42} + 61/2\ O_2 \longrightarrow 20\ CO_2 + 21\ H_2O_{(g)}$ (habis)

	$C_{20}H_{42}$	O_2	CO_2	$H_2O_{(g)}$	
M	30.1309	1378.4866			
R	30.1309	918.9910	602.617	632.7479	
S	0.0000	459.4955	602.617	632.7479	(kmol)

	S	+	O_2	→	SO_2	
M	4.9565		459.496			
R	4.9565		4.95653		4.9565	(Kmol)
S	0		454.539		4.9565	

Komponen	BM	% Berat	Berat (Kg/jam)
C	12	87.75	16569.0
S	32	0.84	158.6
H_2	2	10.49	1980.7
O_2	32	0.64	120.8
N_2	28	0.28	52.9
Total	282	100	18882

Tinjauan Reaksi:

maka $C_{20}H_{42}$ pada reaksi cracking terkonversi 55% , sehingga :

$$C_{20}H_{42} + 61/2\ O_2 \longrightarrow 20\ CO_2 + 21\ H_2O_{(g)}$$

$C_{20}H_{42}$ sisa reaksi I	:	30.1309	x	282	=	8496.9	Kg/jam
$C_{20}H_{42}$ yang bereaksi	:	30.1309	x	282	=	8496.9	Kg/jam -
Sisa $C_{20}H_{42}$ yang bereaksi	:	0.0000	x	282	=	0	Kg/jam

Kebutuhan O_2	:	1378.4866	x	32	=	44111.570	Kg/jam
O_2 yang bereaksi	:	918.9910	x	32	=	29407.713	Kg/jam -
Sisa O_2 yang bereaksi	:	459.4955	x	32	=	14703.8567	Kg/jam

Berat N2 Udara Bebas = 5185.735193 kmol x 28 = 145200.5854 Kg/jam

Produk CO_2 = 602.6170799 x 44 = 26182.828 Kg/jam

Produk H_2O = 632.7479 x 18 = 11389.463 Kg/jam

Reaksi Dekomposisi $C_{20}H_{42} \longrightarrow 20\ C_{(amorph)} + 21\ H_{2(g)}$

Berat $C_{20}H_{42}$ Bahan masuk = 18882 Kg/jam

Mol $C_{20}H_{42}$ $= \dfrac{18882}{282} = 66.9575$ kmol

$C_{20}H_{42}$ Reaksi Perekahan

Produk C = 736.5320 x 12 = 8838.3838 Kg/jam

Produk H_2 = 773.3586 x 2 = 1546.7172 Kg/jam

Sisa C20H42 = 30.1309 x 282 = 8496.9008 Kg/jam

S mula mula	=	4.9565	Kmol	x	32	=	158.6088	Kg/jam
S yang Bereaksi	=	4.9565	Kmol	x	32	=	158.6088	Kg/jam
S yang Sisa						=	0.0000	Kg/jam
SO_2 yang terbentuk	=	4.9565	Kmol	x	64	=	317.2176	Kg/Jam
O_2 sisa Reaksi SO_2	=	454.539	Kmol	x	32	=	14545.2479	Kg/Jam

Kebutuhan Cooling Water = 100970.0363 kg/jam

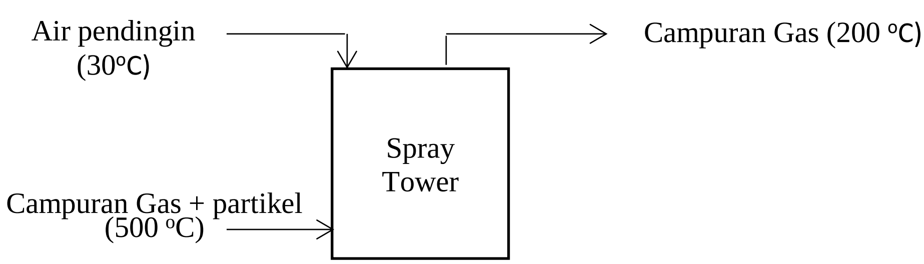
Neraca Massa:

Masuk	Kg/jam	Keluar	Kg/jam
* Residual Oil			
C20H42	16568.9566	C	8838.3838
S	158.6088	H_2	1546.7172
H_2	1980.7220	N_2	52.8696
O_2	120.8448	O_2	120.8448
N_2	52.8696	*Burner Flue	
	18882	SO2	317.2176
		N_2	145200.585
		CO_2	26182.8283
*udara excess 50%		H_2O	11389.4628
N_2	145200.585	O_2	14545.2479
O_2	44111.570	*quench water	
	189312.156	H_2O	100970.04
*quench water			
H_2O	100970.04		
	309164.1937		309164.1937

0.000

2. SPRAY TOWER

Fungsi : Menurunkan suhu bahan sampai dengan 200 ^oC



Kondisi Operasi :

Tekanan Operasi : 1 atm

Suhu Operasi : 200 ^oC

Feed masuk :

Komponen	Berat (Kg/jam)	fraksi
C	8838.3838	0.0286
H_2	1546.7172	0.0050
N_2	145253.4550	0.4698
SO2	317.2176	0.0010
O2	14666.0927	0.0474
CO_2	26182.8283	0.0847
H_2O	112359.4991	0.3634
total	309164.1937	1.0000

Kebutuhan Air Untuk menurunkan Suhu dari 500 ^{o} C menjadi 200 ^{o} C

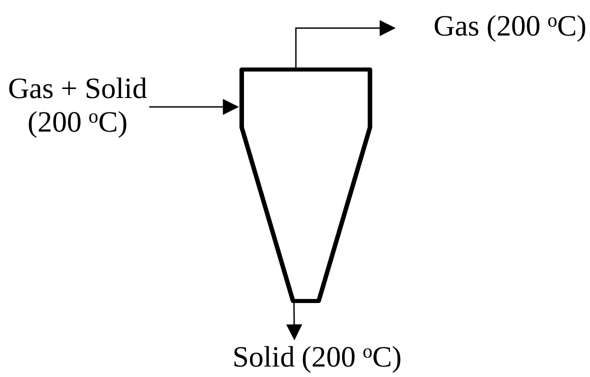
H2O = 110996.76 Kg/jam

Neraca Massa :

Masuk	Kg/jam	Keluar	Kg/jam
* Campuran produk		C	8838.3838
C	8838.383838	H2	1546.7172
H_2	1546.7172	N2	145253.4550
N_2	145253.455	SO2	317.2176
O2	14666.0927	O2	14666.0927
SO2	317.2176	CO2	26182.8283
CO_2	26182.8283	H2O	112359.4991
H_2O	112359.4991		309164.1937
	309164.1937		
		* Air pendingin dari utilitas	
* Air pendingin dari utilitas		H_2O naik	110996.7600
H_2O	110996.7600		
total	420160.9538	total	420160.9538

3. CYCLONE -1

Fungsi : memisahkan solid dan gas



Kondisi operasi :

Suhu operasi = 200 ^oC

Tekanan oper = 1 atm (atmospheric pressure)

Feed masuk :

Komponen	Berat (Kg/jam)
C	8838.3838
H2	1546.7172
N2	145253.4550
SO2	317.2176
O2	14666.0927
CO2	26182.8283
H2O	223356.2591
Total	420160.9538

Efisiensi pemisahan solid = 99% Perry. Gas Solid Separation 17-31 Edisi 8

Berat solid (carbon black) = 8838.3838 Kg/jam

Efisiensi = 99%

Solid tertangkap = 99% x 8838.3838 = 8750.0000 Kg/jam

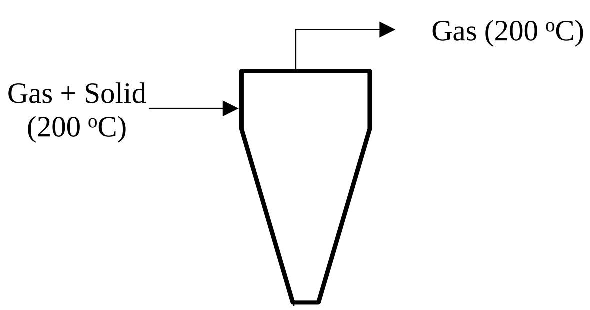
Solid yang lolos = 8838.383838 - 8750.0000 = 88.3838 Kg/jam

Neraca Massa :

Masuk	Kg/jam	Keluar	Kg/jam
* Campuran produk		* Produk bawah ke conveyor	
C	8838.3838	C	8750.0000
H2	1546.7172	* Produk atas	
N2	145253.4550	C	88.3838
SO2	317.2176	H2	1546.7172
O2	14666.0927	N2	145253.4550
CO2	26182.8283	SO2	317.2176
H2O	223356.2591	O2	14666.0927
		CO2	26182.8283
		H2O	223356.2591
total	420160.9538	total	420160.9538

4. CYCLONE -2

Fungsi : memisahkan solid dan gas



Solid (200 ^oC)

Kondisi operasi :

Suhu operasi = 200 ^oC

Tekanan oper = 1 atm (atmospheric pressure)

Feed masuk :

Komponen	Berat (Kg/jam)
C	88.3838
H2	1546.7172
N2	145253.4550
SO2	317.2176
O2	14666.0927
CO2	26182.8283
H2O	223356.2591
Total	411410.954

Efisiensi pemisahan solid	=	99%	**C.M. van 't Land DRYING IN THE PROCESS INDUSTRY 16 Hal 393**			
Berat solid (carbon black)	=	88.3838	Kg/jam			
Efisiensi	=	99%				
Solid tertangkap	=	99%	x	88.38383838	=	87.5000 Kg/jam
Solid yang lolos	=	88.38383838	-	87.5	=	0.8838 Kg/jam

Neraca Massa :

Masuk	Kg/jam	Keluar	Kg/jam
* Campuran produk		* Produk bawah ke conveyor	
C	88.3838	C	87.5000
H2	1546.7172	* Produk atas	
N2	145253.4550	C	0.8838
SO2	317.2176	H2	1546.7172
O2	14666.0927	N2	145253.4550
CO2	26182.8283	SO2	317.2176
H2O	223356.2591	O2	14666.0927
		CO2	26182.8283
		H2O	223356.2591
total	411410.9538	total	411410.9538

5. SCREW CONVEYOR

Fungsi : Membawa carbon black dari Cyclone menuju peletizer

kondisi Operasi :

Suhu rata - rata = 200 ^{o}C
Tekanan operasi = 1 atm (atmospheric pressure)
Total carbon = feed dari Cyclone

Terdiri dari :

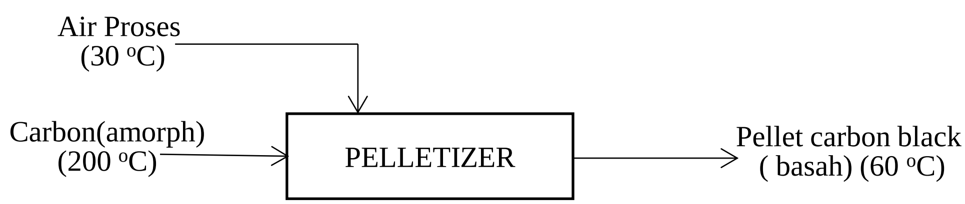
Komponen	Cyclone-1	cyclone -2	total
C	8750.0000	87.5000	8837.5000

Neraca Massa :

masuk	Kg/jam	keluar	Kg/jam
*Carbon black dari Cyclone		*Carbon black ke Pelletizer	
C	8837.5000	C	8837.5
Total	8837.5000	Total	8837.5000

6. PELLETIZER

Fungsi : Membuat pellet carbon black dengan metode basah



Kondisi operasi :

Tekanan operasi = 1 atm (atmospheric pressure)
Suhu keluar rata - rata = 60 ^{o}C
Diameter pellet carbon black = 1 mm
Panjang pellet carbon black = 5 mm
Tipe alat = wet pelletizer

Feed Masuk :

Komponen	Berat (Kg/jam)
C	8837.5000

Kadar air pada produk pellet = 30% berat **US.Patent. (US6807749)**
Maka kadar produk = 70% berat **US.Patent. (US6807749)**
Berat feed = 8837.5000 Kg/jam

Berat produk = $\frac{8837.5000}{70\%}$ = 12625.0000 Kg/jam

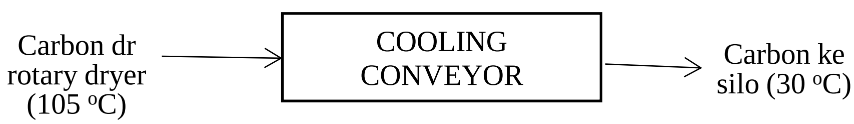
Penambahan air proses = berat produk akhir - berat feed
= 12625.0000 - 8837.5000
= 3787.5000 Kg/jam

Neraca Massa:

Masuk	Kg/jam	Keluar	Kg/jam
* Carbon Black dari screw Conve		* Carbon Black ke rotary Dryer	
C	8837.5	C	8837.5
* Air proses dari utilitas		H_2O	3787.5000
H_2O	3787.5000		
	12625.0000		12625.0000

10. COOLING CONVEYOR

fungsi : mendinginkan carbon black dan menuju ke silo



Terdiri dari :

Komponen	dari rotary dryer
C	8837.500
H_2O	26.592
	8864.092

Neraca massa :

Masuk	Kg/jam	Keluar	Kg/jam
* Carbon black dari rotary Dryer		* Carbon black ke silo	
C	8837.500	C	8837.5000
H_2O	26.592	H_2O	26.592
	8864.092		8864.0923

8864.0923	8864.0923

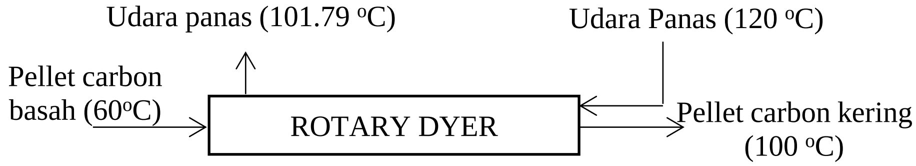
Kapasitas produksi :

penentuan kapasitas produksi	:			
carbon black yang di hasilkan	:	8864.0923	Kg/jam	
kapasitas yang di harapkan	:	70000	Ton/Tahun	
		8838.383838	Kg/jam	
maka faktor scale up	:	8838.3838 / 8837.5000	=	1

46.80382979

8. ROTARY DRYER

Fungsi : Mengeringkan pellet carbon dengan bantuan udara panas



Kondisi Operasi :

Tekanan operasi	=	1 atm		(atmospheric pressure)
Suhu Pengeringan	=	120	^oC	
Kadar air pada produk	=	0.30%		

Feed Masuk :

Komponen	Berat (Kg/jam)
C	8837.5
H_2O	3787.5
	12625.0000

30

Produk Solid :

Berat Solid = 8837.5 Kg/jam

Produk Solid = 8837.5 = 8837.500 Kg/jam

Total Produk selain H_2O

C = 8837.5000 Kg/jam

Kadar air pada produk = 0.30%

Maka berat produk kering = 99.7%

Berat bahan non H_2O = 8837.5000 Kg/jam

Berat produk = 8837.5000 X $\frac{100\%}{99.7\%}$ = 8864.0923 Kg/jam

H_2O pada produk = Berat produk - berat produk non H_2O Kg/jam

= 8864.0923 - 8837.5000 = 26.5923 Kg/jam

Penguapan H_2O = H_2O pada feed - H_2O pada produk

= 3787.5000 - 26.5923

= 3760.9077 Kg/jam

= 8292.80153 lb/jam

Udara :

Komponen	%Berat	BM
Nitrogen	78.08%	28.014
Oksigen	20.95%	32.000
Argon	0.93%	39.948
Neon	0.0018%	20.180
Helium	0.0005%	4.000
CO	0.00017%	28.011
Karbondioksida	0.0380%	44.011

Berat Molekul Udara = ((0,7808 x 28,014)+(0,2095 x 32)+(0,0093x 39,948)+ (0,0018% x 20,180)+(0,0005% x 4)+(0,00017% x 28,011)+ (0,0380% x 44,011))

= 28.9660 kg/kmol

Penentuan Relative Humidity :

Udara masuk pada 30 ℃ = 86 ^oF

Dimana : P_V = Tekanan parsial uap air (KPa)

P_{VS} = Tekanan uap air jenuh (KPa)

Relative Humidity $= 100 \times \frac{P_V}{P_{VS}}$

$= 100 \times \frac{2.85}{4.246}$ **(Geankoplis, Steam Table Appendix A.2-9)**

= 67 %

Dari data Relative Humidity dan suhu masuk pada 30℃ = 86^{o}F dapat diperoleh :

Humidity = 0.019 lb uap air/lb udara kering **(Himmelblau Page 529)**

W_G = 0.019 lb uap air/lb udara kering

Massa Udara yang diumpankan = $\frac{8292.80153}{0.0190}$ = 436463.2384 lb/jam

= 197942.5117 kg/jam

Perhitungan Suhu Wet Bulb (t_w)

$W_W - W_G = \frac{h_G}{29 \times \lambda \times k_G \times P} (t_G - t_W)$ **(Badger Page 383 persamaan 8 - 29)**

Dengan: W_W = Humidity pada temperature wet bulb (udara keluar), lb air/lb udara kering

W_G = Humidity pada temperature dry bulb (udara masuk), lb air/lb udara kering

h_G = heat transfer coefficient dari udara ke permukaan basah

t_G = suhu udara panas masuk ke dryer = 248 ^oF

t_W = suhu wet bulb

k_G = mass transfer coefficient dari permukaan basah ke udara

P = tekanan operasi

λ = Panas laten udara basah pada temperature wet bulb, Btu/lb (Steam Table Smith Vannes)

Digunakan untuk kandungan air dalam uap

$$\frac{h_G}{29 \times k_G \times P} = 0.26$$ **(Badger Page 384)**

Mencari t_w dengan cara trial :

Dipilih t_w sebesar = 104 ℃ = 219 ^oF

Maka λw pada suhu 104 ℃ = 219 oF = 965 Btu/lb

(McCabe 5[ed] Appendix 7 Saturated Steam and Water)

(Geankoplis Fig 9. 3-2

Digunakan untuk kandungan air dalam uap

$$\frac{h_G}{29 \times \lambda \times k_G \times P}(t_G - t_W) = \frac{0.26}{965.00} \times (248 - 219)$$

= **0.0078**

$W_W - W_G$ = 0.0078

Ww - 0.019 = 0.0078

Ww = 0.0078 + 0.019

= 0.0268

Check :

$$W_W - W_G = \frac{h_G}{29 \times \lambda \times k_G \times P}(t_G - t_W)$$

0.0268 - 0.019 = 0.0078

0.0078 = **0.0078** (memenuhi)

Jadi, asumsi t_W = 219 °F = 104 °C (benar atau memenuhi)

Pada t_w 219 °F = 104 °C didapatkan Ww sebesar **(Himmelblau Page 529)**

= 0.0458 lb uap air/lb udara kering

Check :

$$\text{massa udara yang diumpan} = \frac{8292.80153}{0.0458 - 0.0268}$$

= 436463.2384 lb/jam

= 197942.5117 kg/jam (memenuhi)

Kandungan Air = 0.0190 x 436463.2384

= 8292.802 lb

= 3760.908 kg

$$\text{Massa O2 Yang diumpankan} = \frac{20.95\% \times (436463 - 3760.91) \times 32}{28.9660}$$

= 100146.2551 kg

$$\text{Massa N2 Yang diumpankan} = \frac{78.08\% \times (436463 - 3760.91) \times 28}{28.9660}$$

= 326750.0307 kg

$$\text{Massa Ar Yang diumpankan} = \frac{0.93\% \times (436463 - 3760.91) \times 40}{28.9660}$$

= 5549.82 kg

$$\text{Massa Ne Yang diumpankan} = \frac{0.001800\% \times (436463 - 3760.91) \times 20}{28.9660}$$

= 5.42618 kg

$$\text{Massa He Yang diumpankan} = \frac{0.000500\% \times (436463 - 3760.91) \times 4}{28.9660}$$

= 0.29877 kg

$$\text{Massa CO Yang diumpankan} = \frac{0.0002\% \times (436463 - 3760.91) \times 28}{28.9660}$$

= 0.71134 kg

$$\text{Massa CO2 Yang diumpankan} = \frac{0.0380\% \times (436463 - 3760.91) \times 44}{28.9660}$$

= 249.831 kg

Udara :

Komponen	Berat (Kg)
Nitrogen	326750.031
Oksigen	100146.255
Argon	5549.8174
Neon	5.4262
Helium	0.2988
CO	0.7113
Karbondioksida	249.8305
TOTAL	197942.512

Scale Up = 1
TOTAL = 197962.308 kg kebutuhan udara

Neraca massa:

Masuk	Kg/jam	Keluar	Kg/jam
* Carbon Black dari pelletizer		* Carbon black ke cooling Conveyor	
C	8837.5	C	8837.500
H_2O	3787.5000	H_2O	26.592
	12625.0000		8864.092
		*limbah gas	
* Udara kering			
Udara	197962.308	H_2O	3760.908
(uap)		Udara	197962.308
			201723.216
	210587.308		210587.308

235778.674

=

APPENDIX B
PERHITUNGAN NERACA PANAS

Satuan : Kilogram
Waktu operasi : 1 jam proses
suhu refference : 25 ºC = 298 ºK
Basis
1 Tahun Kerja : 330 hari
1 hari kerja : 24 jam
Kapasitas : 70000 ton/tahun

Persamaan panas untuk kondisi aliran steady; Q = $\Delta H = H_2 - H_1$

ΔH = n x Cp x ΔT

$$\Delta H = n \int_{Tref}^{T} Cp\, dT$$

$$= \frac{\text{kmol}}{\text{jam}} \times \frac{\text{kkal}}{\text{kmol.k}} \times K = \frac{\text{kkal}}{\text{Jam}}$$

$$Cp = A + B.T + C.T^2 + D.T^3 + E.T^4$$

Dengan ; ΔH = panas ; kmol
n = berat bahan ; kmol
Cp = spesific heat ; kkal/kmol.K
Treff = suhu reffrerence ; kelvin
Cp = Spesifik heat (kkal/kmol.Kelvin)
A,B,C,D,E = Konstanta
T = Suhu Bahan (Kelvin)
(Himmelblau 5 ed ; 386)

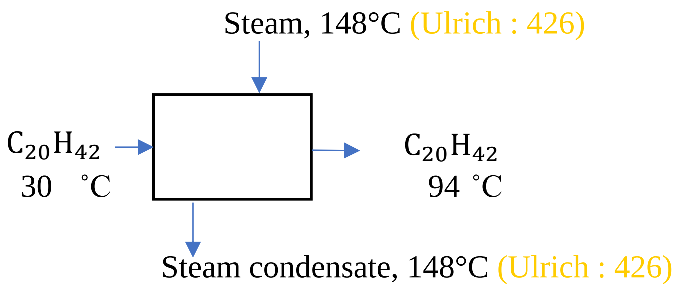
Data konstanta A,B,C,D

Komponen	BM	A	B	C	D	E	literature
$C_{20}H_{42}$	282	235.0000	-	-	-	-	-
C	12	2.6730	0.0026	116900.0000	-	-	perry 7ed;T2-194
CO_2	44	10.3400	0.0027	195500.0000	-	-	perry 7ed;T2-194
H_2	2	6.6200	0.0008	-	-	-	perry 7ed;T2-194
O_2	32	8.2700	0.0003	187700.0000	-	-	perry 7ed;T2-194
N_2	28	6.5000	0.0010	-	-	-	perry 7ed;T2-194
Udara	28.84	6.8720	0.0008	-	-	-	perry 7ed;T2-201
$H_2O_{(g)}$	18	8.2200	0.00015	0.0013	-	-	perry 7ed;T2-194
$H_2O_{(l)}$	18	8.71200	0.00125	0.0000002	-	-	perry 6ed;T2-194
S	32	3.63000	0.0064	-	-	-	perry 6ed;T2-194

SO2	64	7.70000	0.0053	0.00000083	-	-	perry 6ed;T2-194

1. HEATER RESIDUAL OIL

Fungsi : Memanaskan bahan Baku menjadi suhu 94 ºC



Neraca energi total

ΔH bahan masuk + Q supply = ΔH bahan keluar + Q loss

T saat masuk heater	=	30	°C =	303.15	°K
T refference	=	25	°C =	298.15	°K
T saat keluar heater	=	94	°C =	367.15	°K

Entalpi bahan masuk :

1. Entalpi bahan masuk ke heater residual oil pada suhu 30°C, ΔH= n Cp . ΔT

Massa bahan :

Komponen	Berat (kg/j)	BM	kmol/j
C20H42	16568.9566	282	58.7552
H_2	1980.7220	2	990.3610
S	158.6088	32	4.9565
O_2	120.8448	32	3.7764
N_2	52.8696	28	1.8882
Total	18882.0018		1059.7373

Entalpi masuk

Panas masuk ke Heater Residual Oil : 30 ºC

T saat masuk heater : 303.2 ºK ; T refference : 298.15 ºK

Cp C20H42 30ºC = A + B. T + C. T^2

= A x (T94 - T_{ref}) + (B x ($T94^2$ - Tref ^{2}))/2 +(C x ($T94^2$ - Tref ^{2})

= 1175.0000 kkal/K.kmol (Perry 7ed ; T.2-194)

Cp S 30ºC = A + B. T + C. T^2

= A x (T94 - T_{ref}) + (B x ($T94^2$ - Tref ^{2}))/2 +(C x ($T94^2$ - Tref ^{2})

= 27.7708 kkal/K.kmol (Perry 7ed ; T.2-194)

Cp H_2 30ºC = A + B. T

= A x (T30 - T_{ref}) + (B x ($T30^2$ - $Tref^2$))/2
= 34.3176 kkal/k,kmol

Cp O_2 30°C = A + B. T + C. T^2
= A x (T94 - T_{ref}) + (B x ($T94^2$ - Tref ^{2}))/2 +(C x ($T94^2$ - Tref ^{2})
= 52.1213 kkal/k.kmol

Cp N_2 30°C = A + B. T
= A x (T30 - T_{ref}) + (B x ($T30^2$ - $Tref^2$))/2
= 34.0033 kkal/k.kmol

Entalpi keluar
Panas masuk ke Heater Residual Oil : 94 ºC
T saat keluar dari heater : 367.15 ºK ; Trefference : 298.15 ºK

Cp C20H42 94°C = A + B. T + C. T^2
= A x (T94 - T_{ref}) + (B x ($T94^2$ - Tref ^{2}))/2 +(C x ($T94^2$ - Tref ^{2})
= 16215 kkal/K.kmol

Cp S 94°C = A + B. T + C. T^2
= A x (T94 - T_{ref}) + (B x ($T94^2$ - Tref ^{2}))/2 +(C x ($T94^2$ - Tref ^{2})
= 397.3682 kkal/K.kmol

Cp H_2 94°C = A + B. T
= A x (T94 - T_{ref}) + (B x ($T94^2$ - $Tref^2$))/2
= 475.3718 kkal/K.kmol

Cp O_2 94°C = A + B. T + C. T^2
= A x (T94 - T_{ref}) + (B x ($T94^2$ - Tref ^{2}))/2 +(C x ($T94^2$ - Tref ^{2})
= 694.8655 kkal/k.kmol

Cp N_2 94°C = A + B. T
= A x (T94 - T_{ref}) + (B x ($T94^2$ - $Tref^2$))/2
= 471.4529 kkal/k.kmol

Entalpi bahan masuk pada suhu 30°C (303,15 K)

ΔH C20H42 = $n\int_{Tref}^{T} Cp\,dT$
= 58.7552 x 1175.0000
= 69037.3192 kkal/jam

$\Delta H\ S \quad = n\int_{Tref}^{T} Cp\ dT$

= 4.9565 x 27.7708
= 137.6467 kkal/jam

$\Delta H\ H_2 \quad = n\int_{Tref}^{T} Cp\ dT$

= 990.3610 x 34.3176
= 33986.8447 kkal/jam

$\Delta H\ O_2 \quad = n\int_{Tref}^{T} Cp\ dT$

= 3.7764 x 52.1213
= 196.8309 kkal/jam

$\Delta H\ N_2 \quad = n\int_{Tref}^{T} Cp\ dT$

= 1.8882 x 34.0033
= 64.2049 kkal/jam

Total Entalpi masuk = $\Delta H\ C + \Delta H\ H_2 + \Delta H\ S + \Delta H\ O_2 + \Delta H\ N_2$
= 103422.8464 kkal/jam

Entalpi bahan keluar pada suhu 94°C (368.15 K)

ΔH C20I = $n\int_{Tref}^{T} Cp\ dT$

= 58.7552 x 16215.0
= 952715.005 kkal/jam

$\Delta H\ S \quad = n\int_{Tref}^{T} Cp\ dT$

= 4.9565 x 397.3682
= 1969.5658 kkal/jam

$\Delta H\ H_2 \quad = n\int_{Tref}^{T} Cp\ dT$

= 990.3610 x 475.37181
= 470789.6979 kkal/jam

$\Delta H\ O_2 \quad = n\int_{Tref}^{T} Cp\ dT$

= 3.7764 x 694.86553

= 2624.0904 kkal/jam

$\Delta H\ N_2 = n \int_{Tref}^{T} Cp\ dT$

= 1.8882 x 471.45285
= 890.1974 kkal/jam

Total Entalpi keluar = $\Delta H\ C + \Delta H\ H_2 + \Delta H\ O_2 + \Delta H\ N_2$
= 1428988.5567 kkal/j

Neraca energi total
Entalpi bahan masuk + Q supply = Entalpi bahan keluar + Q loss
Q loss maksimum = 10% (Ulrich,432)
Asumsi Q loss = 5% dari supply
103422.8 + Q = 1428988.5567 + 5% Q supply
Q = 1395332.3266
Q loss = 69766.6163
Q total = 1465098.9429

Kebutuhan steam Dipakai steam pada tekanan 4.5 atm dengan suhu 148ºC (Ulrich ; 426)
λ_{steam} = 2119.5000 kJ/kg interpolasi antara 40 sama 50 atm
= 506.5732 kkal/kg

Q steam = $M_{steam} \cdot \lambda$ (panas laten)

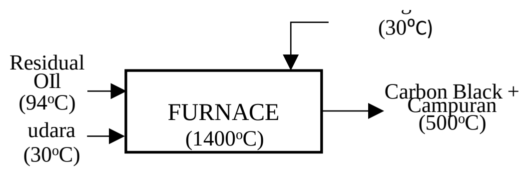
$M_{steam} = \dfrac{Q_{steam}}{\lambda\ steam}$

$= \dfrac{1465098.9429}{506.5732} = 2892.1761$ kg

Masuk	kkal/jam	Keluar	kkal/jam
Residual Oil		Residual Oil	
C	69037.3192	C	952715.0052
H_2	33986.8447	H_2	470789.6979
S	137.6467	S	1969.5658
O_2	196.8309	O_2	2624.0904
N_2	64.2049	N_2	890.1974
Q supply	1395332.3266	Qloss	69766.6163
Total	1498755.1730	Total	1498755.1730

2. FURNACE
Fungsi : Pembakaran residual oil menjadi carbon black
a.

cooling water



Kondisi Operasi :

Tekanan Operasi = 5 atm (karakteristik alat)

Suhu = 1400 ^{o}C = 2552 ºF

Neraca Energi Total pada saat reaksi :

$H_{reaktan}$ + $\Delta H_{g\ eksotermis}$ = H produk

Entalpi reaktan:

1. Entalpi residual oil pada suhu 94 ºC

T = 367.15 ºK ; Trefference = 298.15 ºK

Cp C20H42 ! = A

= A x(T94 - Tref)

= 16215 kkal/K.kmol

Cp S 94^{o}C = A + B. T

= A x ($T94 - T_{ref}$) + (B x ($T94^2$ - $Tref^2$))/2

= 397.3682 kkal/k.kmol

Entalpi combustion gases (kkal/kg kmol)

temp (C)	H2	O2	N2	H2O(g)	udara	SO2	CO2
25	172.4084	175.93985	175.032	201.26	173.51	235.18	217.97
94	646.4897	664.17694	654.715	758.59	654.72	923.53	864.29
1400	10212.33	11405.411	10811.5	13645	10899	17367	17424
500	3494.144	3744.5274	3566.5	4254.4	3593.2	5560.4	5342.4
200	1386.492	1630.1812	1398.67	1630.2	1401.5	2039.3	1923.8

Himmelblau, T-D.6

ΔH C20H42 = $n\int_{Tref}^{T} Cp\ dT$

= 58.7552 x 16215.0000

= 952715.0052 kkal/jam

ΔH S = $n\int_{Tref}^{T} Cp\ dT$

= 4.9565 x 397.3682

= 1969.5658 kkal/jam

$\Delta H\ H_2$ = 990.3610 x 474.0814
= 469511.6841 kkal/jam

$\Delta H\ O_2$ = 1378.4866 x 488.2371
= 673028.27 kkal/jam

$\Delta H\ O_2$ = 3.7764 x 488.2371
= 1843.7787 kkal/jam

$\Delta H\ N_2$ = [n x (ΔH^ 94°C - ΔH^ 25°C)]

= 1.8882 x 479.6834
= 905.7383 kkal/jam

$\Delta H\ N_2$ = [n x (ΔH^ 94°C - ΔH^ 25°C)]

= 5185.7352 x 479.683
= 2487511.0706 kkal/jam

Total ΔH = 4587485.1102 kkal/jam

Total Entalpi reaktan : 4587485.1102 kkal/jam

1. Entalpi untuk perhitungan bahan bakar pada suhu 1400 ºC
T = 1673.15 ºK ; T94 = 367.15 ºK

Cp S 94oC = $A + B.\ T + C.\ T^2$
= $A \times (T94 - T_{ref}) + (B \times (T94^2 - Tref^{\ 2}))/2 + (C \times (T94^2 - Tref^{\ 2})$
= 13267.6018
kkal/K.kmol

Cp O_2 94oC = $A + B.\ T + C.\ T^2$
= $A \times (T94 - T_{ref}) + (B \times (T94^2 - Tref^{\ 2}))/2 + (C \times (T94^2 - Tref^{\ 2})$
= 11543.4091 kkal/k.kmol

Cp N_2 94oC = $A + B.\ T$
= $A \times (T94 - T_{ref}) + (B \times (T94^2 - Tref^2))/2$
= 471.45285 kkal/k.kmol

Cp C 94oC = $A + B.\ T + C.\ T^2$
= $A \times (T95 - T_{ref}) + (B \times (T95^2 - Tref^{\ 2}))/2 + (C \times (T95^2 - Tref^{\ 2})$
= 306910 kkal/K.kmol

ΔH C = $n \int^{T} Cp\ dT$

$\int_{Tref}$ ...

= 58.7552 x 306910

= 18032547.78 kkal/jam

ΔH O_2 = $n\int_{Tref}^{T} Cp\, dT$

= 3.7764 x 11543.4091

= 43592.5343 kkal/jam

ΔH S = $n\int_{Tref}^{T} Cp\, dT$

= 4.9565 x 13267.6018

= 65761.2062 kkal/jam

ΔH N_2 = $n\int_{Tref}^{T} Cp\, dT$

= 1.8882 x 471.453

= 890.1974 kkal/jam

Total H reaktan = 18142791.7168

Q supply = 18142791.7168

Entalpi produk keluar furnace

1.Entalpi didalam furnace = 500 ^oC = 773.15

T = 773.2 ^oK ; T_2 = 25 ^oC = 298.15 ^oK

a. Entalpi bahan produk

Cp C 500^{o}C = A + B. T + C. T^2

= A x (T1400 - T_{ref}) + (B x ($T1400^2$ - Tref ^{2}))/2 +(C x ($T1400^2$ - Tref ^{2})

= 2176.4130 kkal/K.kmol

ΔH C = $n\int_{Tref}^{T} Cp\, dT$

= 736.5320 x 2176.4130

= 1602997.7956 kkal/jam

ΔH H_2 = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 773.3586 x 3321.7360

= 2568893.0579 kkal/jam

ΔH N_2 = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 1.8882 x 3391.4640

= 6403.7630 kkal/jam

$\Delta H\ CO_2$ = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 595.0643 x 5124.3992
= 3049346.9393 kkal/jam

$\Delta H\ SO_2$ = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 4.9565 x 5325.2305
= 26394.6405 kkal/jam

$\Delta H\ O_2$ = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 3.7764 x 3568.5875
= 13476.4152 kkal/jam

$\Delta H\ H_2O$ = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 632.7479 x 4053.1342
= 2564612.2905 kkal/jam

$\Delta H\ O_2$ = [n x (ΔH^ 500°C - ΔH^ 25°C)]

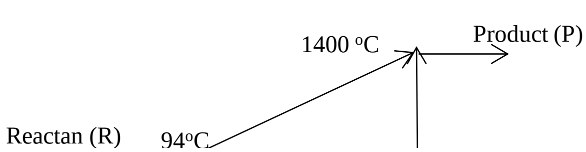
= 454.5390 x 3568.5875
= 1622062.1915 kkal/jam

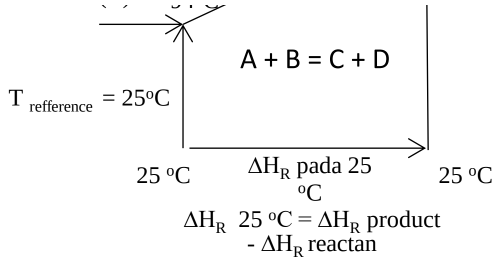
$\Delta H\ N_2$ = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 5185.7352 x 3391.4640
= 17587234.2926 kkal/jam

Total ΔH produk = 29041421.3861 kkal/jam

Panas Reaksi
Diagram Panas Reaksi





Panas Reaksi Standard 25°C

ΔH reaksi pada suhu standard = ΔH_g = $\Delta H_{g\ produk}$ + $\Delta H_{g\ reaktan}$ + 21 $H_2O_{(g)}$

Reaksi yang terjadi

Reaksi 1 : $C_{20}H_{42(l)} \longrightarrow 20\ C_{(amorph)} + 21\ H_{2(g)}$

Reaksi 2 : $C_{20}H_{42(l)} + 61/2\ O_{2(g)} \longrightarrow 20\ CO_{2(g)}$

Reaksi 3 : S + O2 $\longrightarrow$ SO2

Data ΔH komponen (perry 7[ed]; T.2-220)

Komponen	ΔH (kkal/kmol)
$C_{20}H_{42}$	-2120.00
O_2	0
CO_2	-94.052
H_2O	-68.3174
C	0
H_2	0
SO_2	-70.94
S	0
O_2	0

Tinjauan Panas Reaksi

Reaksi : $C_{20}H_{42(l)} + 61/2\ O_{2(g)} \longrightarrow 20\ CO_{2(g)} + 21\ H_2O_{(g)}$

mol	$C_{20}H_{42}$	30.1309	kmol
mol	O_2	918.9910468	kmol
mol	CO_2	602.6170799	kmol
mol	$H_2O_{(g)}$	632.7479339	kmol

$\Delta H_{R\ 298.15}$ = (602.617 x -94.052) + (632.74793 x -68.32

- (30.131 x -2120) + 918.99105 x 0)

= -36027.6248 kkal

Reaksi 2 : $C_{20}H_{42(l)} \longrightarrow 20\ C_{(amorph)} + 21\ H_{2(g)}$

mol $C_{20}H_{42}$ = 36.8266 kmol
mol C = 736.532 kmol
mol H_2 = 773.3586 kmol

$\Delta H_{R\ 298.15}$ = (736.5319865 x 0) + (773.3585859 x 0)-(36.8 x -2120)
= -78072.3920

Reaksi 3 : S + O2 $\longrightarrow$ SO2

mol S = 4.9565 kmol
mol O2 = 459.50 kmol
mol SO2 = 4.9565 kmol

$\Delta H_{R\ 298.15}$ = (4.9565 x -70.94)-(4.9565 x 0)+(459.50 x 0)
= -351.616 kkal

$\Delta H_{reaksi\ I}$ = -36027.6248 kkal
$\Delta H_{reaksi\ II}$ = -78072.3920 kkal
$\Delta H_{reaksi\ III}$ = -351.6159 kkal
$\Sigma\ \Delta H_R$ = -114451.6327 kkal
= 114451.6327 kkal (eksotermis)

Neraca Energi Total furnace :

Asumsi Kehilangan panas = 10% dari Q Supply (Ulrich :432)

H masuk + ΔH reaksi (eksotermis) +Q Supply = H keluar +Q loss

Q supply = 27043871.83
Q loss = 2704387.183

b. Entalpi buat perhitungan air pendingin

1.Entalpi didalam furnace = 1400 ^oC = 1673.2 ^oK

T = 1673 ^oK ; T_2 = 500 ^oC = 773.15 ^oK

a. Entalpi bahan masuk

Cp C 1400^oC = A + B. T + C. T^2
= A x (T1400 - T_{ref}) + (B x (T1400^2 - Tref ^{2}))/2 +(C x (T1400^2 - Tref ^{2})
= 5367.9166 kkal/K.kmol

$$\Delta H\ C = n\int_{Tref}^{T} Cp\ dT$$

= 736.5320 x 5367.9166
= 3953642.2918 kkal/jam

$\Delta H\ H_2$ = [n x (ΔH^ 1400°C - ΔH^ 25°C)]
= 773.3586 x 10039.9231
= 7764460.7597 kkal/jam

$\Delta H\ N_2$ = [n x (ΔH^ 1400°C - ΔH^ 25°C)]
= 1.8882 x 10636.4720
= 20083.7884 kkal/jam

$\Delta H\ CO_2$ = [n x (ΔH^ 1400°C - ΔH^ 25°C)]
= 595.0643 x 17206.3292
= 10238871.9100 kkal/jam

ΔH SO2 = [n x (ΔH^ 1400°C - ΔH^ 25°C)]
= 4.9565 x 17131.8172
= 84914.2885 kkal/jam

$\Delta H\ O_2$ = [n x (ΔH^ 1400°C - ΔH^ 25°C)]
= 3.7764 x 11229.4716
= 42406.9807 kkal/jam

$\Delta H\ H_2O$ = [n x (ΔH^ 1400°C - ΔH^ 25°C)]
= 632.7479 x 13443.7304
= 8506492.6053 kkal/jam

$\Delta H\ O_2$ = [n x (ΔH^ 1400°C - ΔH^ 25°C)]
= 454.5390 x 11229.4716
= 5104232.7662 kkal/jam

$\Delta H\ N_2$ = [n x (ΔH^ 1400°C - ΔH^ 25°C)]
= 5185.7352 x 10636.4720
= 55157927.2454 kkal/jam

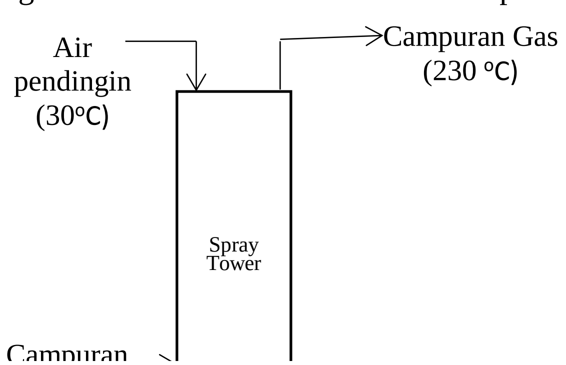
Total H air pendingin = 90873032.6360 kkal/jam
Q terserap air pendingin = 90873032.6360 kkal/jam
Cp air liquid = 1 kkal/kmol. K

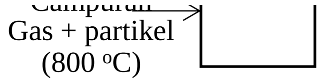
Q = m cp AT
m = 100970.0363

Masuk	kkal/jam	Keluar	kkal/jam
* H Residual oil		* H campuran produk	
$C_{20}H_{42}$	952715.0052	C	1602997.7956
S	1969.5658	H_2	2568893.0579
H_2	469511.6841	N_2	6403.7630
O2	1843.7787		
N_2	905.7383	O_2	13476.4152
Total			
		SO2	26394.6405
O2	673028.2675	N_2	17587234.2926
N_2	2487511.0706	CO_2	3049346.9393
		H_2O	2564612.2905
		O_2	1622062.1915
Q Supply	27043871.8257	Q_{loss}	2704387.1826
$\Delta H_{g\ raksi}$	114451.63		
Total	31745808.5686	Total	31745808.5686

3. Spray Tower

Fungsi = menurunkan suhu bahan sampai dengan 200 °C





Neraca Energi Total

H = H_{keluar} + Q terserap

1. Entalpi campuran gas produk furnace pada suhu = 500 °C

T = 773.15 °K ; Trefferen = 298.15 °K

H = m

Cp C 500°C = A + B. T + C. T^2

= A x ($T800 - T_{ref}$) + (B x ($T800^2$ - Tref ^{2}))/2 +(C x ($T800^2$ - Tref ^{2})

= 2176.4130 kkal/K.kmol

ΔH C = $n\int_{Tref}^{T} Cp\, dT$

= 736.5320 x 2176.4130

= 1602997.7956 kkal/jam

ΔH H_2 = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 773.3586 x 3321.74

= 2568893.0579 kkal/jam

ΔH N_2 = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 5187.6234 x 3391.4640

= 17593638.0556 kkal/jam

ΔH CO_2 = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 595.0643 x 5124.3992

= 3049346.9393 kkal/jam

$\Delta H\ O_2$ = [n x (ΔH^ 500°C - ΔH^ 25°C)]

= 458.3154 x 3568.5875
= 1635538.6067 kkal/jam

$\Delta H\ SO_2$ = [n x (ΔH^ 500°C - ΔH^ 25°C)]
= 4.9565 x 5325.2305
= 26394.6405 kkal/jam

$\Delta H\ H_2O$ = [n x (ΔH^ 500°C - ΔH^ 25°C)]
= 6242.194 x 4053.1342
= 25300451.5738 kkal/jam

Total ΔH = 51777260.6694 kkal/jam

Total entalpi masuk = 51777260.6694 kkal/jam

Entalpi keluar
1. Entalpi campuran gas ke cyclone pada suhu : 200 ^oC
T = 473.15 ^oK ; Treff = 298.15 ^oK

Cp C 200^oC = $A + B.\ T + C.\ T^2$
= $A \times (T200 - T_{ref}) + (B \times (T200^2 - Tref^2))/2 + (C \times (T200^2 - Tref^2)$
= 789.4101 kkal/K.kmol

ΔH C = $n \int_{Tref}^{T} Cp\ dT$
= 736.5320 x 789.4101
= 581425.7551 kkal/jam

$\Delta H\ H_2$ = [n x (ΔH^ 200°C - ΔH^ 25°C)]

= 773.3586 x 1214.0834
= 938921.8469 kkal/jam

$\Delta H\ N_2$ = [n x (ΔH^ 200°C - ΔH^ 25°C)]

= 5187.6234 x 1223.6426
= 6347796.9583 kkal/jam

$\Delta H\ CO_2$ = [n x (ΔH^ 200°C - ΔH^ 25°C)]

= 595.0643 x 1705.7864
= 1015052.5417 kkal/jam

$\Delta H\ O_2$ = [n x (ΔH^ 200°C - ΔH^ 25°C)]

= 458.3154 x 1454.2414
= 666501.2210 kkal/jam

$\Delta H\ SO2$ = [n x (ΔH^ 200°C - ΔH^ 25°C)]

= 4.9565 x 1804.0982
= 8942.0587 kkal/jam

$\Delta H\ H_2O$ = [n x (ΔH^ 200°C - ΔH^ 25°C)]

= 6242.1944 x 1428.9193
= 8919592.2796 kkal/jam

H total = 18478232.6612

Neraca Energi Total :

H masuk = H keluar +Q loss

Q loss = 33299028.0082

Entalpi air pendingin

Suhu campuran gas masuk = 500 C
Suhu air pendingin masuk = 30 C
Suhu air pendingin Keluar : = 200 C
Cp air yang digunakan seb 1 Kkal /kg ***(Perry 6ed; fig 3-11)***

Q a = m . Cp .Δ T

$$m = \frac{Q}{Cp \quad (T2-T1)}$$

Kebutuhan Air = 110996.76 kg

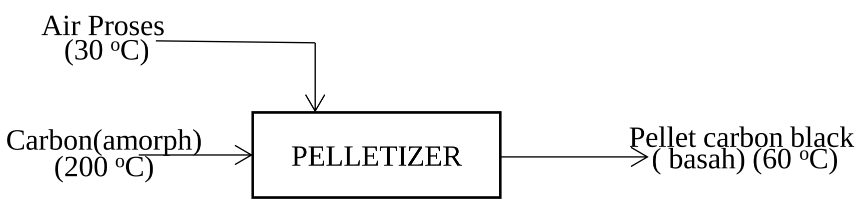
Neraca Energi

Masuk Kkal/jam	Keluar Kkal/jam
* Campuran produk	* produk Atas

C	1602997.7956	C	581425.7551
H_2	2568893.0579	H_2	938921.8469
N_2	17593638.0556	N_2	6347796.9583
CO_2	3049346.9393	CO_2	1015052.5417
H_2O	25300451.5738	H_2O	8919592.2796
SO2	26394.6405	SO2	8942.0587
O_2	1635538.6067	O_2	666501.2210
Total	51777260.6694	Total	18478232.6612
		Q loss	33299028.0082
total	51777260.6694	total	51777260.6694

4. PELLETIZER

Fungs : membuat pellet carbon black dengan metode basah



Kondisi Operasi

Tekanan 1 atm

Suhu keluar rata rata 60 ^oC

Neraca energi total :

H ma = H keluar + Q terserap

Entalphi carbon black dari screw conveyor 200 ºC

T = 473.15 ºK ; Trefference = 298.15 ºK

Cp C 230^{o}C = A x (T230 - T_{ref}) + (B x ($T230^2$ - Tref ^{2}))/2 +(C x ($T230^2$ - Tref ^{2})

= 789.4101 kkal/K.kmol

$$\Delta H\ C = n\int_{Tref}^{T} Cp\, dT$$

f

= 31.3387 x 789.41

= 24739.04734 kkal/jam

Total Entalpi masuk = 24739.0473 kkal/jam

Entalpi carbon black ke rotary dryer 60 ºC

T = 333.15 ^oK ; Trefference = 298.15 ^oK

Cp C = A x (T60 - T_{ref}) + (B x ($T60^2$ - Tref ^{2}))/2 +(C x ($T60^2$ - Tref ^{2})

= 163.6585 kkal/K.kmol

$$\Delta H\ C = n \int_{Tref}^{T} Cp\, dT$$

= 31.33865 x 163.6585

= 5128.8366 kkal/jam

Total Entalpi keluar = 5128.8366 kkal/jam

Neraca Energi Total :

H masuk = H keluar + Q terserap

Neraca Energi Total :

H masuk	=	H keluar	+ Q loss
24739.0473	=	5128.836601	+ Q loss
Q loss	=	19610.2107	

Dasar Pemilihan media Pendingin dan Kebutuhannya :

Digunakan air pendingin sebagai media pendingin karena nilai ΔT kecil.

Suhu air pendingin Masuk = 30 ºC (Ulrich;427)

Suhu air pendingin Keluar = 45 ºC (Ulrich;427)

Cp air yang digunakan sebagai pendingin = 1 Kkal /kg

Kebutuhan air pendingin

$Q = m.Cp.\Delta T$

$$m = \frac{Q}{Cp\ (T2-T1)} = 1307.3474\ \text{kg}$$

Neraca Energi

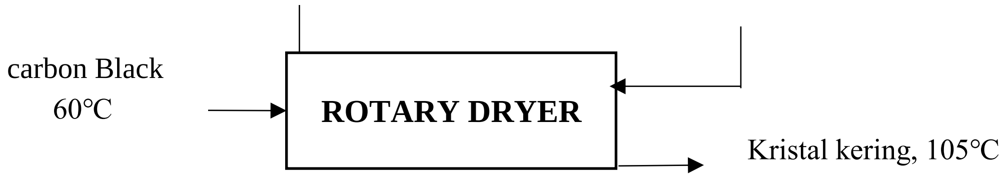
Masuk	Kkal/jam	Keluar	Kkal/jam
* Carbon Black dari screw Conveyor.		* Carbon Black ke rotary Dryer.	
C	24739.04734	C	5128.8366
		Q loss	19610.21074
Total	24739.0473	Total	24739.0473

5. ROTARY DRYER

Fungsi = Mengeringkan pellet carbon dengan bantuan udara panas

Udara panas

↑ 101.79 °C Udara panas, 120°C



Suhu masuk Rotary Dryer	=	60	°C	=	303.15	K
Suhu reference	=	25	°C	=	298.15	K
Suhu keluar Rotary Dryer	=	105	°C	=	378.15	K

Penentuan suhu keluar udara panas :

Suhu udara masuk = 120 °C = 248 °F

Relatif Humidity = 70 %

Humidity udara masuk (WG) 86^{0}F = 0.022 lb H2O/lb udara kering
(Himmelblau 6th Ed. Fig. 5.19a)

Asumsi : Suhu wet bulb = 96 °C = 206 °F

Perhitungan suhu wet bulb

Pers. Badger hal 383 :

$$W_W - W_G = \frac{h_G}{29 \times \lambda \times k_G \times P} (t_G - t_W)$$

Dengan :
- W_W = humidity pada 206 ^{0}F = 0,0124 lb air/lb udara kering
- W_G = humidity pada 86°F = 0,0012 lb air/lb udara kering
- h_G = heat transfer coefficient dari udara ke permukaan basah
- t_G = suhu udara panas masuk ke dryer = 248 °F
- t_W = suhu wet bulb = 206 °F
- k_G = mass transfer coefficient dari permukaan basah ke udara
- P = tekanan operasi
- λ = panas laten udara basah T = 206 ^{0}F =974,1 Btu/lb (Steam Table Smith Vannes)

Dari Badger hal 384 diketahui :

$$\frac{h_G}{29 \times \lambda \times k_G \times P} = 0.26$$

$$W_W - W_G = \frac{h_G}{29 \times \lambda \times k_G \times P} (t_G - t_W)$$

$$0{,}0124 - 0{,}0012 = \frac{0.26}{974.1} \times (248-206)$$

$$0.0112 = 0.0112 \quad \text{(memenuhi)}$$

Jadi, asumsi t_W = 206 °F = 96.67 °C (benar)

Perhitungan suhu udara panas keluar dari dryer (t_{G2}) :

$$NTU = \ln \left[\frac{(t_{G1} - t_W)}{(t_{G2} - t_W)} \right] \quad \text{(Badger ; 508)}$$

Dengan :
- t_{G1} = suhu udara masuk
- t_{G2} = suhu udara keluar

NTU = total Number of Transfer Unit
(1,5 s/d 2; Badger,p.508), ditetapkan = 1.5

maka :
$$1.5 = \ln \left[\frac{(248\text{-}206)}{(t_{G2}\text{-}206)} \right]$$

$$4.4817 = \frac{248.2 - 206}{t_{G2} - 206}$$

t_{G2} = 215.42 °F = 101.79 °C

Entalpi Bahan Masuk :

Bahan Masuk pada Suhu 60^{o}C = 333.15

ΔH C = n Cp ΔT

$$= n \int_{298.15}^{333.15} 2.673+0.0026T-116900T^2$$

$$= \frac{8837.5000}{12} \times 163.6584918$$

= 120527.6601 kkal / jam

ΔH air = n Cp ΔT

$$= n \int_{298.15}^{333.15} 7.7010+0.00045T+0.00000252T^2$$

$$= \frac{3787.5000}{18} \times 318.7297$$

= 67066.0384 kkal / jam

Total Entalpi Masuk = 187593.6985 kkal/jam

Entalpi Bahan Keluar :

Bahan Keluar ke Cooling Conveyor pada Suhu 105^{o}C = 378,15 K

ΔH C = 378.15

$$= n \int_{298.15} 2.673+0.0026T+-116900T^2$$

$$= \frac{8837.5000}{12} \times 367.5830$$

= 270709.5777 kkal / jam

ΔH air = n Cp ΔT

378.15

$$= n \int 7.7010+0.00045T+0.00000252T^2$$

$= \quad n \quad \int \; 7.7010+0.00045T+0.00000252T^2$

298.15

$= \dfrac{26.5923}{18} \times 730.7750$

$= 1079.6095$ kkal / jam

Bahan Keluar ke Cyclone pada Suhu 101,79^oC = 374,94 K

$\Delta H\ C = \int_{298.15}^{374.94}$

$= n \int 2.673+0.0026T+-116900T^2$

$= \dfrac{0.0000}{12} \times 353.1929$

$= 0.0000$ kkal / jam

ΔH air $= n\ Cp\ \Delta T$

$= n \int_{298.15}^{374.94} 7.7010+0.00045T+0.00000252T^2$

$= \dfrac{3755.9177}{18} \times 701.2986$

$= 146334.4349$ kkal / jam

$\lambda\ H_2O$ = 9717 (Sherwood, Appendix A)

ΔH air total $= n \displaystyle\int_{Tref}^{T} Cp\ \Delta T + n\ .\ \lambda$

$= 146334.4349$ kkal/jam $+ \left(\dfrac{3755.9177}{18.0000} \times 9717 \right)$

$= 2173904.0293$ kkal/jam

Total Entalpi Keluar = 2445693.2165 kkal/jam

Neraca Energi Total :

H bahan masuk + H udara masuk = H bahan keluar + H udara keluar

187593.6985 + H udara masuk = 2445693.216 + H udara keluar

Suhu udara masuk = 120 ˚C = 248 ^oF

BM udara = 28.951 kg / kmol (Perry 7th Ed. : T.2-196)

Cp udara pada suhu 120°C = 0.25 BTU / lb.^oF (Kern Fig.3 : 805)

= 7.2378 kkal / kmol.^oF

ΔH udara $= Cp \times \Delta T$

$= 7.2378 \times (248-77)$

$= 1237.6553$ kkal / kmol

Suhu udara keluar = 101.79 ˚C = 215.22 ^oF

Cp udara pada suhu 101,79 °C = 0.24 BTU / lb.^{o}F (Kern Fig.3 : 805)
= 6.9482 kkal / kmol.^{o}F

ΔH udara = Cp x ΔT
= 6.9482 x (215,22-77)
= 960.3857 kkal / kmol

Sehingga :
H bahan masuk + H udara masuk = H bahan keluar + H udara keluar
187593.6985 + H udara masuk = 2445693.216 + H udara keluar
187593.6985 + 1237.6553 n = 2445693.216 + 960.3857
277.2695 n = 2258099.5179 kkal/jam
n udara = 8144.0598 kmol/jam

Massa udara kering = 8144.0598 kmol / jam x 28.9510 kg / kmol
= 235778.6741 kg / jam

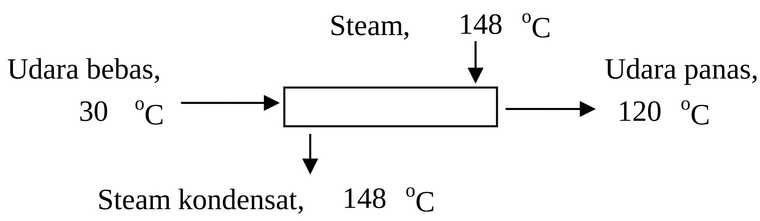
Perhitungan Entalpi Udara :
Entalpi udara masuk :
Cp.ΔT udara (120°C) = 1237.6553 kkal / kmol
Mol udara = 8144.0598 kmol / jam
H udara masuk = 10079538.3193 kkal / jam
Entalpi udara keluar :
Cp.ΔT udara (101,79°C) = 960.3857 kkal / kmol
Mol udara = 8144.0598 kmol / jam
H udara keluar = 7821438.8014 kkal / jam

Neraca Energi

Masuk (kkal/jam)		**Keluar (kkal/jam)**	
* Carbon Black dari pelletizer		* Carbon black ke cooling Conveyor	
Carbon	120527.6601	Carbon	270709.5777
Air	67,066.0384	Air	1079.6095
Udara kering dari Heater :		* Carbon black ke cyclone-3	
Udara masuk	10079538.32	Carbon	0.0000
		Air	2173904.02927
		Udara keluar	7821438.8014
Total	10267132.0178	**Total**	10267132.0178

6. HEATER-1

Fungsi : Memanaskan udara pada suhu 120 ^{o}C



Neraca energi total :

ΔH bahan masuk + Q supply = ΔH bahan keluar + Q loss

BM udara = 28.951 kg / kmol (Perry 7th Ed. : T.2-196)

Entalpi udara bebas pada suhu = 30 ˚C = 86 °F

Cp udara pada suhu 30°C = 0.26 BTU / lb.°F (Kern Fig.3 : 805)

= 7.5273 kkal / kmol.°F

ΔH udara = Cp x ΔT

= 7.5273 x (303,15-298,15)

= 37.6363 kkal / kmol x n

Entalpi udara masuk :

Mol udara = 8144.0598 kmol / jam (perhitungan dryer)

H udara masuk = 37.6363 kkal / kmol x 8144.0598 kmol / jam

= 306512.2764 kkal / jam

Entalpi udara keluar :

Dari perhitungan dryer, entalpi udara kering = 10079538.3193 kkal / jam

Neraca Energi Total :

Entalpi bahan masuk + Q supply = Entalpi bahan keluar + Q loss

Kehilangan maksimum = 10 % (Ulrich: hal 432)

Asumsi : Q loss = 5 % dari Q supply

306512.2764 Q supply = 10079538.3193 + 5% Q supply

Q supply = 10287395.8347 kkal / jam

Q loss = 514369.7917 kkal / jam

Kebutuhan steam :

Dipakai steam pada tekanan steam 4.5 atm dengan suhu steam 148˚C

λ_{steam} = 2119.5000 kJ / kg (Smith : Steam Table F-1)

= 506.5732 kkal / kg

$Q_{steam} = M_{steam} \times \lambda$

$$M_{steam} = \frac{Q_{steam}}{\lambda\ steam} = \frac{10287395.8347}{506.5732}$$

= 20307.8163 kg / jam

Neraca Energi

Masuk	**kkal/jam**	**Keluar**	**kkal/jam**
Dari Udara Bebas		Ke Rotary Dryer	
Udara bebas	306512.2764	Udara kering	10079538.3193
Dari Steam		Ke Steam Kondensat	
Q supply	10287395.8347	Q loss	514369.7917
Total	**10593908.1110**	**Total**	**10593908.1110**

6. COOLING CONVEYOR

fungsi : mendiinginkan carbon black dan menuju ke silo

1. Entalpi masuk carbon dari rotary dryer pada suhu = 105 ºC

T = 378.15 ºK ; Trefference = 298.15 ºK

Cp C 105ºC = A x (T105 - T_{ref}) + (B x ($T105^2$ - $Tref^2$))/2 +(C x ($T105^2$ - $Tref^2$)

= 367.5830 kkal/K.kmol

$$\Delta H\ C = n\int_{Tref}^{T} Cp\ dT$$

= 736.4583 x 367.5830

= 270709.5777 kkal/jam

Cp H_2O 105ºC = A x (T105 - T_{ref}) + (B x ($T105^2$ - $Tref^2$))/2 +(C x ($T105^2$ - $Tref^2$)

= 730.7750 kkal/K.kmol

$$\Delta H\ H_2O = n\int_{Tref}^{T} Cp\ dT$$

= 1.4773 x 730.7750

= 1079.609506 kkal/jam

2. Entalpi masuk carbon dari cyclone pada suhu = 115 ºC

T = 388.15 ºK ; Trefference = 298.15 ºK

Cp C = A x (T115 - T_{ref}) + (B x ($T115^2$ - $Tref^2$))/2 +(C /(T-Tref)

= 528.6215 kkal/K.kmol

$$\Delta H\ C = n\int_{Tref}^{T} Cp\ dT$$

= 0.0000 x 528.6215
= kkal/jam

Total Entalpi masuk = 271789.1872 kkal/k.kmol

Entalpi keluar carbon ke silo pada suhu = 30 ⁰C
T = 303.15 ⁰K ; Trefference = 298.15 ⁰K

Cp C 35⁰C = A x ($T35 - T_{ref}$) + (B x ($T35^2$ - Tref ^{2}))/2 +(C x ($T35^2$ - Tref ^{2})
= 23.7658 kkal/k.kmol

ΔH C = $n \int_{Tref}^{T} Cp\, dT$
= 736.4583 x 23.7658
= 17502.5549 kkal/jam

Cp H_2O 35⁰C = A x ($T35 - T_{ref}$) + (B x ($T35^2$ - Tref ^{2}))/2 +(C x ($T35^2$ - Tref ^{2})
= 45.4391 kkal/k.kmol

.H H_2(= $n \int_{Tref}^{T} Cp\, dT$
= 1.4773 x 45.4391
= 67.1293 kkal/jam

Total Entalpi keluar = 17569.6843 kkal/jam

Neraca Energi Total :
H masuk = H keluar + Q terserap
Neraca Energi Total :

H masuk	=	H keluar	+	Q loss
271789.1872	=	17569.6843	+	Q loss
Q loss	=	254219.5029		

Dasar Pemilihan media Pendingin dan Kebutuhannya :

Digunakan air pendingin sebagai media pendingin karena nilai ΔT kecil.
Suhu air pendingin Masuk = 30 ⁰C (Ulrich;427)
Suhu air pendingin Keluar = 45 ⁰C (Ulrich;427)
Cp air yang digunakan sebagai pendingin = 1 Kkal /kg

Kebutuhan air pendingin
Q = m.Cp.ΔT
m = Q / ——— = 16947.9669 kg

m = ... = 16947.9669 kg
Cp (T2-T1)

Neraca Energi

Masuk	Kkal/jam	Keluar	Kkal/jam
* Carbon black dari rotary Dryer		* Carbon black ke silo	
C	270709.5777	C	17502.5549
H2O	1079.6095	H2O	67.1293
Total	271789.1872	Total	17569.6843
		Q terserap	254219.5029
Total	271789.1872	Total	271789.1872

1.4 Perhitungan Pemanas

Kebutuhan Fuel Oil untuk pembakaran udara :

Digunakan Residual Oil 33 °API (0,22% sulfur) (Perry 7ed, T.27-6)

sg = 0.79

r = 0.79 gr/cc

Heting value = 137273 Btu/gal

r = 0.79 gr/cc = 54 lb/cuft = 7.2 lb/gal

maka, Heating value bahan bakar $= \dfrac{137273}{7.2}$

= 19065.6944 Btu/lb

= 10562.3947 kkal/kg

Kebutuhan Residual oil :

Digunakan Residual oil = 10562.3947 kkal/kg

33°API dengan heating value

Panas yang dibutuhkan = 18142791.7168 kkal/jam

Kebutuhan Fuel Oil $= \dfrac{18142791.7168}{10562.3947}$

= 1717.6779 kg/jam 571

= 3761.7145 lb/jam 1250.4900

= 60639.46442 liter/hari 20158.10688

Burner Rotary dryer

Fungsi : Untuk memanaskan udara yang akan masuk ke rotary kiln

Kond 1. Tekanan operasi : 1 atm

2. Suhu operasi : 120°C

Data :

Suhu = 30 °C

Suhu = 120 °C

Neraca panas total :

Entalpi udara masuk + Q pembakaran = Entalpi udara keluar

ΔH udara masuk rotary dryer= 10079538.3193 kkal/jam

Maka,

Entalpi udara keluaı 10079538.3193 kkal/jam

Entalpi udara masuk burner pada suhu 30°C

Cp udara = 0.24 kkal/kmol °C

ΔH udara masuk = n ∫ Cp dT

= 197962.3080 x (0,24 x (30-25))

= 237554.7696 kkal/jam

Cp H_2O uap = 0.466 kkal/kmol °C

Humidity udara = 0.026 kg H_2O uap/kg udara

ΔH H_2O uap = n ∫ Cp dT

= 197962.3080 x 0,466 x 0,026 x (30-25)

= 11992.5566 kkal/jam

Total entalpi udara masuk = 237554.77 + 11992.5566

= 249547.3262 kkal/jam

Neraca panas total :

Entalpi udara masuk + Q pembakaran = Entalpi udara keluar

249547.3262 + Q pembakaran = 10079538.3193

Q pembakaran = 9829990.9931 kkal/jam

Kebutuhan Fuel Oil

Digunakan fuel oil no 6 Low Sulfur (Perry 7ed : 27-10)

Panas = 9829990.9931 kkal/jam

Reaksi pembakaran Fuel Oil (mengandung sulfur)

$C + 1/2\ O_2 \rightarrow$	CO	HV	=	28918	kkal/kg
$H_2 + 1/2\ O_2 \rightarrow$	H_2O	HV	=	2418	kkal/kg
$S + O_2 \rightarrow$	SO_2	HV	=	2191	kkal/kg
Total HV			=	33527	kkal/kg

Total heating value = 33527 kkal/kg

Kebutuhan fuel oil $= \dfrac{9829990.9931}{33527}$

= 293 kg/jam

Komposisi (Perry 7ed : 27-10)

Komponen	% berat	kg/jam	kmol/jam
Carbon	87.26%	256	21.320255
Hydrogen	10.49%	31	15.3781
Sulfur	0.84%	2	0.0770
Impurities	1.41%	4	0.4134
Total	100.00%	293	37.1888

Kebutuhan O_2 untuk bereaksi dengan C = 1 kmol (1/2 mol stoikiometri C)

Kebutuhan O_2 untuk bereaksi dengan H_2 = 1 kmol (1/2 mol stoikiometri H_2)

Kebutuhan O_2 untuk bereaksi dengan S = 2 kmol (1 mol stoikiometri S)

Kebutuhan O_2 untuk reaksi pembakaran 4 kmol

Digunakan O_2 berlebih 20% untuk menyempurnakan pembakaran

Kebutuhan O_2 berlebih 20% = 4 kmol

= 128 kg (BM O_2 = 32 kg/kmol)

Digunakan udara kering yang sudah melewati dehumidifier dengan 21% O_2 dan 79% N_2

Kebutuhan O_2 berlebih 20% = 128 kg

Berat total udara (21% O2) = 610 kg

Berat N_2 dalam udara = 482 kg

Kebutuhan fuel oil = 293 kg

Kebutuhan udara untuk pembakaran = 610 kg

Perbandingan flowrate fuel oil dan udara = 1 : 2.08

Panas Burner Rota					
Masuk			Keluar		
Kompo	kkal/j		mpon		kkal/jam
*Udara			*Udara Panas ke Rotary Kiln		
Ud	=	#	Uda	=	###
*Panas pembakaran					
Fuel d		#			
To	=	#	Tota	=	###

APPENDIX C
PERANCANGAN SPESIFIKASI ALAT

1. TANGKI PENAMPUNG RESIDUAL OIL

Fungsi : Menampung Residual oil
Type : silinder tegak, tutup bawah datar dan tutup atas dishead.
Dasar pemilihan : umum digunakan pada tekanan atmospheric.

Perhitungan tangki :

Bahan Masuk : Perry 7ed, T.2-1/2

Komponen	Fraksi Berat	Berat (kg)	ρ (gr/cc)
C	0.8775	16568.957	0.7886
S	0.0084	158.6088	1.9600
H2	0.1049	1980.7220	0.0709
O2	0.0064	120.8448	1.1400
N2	0.0028	52.8696	1.0260
Total	1	18882.002	

Rate Massa Bahan Baku: 18882.0018 kg/jam = 41627.2612 lb/jam
Total : 18882.0018 kg/jam = 41627.2612 lb/jam

r Campuran :

$$= \frac{1}{\Sigma \frac{fraksi\ berat}{\rho\ komponen}} x\ 62{,}43 \frac{\text{lb}}{\text{cuft}} = \ldots \frac{\text{lb}}{\text{cuft}} (1 \frac{\text{gr}}{\text{cc}} = 62.43 \frac{\text{lb}}{\text{cuft}})$$

= 23.9663 lb/cuft

Rate Volumetrik = $\frac{Rate\ massa\ \left(\frac{lb}{jam}\right)}{densitas\ \left(\frac{lb}{cuft}\right)}$ = 1736.9089 cuft/jam

Direncanakan penyimpanan untuk 6 hari dengan
3 buah tangki, sehingga volume masing -masing tangki :

in $= \frac{rate\ volumetrik\ \frac{cuft}{jam}\ x\ (6\ x\ 24\ jam)}{jumlah\ \ tangki} =$ 83371.627 cuft

Menentukkan ukuran tangki dan ketebalannya :

Asumsi untuk bahan 85% dari volum tangki :
Asumsi dimention ratio : H/D = 1 ***(ulrich tab.4.27)***
Volume tangki : 98084.2670 cuft

Volume = ¼ π D^2 H
98084.2670 = ¼ π D^2 D
D^3 = 124948.1109
D = 49.99308 ft 599.9169659 in 15.2 m
H = 49.99308 ft 599.9169659 in 15.2 m

Menentukan tebal minimum shell :

tebal shell berdasarkan ASME Code untuk cylindrical tank :

$$t = \frac{P\ x\ ri}{\ldots} + C$$

$$t_{min} = \frac{\quad}{fE\ - 0.6\,P} + C$$ ***(brownell, pers.13-1, hal 254)***

dengan :

t.min	=	tebal shell minimum ; in
P	=	tekanan tangki ; psi
ri	=	jari - jari tangki ; in r = ½ x D ; r = **299.958483 in**
C	=	faktor korosi ; in digunakan yaitu = 1/8 in = **0.125 in**
E	=	Faktor pengelasan, digunakan double welded, E = **0.8**
f	=	Stress allowable, bahan konstruksi Carbon Steel SA-283 grade C,

maka nilai f = **12650** psi ***(Brownell, T.13-11)***

Volum bahan	=	¼ π D2 H	
83371.627	=	¼ π D2 H	
83371.627	=	1961.957 H	
H	=	42.494118 ft	509.929421 in

P operasi = 1 atm = 14.7 psia

P hidrostatis = $\frac{\rho\ x\ H}{144}$ = 7.0724 psia

P design = P in - P out + Phidrostatis

P design = 7.0724 psia

$$t_{min} = \frac{P\ hidrostatis\ \ x\ r\ tangki}{12650\ x\ 0.8\ - 0.6\ x\ P\ hidrisostat}$$ = 0.3347 in

digunakan t = 1 in

> untuk tebal tutup atas karena tekanan atmospheric, maka tebal tutup atas disamakan dengan tebal shell = 1 in

> Untuk tebal tutup bawah datar karena tutup menumpang di atas semen, maka tebal tutup = 5/16 in

Spesifikasi :

Fungsi	:	Menampung Residual oil
Type	:	silinder tegak, tutup bawah datar dan tutup atas conical.
Volume	:	98084.2670 cuft
Diameter	:	50 ft 15.1979 m
Tinggi	:	50 ft 15.1979 m
Tebal shell	:	1 in
Tebal tutup atas	:	1 in
Tebal tutup bawah	:	5/16 in
Bahan konstruksi		Carbon steel SA-283 grade C (Brownell : 251)
Jumlah	:	3 buah

2. POMPA-1 (Feed)

Fungsi	:	Mengalirkan Bahan Baku ke Heater -1
Tipe	:	*Centrifugal Pump*
Dasar Pemilihan	:	Sesuai untuk bahan liquid, viskositas rendah.

Perhitungan :

ρ Bahan = 23.9663 lb/cuft = 0.3839 gr/cc

Bahan masuk = 18882.0018 kg/jam
= 41634.8140 lb/jam

Rate Volumetrik $= \dfrac{\text{Rate Massa} \quad \text{lb/jam}}{\text{Densitas} \quad \text{lb/cuft}}$

$= \dfrac{41634.8140 \quad \text{lb/jam}}{23.9663 \quad \text{lb/cuft}}$

= 1737.2240 cuft/jam
= 28.9537 cuft/menit
= 216.5890 gpm
= 0.4826 cuft/detik

Asumsi aliran turbulen : **[Peters, 4ed, pers,15 hal 496]**

Di optimum untuk aliran turbulen, Nre > 2100, digunakan persamaan :

Diameter Optimum $= 3.9 \times qf^{0.45} \times \rho^{0,13}$

dengan : qf = fluid flow rate ; cuft/dt (cfs)
ρ = fluid density ; lb/cuft

Diameter Optimum $= 3.9 \times 0.4826^{0.45} \times 23.9663^{0.13}$
= 4.2463 in

Dipilih pipa 5 in, sch 40

OD = 5.563 in (Geankoplis 3ed, App A.5-1, hal.892)
= 0.4636 ft

ID = 5.047 in A = 0.1390 ft^2
= 0.4206 ft
= 0.1282 m

Kecepatan linier $= \dfrac{qf}{A} = \dfrac{0.4826}{0.1390} = 3.4717$ ft/dt

sg bahan $= \dfrac{\rho \text{ bahan}}{\rho \text{ reference}} \times \text{sg reference}$

$= \dfrac{23.9663}{62.4300} \times 1$

= 0.38389

μ berdasarkan sg bahan:

μ bahan $= \dfrac{\text{sg bahan}}{\text{sg reference}} \times \mu \text{ reference}$

$= \dfrac{0.3839}{1.0000} \times 0.9500$

= 0.3647 cP = 0.9500 cS
= 0.0002 lb/ft dt

μ = 0.00025 lb/ft dt (berdasarkan sg bahan)

$N_{Re} = \dfrac{D\, v\, \rho}{\mu} = \dfrac{0.4206 \times 3.4717 \times 23.9663}{0.00025}$

= 142794.37 > 2100 (asumsi benar)

Dipilih pipa *Commercial steel* :

e = 0.000046 m (Geankoplis 3ed. Fig. 2.10-3, hal 88)
e/D = 0.000359
f = 0.0048

Digunakan persamaan Bernoully :

$$\frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta v^2}{2\alpha \times gc} + \Sigma F = -Wf$$

Perhitungan friksi berdasarkan Geankoplis 3ed, Tabel 2.10-1, hal 93

Taksiran panjang pipa lurus = 53.0000 ft

- 2 elbow 90^o = 2 x 35 x 0.4206
  = 29.4408 ft
- 1 gate valve = 1 x 9 x 0.4206
  = 3.7853 ft

Panjang total pipa = 86.2261 ft

Friksi yang terjadi :

1. Friksi karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times Le}{gc \times D}$$ (Geankoplis 3ed, eq 2.10-6)

$$= \frac{2 \times 0.0048 \times 3.4717^2 \times 86.2261}{32.2 \times 0.4206}$$

= 0.7367 ft.lbf/lbm

2. Friksi karena kontraksi dari tangki ke pipa

$$F_2 = \frac{K_c \times v^2}{2 \times \alpha \times gc}$$ K_c = 0.55 A tangki > A pipa

(Geankoplis 3ed, eq 2.10-16)

= 0.103 ft.lbf/lbm

3. Friksi karena enlargement (ekspansi) dari pipa ke tangki

$$F_3 = \frac{v^2}{2 \times \alpha \times gc} = \frac{\Delta v_2^2 - \Delta v_1^2}{2 \times \alpha \times gc}$$ α = 1 untuk aliran turbulen

$= 0.187 \frac{ft . lbf}{lbm}$ (A_1 <<< A_2, maka V_1 dianggap = 0)

(Geankoplis 3ed, eq 2.10-15)

4. Friksi karena Elbow 90^o

$$F_4 = 2 \quad K_f \quad \frac{v_1^2}{2}$$ (Geankoplis 3ed, eq 2.10-17)

= 2 x 0.75 x 6.0262

= 13.5591 ft.lbf/lbm

5. Friksi karena Gate Valve

$$F_5 = K_f \quad \frac{v_1^2}{2}$$ (Geankoplis 3ed, eq 2.10-17)

= 0.17 x 6.0262

= 1.0245 ft.lbf/lbm

Sehingga : **ΣF** = 15.6103 ft.lbf/lbm

P_1 = 1 atm + (ρ x g x h)

= (14.7 x 144) + (23.97 x 1 x 49.9931)

= 3314.948635 lbf / ft^2

P_2 = 1 atm = 14.7 psi = 14.7 x 144

= 2116.8000 lbf / ft^2

ΔP = P_2 - P_1 = 1198.1486 lbf / ft^2

$$\frac{\Delta P}{\rho} = \frac{1198 \text{ lbf / ft}^2}{23.97 \text{ lbm /cuft}} = 49.9931 \frac{ft . lbf}{lbm}$$

$$\frac{\Delta v^2}{2\alpha \times gc} = \frac{3.4717^2}{2 \times 1 \times 32.2} = 0.1872 \frac{ft . lbf}{lbm}$$

Z_1 = 38 ft

Z_2 = 45 ft

ΔZ = Z_2 - Z_1 = 7 ft

$$\Delta Z \frac{g}{gc} = 7 \text{ ft} \times 1 \frac{lbf}{lbm} = 7 \frac{ft \cdot lbf}{lbm}$$

Persamaan Bernoully :

$$\frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta v^2}{2\alpha \times gc} + \Sigma F = -Wf$$

49.9931 + 7.0000 + 0.1872 + 15.6103 = - Wf

72.7905 = - Wf

$$-Wf = 72.7905 \frac{ft \cdot lbf}{lbm}$$

$$hp = \frac{-Wf \times \text{flowrate (gpm)} \times sg}{3960}$$ [Perry 6ed; pers.6-11 hal.6-5]

$$= \frac{72.7905 \times 216.5890 \times 0.3839}{3960}$$

= 1.5284 hp

Effisiensi pompa = 78% (Peters 4ed ; fig 14-37 ; hal 520)

$$Bhp = \frac{hp}{ef.pompa} = \frac{1.5284}{0.78} = 1.96 \text{ hp}$$

Effisiensi motor = 88% (Peters 4ed ; fig 14-38 ; hal 521)

$$\text{Power motor} = \frac{Bhp}{ef.\ motor} = \frac{1.9594}{0.88} = 2.2 \text{ hp} = 2.2 \text{ hp}$$

Spesifikasi :

Fungsi	:	Mengalirkan Residual Oil dari tangki penampung menuju ke heater -1
Dasar Pemilihan	:	Sesuai untuk bahan liquid, viskositas rendah.
Tipe	:	*Centrifugal Pump*
Bahan	:	*Commercial Steel*
Rate volumetrik	:	1737.2240 cuft/jam
Total Dynamic Head	:	72.7905 ft.lbf/ lbm
Effisiensi motor	:	88%
Power	:	2.2 hp
Jumlah	:	3 buah

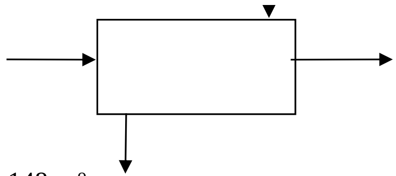
3. Heater -1 (Pemanasan Bahan Baku)

Fungsi	=	Memanaskan $C_{20}H_{42}$ dari suhu 30°C menjadi suhu 94°C
Type	=	1 - 2 Shell and Tube Heat Exchanger (Fixed Tube)
Dasar Pemilihan	=	panas yang besarUmum digunakan dan mempunyai range perpindahan
Kondisi Operasi	=	- Tekanan = 1 atm
		- Suhu = 94 °C
		- Sistem Kerja = Kontinyu

T_1 = 148 °C

= 298.4 °F

t_1 = 30 ^oC
= 86 ^oF



t_2 = 94 ^oC
= 201.2 ^oF

T_2 = 148 ^oC
= 298.4 ^oF

1). Q supply	=	1395332.327	kkal/jam	=	5533469	Btu/jar
W bahan masuk	=	18882.0018	kg/jam	=	41627.6389	lb/jam
W steam masuk	=	2892.1761	kg/jam	=	6376.1492	lb/jam

2. Penentuan ΔT_{LMTD}

hot fluida		cold fluida	diff.
298.4	higher temp.	201.2	97.2
298	lower temp.	86	212.4
0		115.2	115.2

$$\Delta t\ LMTD = \frac{\Delta t_1 - \Delta t_2}{\ln \dfrac{\Delta t_1}{\Delta t_2}}$$

$$\Delta t\ LMTD = \frac{97 - 212}{\ln\ 97 / 212} = 147.3710\ ^oF$$

3. Tc dan tc

$$Tc = \frac{T_1 + T_2}{2} = \frac{298 + 298}{2}$$

$= 298\ ^oF$ (μ = 0.0220) (Kern hal 825)

$$tc = \frac{t_1 + t_2}{2} = \frac{86 + 201}{2}$$

$= 144\ ^oF$ (μ = 0.0019) (Kern hal 825)

Penentuan Tube = 6 - 60

Koefisien perpindahan panas U_D = 45 $\frac{BTU}{ft^2\ F}$ Kern Table 8

Luas perpindahan panas A $= \frac{Q}{U_D \times \Delta T\ LMTD}$

$= \frac{5533469.4075}{45 \times 147.3710}$

= 834.397 ft^2

= 77.518 m^2

Kern Tabel 10 pg. 843

Pemilihan Design Tube

OD		=	1	in
BWG		=	16	
ID		=	0.8700	in
Wall ticknes		=	0.065	in
Flow area per tube	(a't)	=	0.5940	in^2

Outside surface per lin ft	(a")	=	0.2618	ft^2
Pitch		=	Square in	
Pitch Size		=	1 1/4	in
Asumsi Panjang Tube (L)		=	13 ft = 4.0	m

Jumlah Tube $Nt = \dfrac{A}{a'' \times L}$

$= \dfrac{834.3974}{0.2618 \times 13}$

$= 245.166$

Kern Table 9 pg 841

Phase	=	2	
ID Shell	=	25	in
Jumlah Tube Standar	=	252	

Spesifikasi Heater

Fungsi	:	Menaikkan suhu residual oil dari suhu 30^{O}C ke suhu 94^{O}C sebelum memasuki Furnace
Type	:	Shell and tube heat exchanger
Panjang Tube	:	13 ft
Diameter Tube (ID)	:	0.8700 in
Diameter Tube (OD)	:	1 in
Jumlah Tube Standar	:	252 buah
Flow area per tube	:	0.594 in^2
Outside surface per lin ft	:	0.2618 ft^2
BWG	:	16
Pitch	:	Square in
Pitch Size	:	1.25 in
Phase	:	2
Diameter Shell	:	25 in
Jumlah	:	3 buah
Bahan konstruksi	:	Carbon Steel

4. Air Filter -1

Fungsi	:	Untuk menyaring udara bebas
Type	:	Dry type Airmat Dust Arrester
Bahan konstruksi	:	Carbon Steel

Perhitungan :

Rate udara = 189312.1556 kg/jam = 417433.3 lb/jam

BM udara = 28.95

ρ campuran pada I = 1 atm, T 30 ^oC = 546 Ra ; udara = 492

$\rho = \dfrac{492\ Ra}{546\ Ra} \times \dfrac{1}{1} \times \dfrac{28.95}{359} = 0.0727$ lb/cuft (***Himmelblau; 270***)

Rate Volumetrik $= \dfrac{417433.3\ lb/jam}{0.07267\ lb/cuft} \dfrac{1}{60} = 95740.185$ cuft/mnt = 45.74 ft/mnt

Dipilih air filter berdasarkan jenis pengoperasian otomatis, ***perry 6*** ^{ed} ***, tabel 20-39***

SPESIFIKASI

Fungsi	:	Untuk menyaring udara bebas
Type	:	Dry type Airmat Dust Arrester
Dasar Pemilihan	:	Penanganan otomatis dan sesuai dengan bahan
Ukuran filter	:	otomatis
Kecepatan	:	46 ft/mnt
Resistansi	:	0.4 in water
Filter Medium	:	glass fiber
Jumlah	:	1 buah

5. BLOWER

Fungsi	:	Memindahkan udara dari udara bebas ke Furnace
Tipe	:	Centrifugal Blower
Dasar Pemilihan	:	Sesuai dengan jenis bahan, effisiensi tinggi

Perhitungan :

Rate massa udara	=	189312.1556	kg/jam	BM Udara	=	28.9510	kg/kmol
	=	417433.3032	lb/jam	ρ	=	0.0727	lb/cuft
udara	=	0.0727	lb/cuft				

Dimana : P_2 = 20.0 psi

P_1 = 14.7 psi

Rate volumetrik udara (Q) =

$$= 417433.3032 \; \frac{lb}{jam} \times \frac{1 \; jam}{60 \; menit} \times \frac{1 \; cuft}{0.0727 \; lb}$$

= 95740.1852 cuft/menit

Power untuk menghembuskan udara :

HP = 0.000157 x Q x ΔP (Perry 6th ed., hal.6-22)

= 0.000157 x 95740.1852 x 5.30

= 79.6654 HP ≈ 80 HP

$$\text{Effisiensi} = \frac{\text{HP blower}}{\text{HP shaft}}$$ (Perry 5th ed., pers.6-35)

Effisiensi blower = 40% - 70% (Perry 5th ed., hal.6-21)

Diambil = 70%

$$\text{HP shaft} = \frac{79.6654}{0.7} = 113.8077 \text{ HP} \approx 114 \text{ HP}$$

Spesifikasi :

Fungsi	:	Memindahkan udara dari udara bebas ke Furnace
Tipe	:	Turbo Blower
Kapasitas	:	95740.1852 cuft/menit
HP shaft	:	114 hp
Power	:	80 hp
Bahan Konstruksi	:	Carbon Steel
Jumlah	:	1 buah

6. FURNACE

Fungsi	:	Membentuk Carbon Black dari Residual oil
Dasar Pemilihan	:	Untuk membentuk carbon type N330 Furnace

type HAF Lebih effisien

Kondisi Operasi : 1400 ^oC
Type : HAF (High Abratio Furnace) LL-D2800*7500
Kapasitas : residual oil = 18882 kg/jam
41627.68564 lb/jam
udara = 189312.1556 kg/jam
417361.8333 lb/jam

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ komponen}}} \times 62.43 = 23.9663 \text{ lb/cuft}$$
= 383.90305 kg/m3

$$\text{Rate Volumetrik} = \frac{208194}{383.9030} = 542.3092068 \text{ m3/jam}$$
= 0.150641446 m/detik

a) Menentukan dimensi ruang pembakaran (crucible)
Bentuk crucible dipilih berbentuk silinder horizontal dengan pertimbangan distribusi panas yang lebih bail .
Berdasarkan ASME International Mechanical Engineering Congress 2006 , residence time black smc setelah pembakaran adalah 30 m/detik maka diambil residence time = 30 m/detik

$$t = \frac{\text{Volume}}{\text{Rate volumetrik}}$$

Volume = 0.151 x 30
= 4.519243 m³

Menentukan dimensi crucible Furnace
H/D = 1.6
V = 1/4 $\pi D^2 H$
4.5192 = 0.25 x 3.14 x 0.625 D^3
D = 2.096 m
H = 1.31 m
dinding crucible dilapisi refactory brick setebal = 30 cm
dan insulasi dengan alumina dengan tebal = 1/4 in

b) Menentukan Dimensi Kubah Furnace
Kubah furnace berbentuk silinder horizontal dengan panjang = 3 x panjang crucible,
maka, panjang sisi kubah = 3 x 1.310143
= 3.9304 m
jadi panjang sisi kubah furnace :
panjang = lebar = 3.9304 m = 12.9 ft
tinggi = 1.5 x diameter crurible ,
tinggi = 1.5 x 2.0962 = 3.144343 m = 10.317 ft
Konstruksi kubah terbuat dari Low -Alloy Steel Plate 217 C5

c) Perhitungan tebal shell kubah Furnace
P operasi = 5 atm
= 73.4800 psi
Untuk faktor keamanan 10% digunakan tekanan
P design = 1.1 x 73.4800
= 81.8280 psi

Tebal Shell digunakan ASME Code

$$t_{min} = \frac{P \times r}{fE - 0,6P} + C$$ (Brownell,pers. 13-1,hal 254)

dengan :

t_{min} = tebal shell minimum ; in
P = tekanan tangki ; psi
r = jari-jari tangki ; in (1/2 D)
C = faktor korosi ; in (digunakan 1/8 in)
E = faktor pengelasan, digunakan dobel welded E = 0.8
f = stress allowable, bahan konstruksi Low Alloy steel SA-217 C5
f = 2000 psi (Brownell Table 13.1)

$$t_{min} = \frac{P \times r}{fE - 0,6P} + C$$

$$= \frac{81.828 \times 1.0481}{1600 - 49.097} + \frac{1}{8}$$

$$= \frac{85.7651}{1550.9032} + 0.125$$

= 0.1803 in

digunakan t = 4/16 in

SPESIFIKASI :

Fungsi	:	pembakaran residual oil menjadi carbon black
Type	:	HAF (High Abratio Furnace) LL-D2800*7500
Dasar Pemilihan	:	Penanganan otomatis dan sesuai dengan bahan
Manufacture	:	YILONG
Temperature	:	Maksimum 1400 ^{o}C = 2552 ^{o}F
Panjang	:	3.930429 m = 12.895738 ft
Lebar	:	3.930429 m = 12.895738 ft
Tinggi	:	3.1443432 m = 10.31659 ft
Kapasitas	:	542.31 m3/jam
Bahan	:	Low -Alloy Steel Plate 217 C5
Tebal Shell kubah	:	4/16 in
Isolasi	:	Refractory Brick
Tebal isolasi	:	24 in
Accesory	:	Internal Quench System
Jumlah	:	1 buah

7. Spray Tower

Fungsi	:	Menurunkan suhu bahan sampai dengan 200 ^{o}C
Type	:	Silinder tegak, tutup bawah dan atas dish pada bagian atas di pasang perfored pipe untuk distribusi aliran air pendingin
Dasar Pemilihan	:	Umum digunakan pada tekanan atmospheric

Komponen	Berat (Kg/jam)	Fraksi	ρ	fraksi/ρ
C	8838.3838	0.02103571	2.267	0.0092791
H_2	1546.7172	0.003681249	0.0709	0.0519217
N_2	145253.4550	0.3457091	1.0260	0.3369484
O2	14666.0927	0.0349	1.1400	0.0306192
SO2	317.2176	0.0014	1.434	0.0009904

CO_2	26182.8283	0.0623	1.101	0.0565996
H_2O	223356.2591	0.5316	1	0.5315969
total	420160.9538	1.001		1.0179553

Rate massa = 420160.9538 kg/jam = 926286.8387 lb/jam

ρ gas = 0.104 lb/cuft (pada tekanan 3 atm, 372 ºC
ρ liquid = 62.43 lb/cuft (densitas air)
ρ solid = 141.53 lb/cuft (densitas carbon)

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ komponen}}} \times 62 = 61.3288 \text{ lb/cuft}$$

$$\text{Rate Volumetrik} = \frac{\text{massa lb/jam}}{\text{densitas lb/cuft}} = \frac{926286.8387}{61.3288} = 15103.6143$$

Direncanakan waktu tinggal selama 1 menit (Ulrich Table 4-18) dengan 1 buah tangki, sehin

$$\text{Volume tangki} = \frac{15103.6143 \times (1 / 60 \text{ jam})}{1 \text{ tangki}}$$

= 251.7269 cuft

Asumsi Volume bahan = 85 % volume tangki

$$\textbf{Volume tangki} = \frac{251.7269}{0.85} = 296.1493 \text{ Cuft}$$

* Menentukan Ukuran Tangki dan Ketebalannya
Asumsi dimension ratio : H / D = 15 (Ulrich; T.4-18)

Volume = 1/4 π D^2 H
296.1493 = 1/4 π D^2 15 D
D = 3.3539 ft = 40.2465 in = 1.0223 m
H = 50.308142 ft = 603.6977 in = 15.33392 m

* Menentukan Tebal Minimum Shell

$$t \min = \frac{P \times ri}{f \times E - 1 P} + C$$ (***Brownell, pers 13-1, hal254***)

dengan;
t m = tebal shell minimum ; in
P = tekanan tangki ; Psi
ri = jari - jari tangki ; in 1/2 D)
C = faktor korosi ; in (digunakan 0.125 in)
E = faktor pengelasan, digunakan double welded: E = 1
f = stress allowable, bahan konstruksi Carbon steel SA-283
grade C, maka f 12650 Psi (***Brownell; T.13-1***)

P operasi = 3 atm absolut
= (3 atm x 14.7) - 15 = 29.4 Psig

P design diambil 10% lebih besar dari P operasi untuk faktor keamanan
P design = 3.3 x 14.7 = 48.51 Psi

R = 1/2 D = 0.5 x 40.2465 = 20.1233 in

$$t\ min = \frac{48.51 \times 20.1233}{12650 \times 1 - 0.6 \times 49} + 0.125$$

= 0.2217 in ; digunakan 0.375 in

Untuk tebal tutup atas disamakan dengan tebal tutup bawah, karena tutup bawah menerima beban lebih besar

untuk D = 40.2465 in dari ***Brownell tabel 5.7*** didapat rc = 90 in

* Tebal Standart Torispherical Dished :

$$t_h = \frac{0.885 \times P \times rc}{f \times E - 0.1 \times P}$$

Dengan : t_h = tebal dished minimum ; in

P = tekanan tangki ; Psi

rc = knuck radius ; in (***B&Y, T-5.7)***

E = faktor pengelasan, digunakan double welded, E = 0.8

f = stress allowable, bahan konstruksi Carbon Steel SA-283 grade C, maka f = 12650 Psi (***Brownell, T.13-1***)

P design = 48.51 psi

$$t_h = \frac{(0.885 \times 48.51 \times 90)}{(12650 \times 0.8)-(0.1 \times 48.51)}$$

= 0.3820 in , digunakan t = 0.5 in

$$h = Rc - \sqrt{Rc^2 - \frac{D^2}{4}}$$

$$= 90 \sqrt{90^2 - \frac{40.2}{4}^2}$$

= 2.2785 ft

* Perhitungan Nozzle :

Rate Bahan = 15103.6143 kg/jam = 33297.4280 lb/jam

ρ bahan = 62.43 lb/cuft

$$\text{Rate volumetrik} = \frac{\text{massa lb/jam}}{\text{densitas lb/cuft}} = 533.35621 \text{ cuft/jam}$$

Rate volumetrik = 533.3562 cuft/jam = 8.8893 cuft/mnt

Berdasarkan ***Peter 4ed, fig. 14-2. halaman 498*** , dengan asumsi aliran turbulen didapat

ID optimum = 3 in

maka digunakan pipa ukuran : 3 in 40 sch

Dari ***foust, app. C-6a*** , didapat :

OD = 3.5 in

ID = 3.068 in = 0.2557 ft

A = (π /4 . D^2) = 0.0513 ft^2

Kecepatan aliran, V = $\frac{8.8893 \text{ cuft/mnt}}{0.0513 \text{ ft}^2} \times \frac{1}{60}$ = 2.8873 ft/dt

dengan : μ = 1 cp = 0.000672 lb/ft.dt

Nre = $\frac{D \cdot V \cdot \rho}{\mu}$ = 68579.63172 > 2100

dengan Nre > 2100 untuk menentukan diameter sparger digunakan persamaan 6.5 dari ***Treybal halaman 141*** : dp = 0.0071 x $Nre^{-0.05}$

ft

dengan : dp = diameter sparger ; ft

dp = 0.0071 x (68579.6317 $)^{-0.05}$ = 0.0041 ft

= 1.2401 mm

Untuk pemasangan sejajar atau segaris pada pipa, jarak interface (C) dianjurkan minimal menggunakan jarak 3 x dp maka C = 3 x 0.0041 ft

= 0.0122 ft

Panjang pipa direncanakan 0.75 panjang shell = 0.75 x 12

= 9 ft

Posisi sparger direncanakan disusun bercabang = 25

maka banyaknya lubang = $\frac{\text{panjang pipa} \times \text{cabang}}{C}$ = 18433.70666 lubang

Jumlah lubang tiap cabang = $\frac{\text{jumlah lubang}}{\text{cabang}}$ = 737.35 lubang tiap cabang

SPESIFIKASI :

Fungsi	:	menurunkan suhu bahan sampai dengan 200 ^oC
Type	:	Silinder tegak, tutup bawah dan atas dish pada bagian atas di pasang perfored pipe untuk distribusi aliran air pendingin
Volume	:	296.1493 cuft
Diameter	:	3.3539 ft
Tinggi	:	50.3081 ft
Tebal Shell	:	3/8 in
Tebal Tutup atas	:	1/2 in
Tebal Tutup bwh	:	1/2 in
Bahan Konstruksi	:	Carbon steel SA-283 grade C (***Brownell :253***)
Jumlah	:	1 buah

8. Cyclone

Fungsi	:	Untuk memisahkan padatan yang terikut flue gas
Tipe	:	Stairmand Cyclone separator
Dasar pemilihan	:	Efektif dan sesuai dengan jenis bahan

Perhitungan :

Bahan Masuk :

Komponen	Fraksi Berat	Berat(kg/jam)	ρ (gr/ml)	BM	Fraksi Komp
C	0.0210	8838.3838	2.267	12	0.009279096
H2	0.0037	1546.7172	0.0709	2	0.051921709
N2	0.3457	145253.4550	1.0260	28	0.336948417
SO2	0.0008	317.2176	1.1400	64	0.000662273

O_2	0.0349	14666.0927	1.4340	32	0.024341626
CO_2	0.0623	26182.8283	1.1010	44	0.056599624
H_2O	0.5316	223356.2591	1.0000	18	0.531596897
Total	1.0000	420160.9538	8.0389		1.011349641

ρ campuran = $\dfrac{1}{\sum \dfrac{\text{fraksi berat}}{\rho\ \text{komponen}}} \times 62{,}43$

= 0.9888 gr/ml x 62.43 $\dfrac{\text{lb/cuft}}{\text{gr/ml}}$

= 61.7294 lb/cuft

Rate massa = 420160.9538 kg/jam = 926295.2419 lb/jam

Rate volumetrik = $\dfrac{\text{Rate massa}}{\text{Densitas}}$

= 15005.740 cuft/jam

Total Rate Volumetrik = 4.1683 cuft/detik

Time of Passes = 2 detik (Asumsi)

Volume Bahan = 4.168 x 2 detik

= 8.337 cuft

Volume Cyclone = 20% lebih besar volume bahan

= 10.003827 cuft

Tinggi = 4 m (Ulrich, Tabel 4-32)

= 13 ft

Volume cyclone = $1/4\ \pi\ D^2\ H$

10.004 cuft = $1/4\ \pi\ (D)^2\ H$

10.004 cuft = 0.785 x D^2 x 13

D = 0.9854 ft

= 0.3004 m = 11.8252 in

Dc = 11.8252 in

Bc = 1/4 Dc = 2.9563 in (Perry 7ed, 17-27)

De = 1/2 Dc = 5.9126 in (Perry 7ed, 17-27)

Hc = 1/2 Dc = 5.9126 in (Perry 7ed, 17-27)

Lc = 2 Dc = 23.650 in (Perry 7ed, 17-27)

Sc = 1/8 Dc = 1.4781 in (Perry 7ed, 17-27)

Zc = 2 Dc = 23.650 in (Perry 7ed, 17-27)

Jc = 1/4 Dc = 2.9563 in (Perry 7ed, 17-27)

Area Cyclone = 0.25 π D^2

= 0.7623 ft^2

Kecepatan Bahan = $\dfrac{4.168}{0.7623}$

= 5.4681 ft/dt

= 1.6667 m/dt

Dpc = $\left(\dfrac{9\ \mu\ Bc}{\pi\ Ns\ Vc\ (\rho_s - \rho)} \right)^{0.5}$ (Perry 7ed, 17-28)

Keterangan :

Dpc = ukuran partikel yang bisa lolos dari ayakan

Dp = ukuran partikel yang diijinkan lolos

Bc = besar inlet dust, ft
Ns = jumlah belokan yang dilalui udara
Vc = kecepatan gas masuk cyclone, ft/dt
ρs = densitas bahan, lb/cuft
ρ = densitas gas, lb/cuft
μ = viskositas gas, lb/ft dt
μ udara = 0.0210 cP = 0.00001 lb/ft dt
Ns = 0.8 (Perry 7ed, 17-30)

$$Dpc = \left(\frac{9\ \mu\ Bc}{\pi\ Ns\ Vc\ (\rho_s - \rho)} \right)^{0.5}$$

$$= \left(\frac{9 \times 0.000014 \times 2.9563}{3 \times 0.8 \times 5.4681 \times 61.7294} \right)^{0.5}$$

Dpc = 0.0007 ft

Perencanaan tebal shell dan tutup :

Bahan konstruksi dipilih Carbon Steel SA-283 grade C

$f_{allowable}$ = 12650 psi (Brownell, T.13-1, hal.251)

faktor korosi : C = 1 / 8 = 0.125

Dipakai sambungan las double welded but joint, 80 %

Tekanan design = 1 atm = 14.7

Tebal shell cilindrical shell :

$$t_s = \frac{P \times r}{f\,E - 0.6\,P} + C \quad \text{(Brownell, T.13-1, hal.254)}$$

$$t_s = \frac{14.7 \times 5.913}{12650 \times 0.8 - 0.6 \times 14.7} + \frac{1}{8}$$

= 0.1336 in

Dipilih t = 8/16 in

Tebal tutup atas :

Karena cyclone pada kondisi atmospheric

maka tebal tutup = 0.25 in

Tebal tutup bawah : (Brownell, Pers.6-154, hal.118)

$$\text{Tebal conical} = \frac{P \times d}{2 \cos \alpha\ (f\,E - 0.6\,P)}$$

dengan α = 0.5 x sudut conis = 60 / 2 = 30 °

$$tc = \frac{14.7 \times 11.8252}{2 \times \cos 30^o \times (12650 \times 0.8 - 0.6 \times 14.7)}$$

= 0.0099 in

Dipilih t = 4/16 in

Spesifikasi :

Fungsi : Untuk memisahkan padatan yang terikut udara

Tipe : Cyclone Separator

Kapasitas : 926295.2419 lb/jam

Ukuran : Bc = 2.9563 in ; Lc = 23.6503 in
Dc = 11.8252 in ; Sc = 1.4781 in
De = 5.9126 in ; Zc = 23.6503 in
Hc = 5.9126 in ; Jc = 2.9563 in

Tebal shell	:	8/16	in
Tebal tutup atas	:	4/16	in
Tebal tutup bawah	:	4/16	in
Bahan konstruksi	:	Carbon Steel SA 283 Grade C	
Jumlah	:	1	buah

9. Cyclone - 2

Fungsi : Untuk memisahkan padatan yang terikut udara
Tipe : Cyclone separator
Dasar pemilihan : Efektif dan sesuai dengan jenis bahan

Perhitungan :

Bahan Masuk :

Komponen	**Fraksi Berat**	**Berat(kg/jam)**	**ρ (gr/ml)**	**BM**	Fraksi Komp
C	0.0002	88.3838	2.2670	12	0.0001
H2	0.0038	1546.7172	0.0709	2	0.0530
N2	0.3531	145253.4550	1.0260	28	0.3441
SO2	0.0008	317.2176	1.1400	64	0.0007
O2	0.0356	14666.0927	1.4340	32	0.0249
CO2	0.0636	26182.8283	1.1010	44	0.0578
H2O	0.5429	223356.2591	1.0000	18	0.5429
Total	1.0000	411410.9538	8.0389		1.0235

ρ campuran = $\dfrac{1}{\sum \dfrac{\text{fraksi berat}}{\rho\,\text{komponen}}} \times 62{,}43$

= 0.9771 gr/ml x 62.43 $\dfrac{\text{lb/cuft}}{\text{gr/ml}}$

= 60.9979 lb/cuft

Rate massa = 411410.9538 kg/jam = 907004.8169 lb/jam

Rate volumetrik = $\dfrac{\text{Rate massa}}{\text{Densitas}}$

= 14869.440 cuft/jam

Total Rate Volumetrik = 4.1304 cuft/detik

Time of Passes = 2 detik (Asumsi)
Volume Bahan = 4.130 x 2 detik
= 8.261 cuft
Volume Cyclone = 20% lebih besar volume bahan
= 9.9129599 cuft
Tinggi = 4 m (Ulrich, Tabel 4-23)
= 13 ft
Volume cyclone = $1/4\ \pi\ D^2\ H$
9.9130 cuft = $1/4\ \pi\ (D)^2\ H$
9.9130 cuft = 0.785 x D^2 x 13
D = 0.9809 ft
= 0.299 m = 11.7713 in
Dc = 11.7713 in
Bc = 1/4 Dc = 2.9428 in (Perry 7ed, 17-27)
De = 1/2 Dc = 5.8857 in (Perry 7ed, 17-27)

Hc	=	1/2 Dc	=	5.8857	in	(Perry 7ed, 17-27)
Lc	=	2 Dc	=	23.543	in	(Perry 7ed, 17-27)
Sc	=	1/8 Dc	=	1.4714	in	(Perry 7ed, 17-27)
Zc	=	2 Dc	=	23.543	in	(Perry 7ed, 17-27)
Jc	=	1/4 Dc	=	2.9428	in	(Perry 7ed, 17-27)

Area Cyclone = $0.25\ \pi\ D^2$

= $0.7554\ ft^2$

Kecepatan Bahan = $\dfrac{4.130}{0.7554}$

= 5.4681 ft/dt

= 1.6667 m/dt

$$Dpc = \left(\frac{9\ \mu\ Bc}{\pi\ Ns\ Vc\ (\rho_s - \rho)}\right)^{0.5}$$ (Perry 7ed, 17-28)

Keterangan :

Dpc = ukuran partikel yang bisa lolos dari ayakan

Dp = ukuran partikel yang diijinkan lolos

Bc = besar inlet dust, ft

Ns = jumlah belokan yang dilalui udara

Vc = kecepatan gas masuk cyclone, ft/dt

ρs = densitas bahan, lb/cuft

ρ = densitas gas, lb/cuft

μ = viskositas gas, lb/ft dt

μ udara = 0.0210 cP = 0.00001 lb/ft dt

Ns = 0.8 (Perry 7ed, 17-30)

$$Dpc = \left(\frac{9\ \mu\ Bc}{\pi\ Ns\ Vc\ (\rho_s - \rho)}\right)^{0.5}$$

$$= \left(\frac{9 \times 0.00001 \times 2.9428}{3.14 \times 0.8 \times 5.4681 \times 60.9979}\right)^{0.5}$$

Dpc = 0.0007 ft

Perencanaan tebal shell dan tutup :

Bahan konstruksi dipilih Carbon Steel SA-283 grade C

$f_{allowable}$ = 12650 psi (Brownell, T.13-1, hal.251)

faktor korosi : C = 1 / 8 = 0.125

Dipakai sambungan las double welded but joint, 80 %

Tekanan design = 1 atm = 14.7

Tebal shell cilindrical shell :

$$t_s = \frac{P \times r}{f\,E - 0.6\,P} + C$$ (Brownell, T.13-1, hal.254)

$$t_s = \frac{14.7 \times 5.886}{12650 \times 0.8 - 0.6 \times 14.7} + \frac{1}{8}$$

= 0.1336 in

Dipilih t = 8/16 in

Tebal tutup atas :

Karena cyclone pada kondisi atmospheric

maka tebal tutup = 0.25 in

Tebal tutup bawah : (Brownell, Pers.6-154, hal.118)

Tebal conical = $\frac{P \times d}{2 \cos \alpha \,(f E - 0.6 P)}$

dengan α = 0.5 x sudut conis = 60 / 2 = 30 °

tc = $\frac{14.7 \times 11.7713}{2 \times \cos 30^{o} \times (12650 \times 0.8 - 0.6 \times 14.7)}$

= 0.0099 in

Dipilih t = 4/16 in

Spesifikasi :

Fungsi : Untuk memisahkan padatan yang terikut udara

Tipe : Cyclone Separator

Kapasitas : 907004.8169 lb/jam

Ukuran : Bc = 2.9428 in ; Lc = 23.5427 in

Dc = 11.7713 in ; Sc = 1.4714 in

De = 5.8857 in ; Zc = 23.5427 in

Hc = 5.8857 in ; Jc = 2.9428 in

Tebal shell : 8/16 in

Tebal tutup atas : 4/16 in

Tebal tutup bawah : 4/16 in

Bahan konstruksi : Carbon Steel SA 283 Grade C

Jumlah : 1 buah

10. Screw Conveyor

Fungsi = Mengangkut carbon black menuju ke bucket elevator

Dasar Pemilihan = Untuk padatan dengan sistem tertutup

Jumlah = 1 unit

Bahan Masuk:

Komponen	Berat (kg/jam)	Fraksi berat	ρ (gr/cm^3)
C dari cyclone -1	8750.0000	0.9901	2.267
C dari cyclone -2	87.50	0.0099	2.267
Total	8837.5000	1	

perry tabel 3.2

Rate massa screw conveyor = 8837.5000 kg/jam

= 17895.9375 lb/jam

ρ bahan = 141.3248 lb/cuft

Volumetrik bahan = $\frac{\text{Rate massa}}{\text{Densitas}}$ = $\frac{17895.9375 \text{ lb/jam}}{141.3248 \text{ lb/cuft}}$

= 126.6299 cuft/jam

= 2.1105 cuft/menit

Untuk densitas = 141.3248 lb/cuft, bahan termasuk kelas D dengan F = 3

Power motor = $\frac{C.L.W.F}{33000}$ (Badger, Tabel 16-6)

Dengan : C = Kapasitas (cuft/menit)

L = Panjang (ft)

W = Densitas bał (lb/cuft)

F = Faktor bahan

Asumsi panjang screw conveyor, L = 30 ft

Power motor = $\frac{2.1105 \text{ cuft/m} \times 30 \text{ ft} \times 141.325 \text{ lb/cuft} \times 3.0}{33000}$

= 0.8135 Hp

Untuk power < 2 Hp, maka dikalikan 2 (Badger halaman 713)

0.8135 x 2 = 1.6269 hp

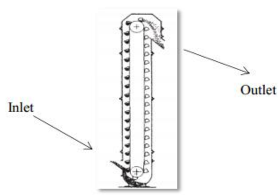
Efisiensi motor = 80% , maka
Power motor = 2.0336 hp
(Dari Badger halaman 712 Fig, 16-20), untuk kapasitas 126.6299 cuft/jam
digunakan ukuran :
Diameter = 9 inch
Kecepatan putaran = 28 rpm

Spesifikasi :

Fungsi	=	Mengangkut carbon black menuju bucket elevator
Kapasitas	=	126.6299 ft^3/jam
Panjang	=	30 ft
Diameter	=	9 inch
Kecepatan putaran	=	28 rpm
Power motor	=	2.0 hp
Jumlah	=	1 unit

11. BUCKET ELEVATOR

Fungsi : Memindahkan karbon black dari screw conveyor
Tipe : *Continous bucket elevator*



Kondisi Operasi :
T = 200 °C
P = 1 atm

Perhitungan :
Rate massa = 8837.5000 kg/jam = 8.8375 ton/jam
ρ carbon = 141.3248 lb/cuft
Dari Perry 7 Ed. T 21-9 dipilih bucket elevator dengan spesifikasi :
Tinggi Bucket = 10 ft
Putaran head shaft (kepala poros) = 28 rpm
Kapasitas maksimum = 35 ton/jam
Bucket linear speed = 150 ft/min

Sehingga, untuk kapasitas 8.8375 ton/jam, maka :

Kecepatan bucket elevator = $\frac{8.8375}{35}$ x 150 ft/min
= 37.875 ft/min

Power pada head shaft = 1.8 hp
Power tambahan = 0.06 hp tiap ft
= 0.06 x 10
= 0.5743 hp

Power total = 1.8 + 0.5743
= 2.374 hp

Ukuran bucket = lebar x Proyeksi x kedalaman
= 8" x 5,5" x 7,75"

Bucket spacing = 8 in
Efisiensi motor = 80%

Maka, motor penggerak yang digunakan = $\frac{2.374}{}$ = 2.9678 hp = 3.0 hp

80%

Spesifikasi :

Fungsi = Memindahkan carbon black dari screw conveyor menuju bin

Kapasitas = 8.8375 ton/jam

Bucket = Tinggi bucket = 9.5713 ft
= Kecepatan bucket = 37.8750 ft/min
= Bucket spacing = 8 in
= Ukuran bucket = 8" x 5,5" x 7,75"
= Putaran head shaft = 28 rpm

Power = 3.0 hp

Jumlah = 1 buah

12. Tangki Penampung (Bin)

Fungsi : Menampung carbon Black sebelum masuk ke dalam pelletizer
Type : Silinder dengan tutup bawah berbentuk conical posisi vertikal
Temperatur : 200 C

Komponen	Berat (Kg/jam)	Fraksi Berat	ρ bahan (gr/cm^3)
C	8837.5000	1	2.267
Total	8837.5000	1	

r campuran :

$$= \frac{1}{\Sigma \frac{fraksi\ berat}{\rho\ komponen}}\ x\ 62{,}43 \frac{\text{lb}}{\text{cuft}} = \ ....\frac{\text{lb}}{\text{cuft}} (1 \frac{\text{gr}}{\text{cc}} = 62.43 \frac{\text{lb}}{\text{cuft}})$$

r campuran :

$$= \frac{1}{\frac{1}{2.267}} x62.43$$

= 141.5288 lb/cuft

Rate Massa = 8837.5000 kg/jam = 19483.1525 lb/jam

Rate Volumetrik = 137.6621 cuft/jam
Asumsi proses = 1 jam
= 137.6621 cuft/jam X 1 jam
= 137.6621 cuft

* Untuk faktor keamanan, asumsi bahan mengisi 80% volume tanki

Maka volume tanki = (100 / 80) x 137.6621
= 172.0776 Cuft

Menentukan ukuran tanki dan ketebalan :

Asumsi Dimension ratio : H/D = 2 (Ulrich : T.4-27)

Volume = ¼ π D2 H
172.0776 = ¼ π D^2 2D
172.0776 = 1.57 D^3
D^3 = 109.6 ft
D = 4.79 ft = 57 in 1.4587 m
H = 9.57 ft = 115 in 2.9173 m

Menentukan tebal minimum shell :

Tebal shell berdasarkan ASME Code untuk cylindrical tank :

$$t = \frac{P\ x\ ri}{\ldots} + C$$

$t_{min} = \frac{}{fE\ - 0.6\,P} + C$ **(brownell, pers.13-1, hal 254)**

dengan :

t.min = tebal shell minimum ; in

P = tekanan tangki ; psi

ri = jari - jari tangki ; in

C = faktor korosi ; in digunakan yaitu = 1/8 in

E = Faktor pengelasan, digunakan double welded, E 0.8

f = Stress allowable, bahan konstruksi Carbon Steel SA-283 grade C,
maka nilai f = **12650** psi [Brownell,T. 13-1]

Penentuan tekanan design pada tanki :

$$P_B = \frac{r\,\rho_B((\frac{g}{gc})}{2\mu k}\left[1 - e^{-2\mu k Zt/r}\right]$$ (Mc. Cabe, pers 26-24)

dimana :

P_B = tekanan vertikal dasar bejana

ρ_B = bulk densitas bahan, lb/cuft

μ = koefisien gesek = 0.35 - 0.55 dipilih 0.45

K' = ratio tekanan normal

k' = $\frac{1 - \sin\alpha}{1 + \sin\alpha}$ = 0.334 (sudut=30°)

Z_T = Tinggi total material dalam tangki

= 9.571 x 80% = 7.66 ft

r = jari-jari bin

= $\frac{1}{2}$ x 4.79 = 2.3928 ft

$$P_B = \frac{r\,\rho_B\,(\frac{g}{gc})}{2\,\mu\,k'}\left[1 - e^{-2\mu k' Z_T/r}\right]$$

= 802.3603 lb/ft2 = 5.571947 psi

1 psi = 144 lbf/ft2

Tekanan lateral, = k x PB (Mc.Cabe, hal 302)

P_L = 0.334 x 5.571946513 = 1.9 psi

P operasi = PB x PL = 5.5719 + 1.9 = 7.4 psi

P design = 1 x 7.4 = 8.18 psi

(10% faktor keamanan)

r = 1/2 D = 4.786 ft

tmin = $\frac{8.17627 \times 4.7857 \times 12}{(12650 \times 1) - (0.6 \times 8.1763)}$ + 0.125

= 0.17142034 in digunakan t = $\frac{1}{2}$ in

Untuk tebal tutup disamakan dengan tebal shell, karena bekerja pada tekanan atmosfer

Tutup bawah, conis :

Tebal conical = $\frac{P \times D}{2\cos\alpha\,(fE - 0.6P)}$ + C (Brownell, hal 118)

dengan α = $\frac{1}{2}$ sudut conis = $\frac{30}{2}$ = 15° = cos 15° = 0.966

tc = $\frac{469.5461}{}$ + 0.125

2 Cos α x 10115.094

= 0.1490 in = 1/2 inch

Tinggi conical :

$$h = \frac{tgn\ \alpha \times (D - m)}{2}$$ (Hesse, pers 14-7)

Keterangan :

α = 1/2 sudut co 15° = tgn 15° = 0.268

D = diameter tangki; ft

m = flat spot center; 12 in = 1 ft

maka, $h = \frac{1.01}{2} = 0.5$ ft

Spesifikasi:

Fungsi	:	Menampung Carbon Black sebelum masuk ke Pelletizer
Type	:	Silinder dengan tutup bawah berbentuk conical posisi vertikal
Volume	:	172.0776 cuft = 5 m^3
Diameter	:	4.8 ft
Tinggi	:	10 ft
Tebal Shell	:	1/2 in
Tebal tutup atas	:	1/2 in
Tebal tutup bawah	:	1/2 in
Tinggi tutup Conical	:	0.5 ft
Bahan Konstruksi	:	Carbon steel SA-283 grade C (Brownell : 253)
Jumlah	:	1 buah

13.Pelletizer

Fungsi	:	Membuat pellet carbon black dengan metode basah
Type	:	Wayne Strand Pelletizer (Model 221)
Dasar Pemilihan	:	Penanganan otomatis dan sesuai dengan bahan

Kondisi Operasi :

Suhu keluar rata - rata	=	60 ^oC	(***US. Patent: 6807749***)
Diameter pellet carbon black	=	1 mm	(***US. Patent: 6807749***)
Panjang pellet carbon black	=	5 mm	(Wayne Pelletizer)

Di pilih mesin pellet dari tabel spesifikasi alat dari wayne Strand Pelletizer :

SPESIFIKASI :

Fungsi	:	Membuat pellet carbon black dengan metode basah
Type	:	Wayne Strand Pelletizer (Model 221)
Manufacture	:	Wayne Inc.
Diameter pellet	:	1 mm
Panjang pellet	:	5 mm
Solid Rotor Cutter	:	2 in
Speed	:	500 rpm
Power	:	5 hp
Control Voltage	:	480 volt
Accesory	:	Feed & Cutter roll control
Jumlah	:	1 buah

14. Screw Conveyor

Fungsi : Memindahkan produk dari *Pelletizer* ke *Rotary Dryer*
Tipe : Troughed belt on 45° idlers with rolls of equal length
Dasar pemilihan : Dipilih conveyor jenis belt sesuai dengan bahan
Perhitungan :
Bahan Masuk : (Perry 7 Ed. T. 2-1)

Komponen	Berat	Fraksi berat	ρ	Fraksi berat/ρ	ρ bahan (lb/cuft)
C	8837.5000	0.7006	2.267	0.3091	141.524276
H_2O	3787.5000	0.3003	1	0.3003	62.4280
Total	12613.800	1		0.6093	

$$\rho \text{ campuran} = = \frac{1}{\frac{0.701}{2.267} + \frac{0.300}{1}} \times 62.3 \text{ lb/Cuft}$$

$$= 102.2453 \text{ lb/cuft}$$

Rate massa = 8837.5000 kg/jam = 19486.6875 lb/jam
Rate volumetrik = 190.5875 cuft/jam
= 3.1765 cuft/menit
= 23.7631 gpm

(Badger, Tabel 16-6)
Untuk densitas 102.2453 lb/cuft, bahan termasuk kelas D dengan F = 3

$$\text{Power Motor} = \frac{C.L.W.F}{33000}$$ (Badger, Tabel 16-5)

Dengan : C = kapasitas ; cuft/menit
L = panjang ; ft
W = densitas bahan ; lb/cuft
F = faktor bahan

Asumsi panjang conveyor, L = 50 ft

$$\text{Power Motor} = \frac{C.L.W.F}{33000} = \frac{3.2872 \times 50 \times 102.245 \times 3}{33000}$$

$$= 1.5277 \text{ hp} \approx 1.6 \text{ hp}$$

Untuk power < 2 hp, maka dikalikan 2 [Badger : 713]
1.5 x 2.00 = 3.055 hp
Efisiensi motor = 80% maka;

$$\text{Power Motor} = \frac{3.0555}{0.8} = 3.819 \text{ hp} \approx 3.82 \text{ hp}$$ $\frac{ft}{mir}$

Dari Badger, fig 16-20 untuk kapasitas 190.5875 cuft/jam
digunakan ukuran :
Diameter = 10 in
Kecepatan putaran = 30 rpm

Spesifikasi :

Fungsi : Memindahkan produk dari Pelletizer ke Rotary Dryer
Tipe : Troughed belt on 45° idlers with rolls of equal length
Kapasitas : 190.5875 cuft/jam
Panjang : 50 ft

Diameter	:	10	in
Kecepatan putaran	:	30	rpm
Power	:	3.8	hp
Jumlah	:	1	buah

15. Air Filter -2

Fungsi : Untuk menyaring udara bebas
Tipe : Dry type Airmat Dust Arrester
Bahan konstruksi : Carbon Steel

Perhitungan :

Rate udara = 197962.3080 kg/jam = 436506.89 lb/jam

BM udara = 28.95

ρ campuran pada P = 1 atm, T 30 ^oC = 546 Ra ; udara = 492

$$\rho = \frac{492\ Ra}{546\ Ra} \times \frac{1}{1} \times \frac{28.95}{359} = 0.0727\ lb/cuft$$

(***Himmelblau; 270***)

$$\text{Rate Volumetrik} = \frac{436506.89\ lb/jam}{0.07267\ lb/cuft} \frac{1}{60} = 100114.80\ cuft/mnt = 49.21\ ft/mnt$$

Dipilih air filter berdasarkan jenis pengoperasian otomatis, ***perry 8 ^{ed}, hal.17-54***

SPESIFIKASI

Fungsi	:	Untuk menyaring udara bebas
Type	:	Dry type Airmat Dust Arrester
Dasar Pemilihan	:	Penanganan otomatis dan sesuai dengan bahan
Ukuran filter	:	otomatis
Kecepatan	:	49 ft/mnt
Resistansi	:	0.4 in water
Filter Medium	:	glass fiber
Jumlah	:	1 buah

16. Blower -2

Fungsi : Memindahkan udara dari udara bebas ke Heater Udara
Tipe : Centrifugal Blower
Dasar Pemilihan : Sesuai dengan jenis bahan, effisiensi tinggi

Perhitungan :

Rate massa udara = 197962.308 kg/jam
= 436506.889 lb/jam

udara = 0.0727 lb/cuft

Dimana : P_2 = 20.0 psi
P_1 = 14.7 psi

Rate volumetrik udara (Q) =

$$= 436506.889 \frac{lb}{jam} \times \frac{1\ \ jam}{60\ \ menit} \times \frac{1\ \ cuft}{0.0727\ \ lb}$$

= 100114.797 cuft/menit

Power untuk menghembuskan udara :

HP = 0.000157 x Q x ΔP (Perry 6th ed., hal.6-22)
= 0.000157 x 100114.797 x 5.30
= 83.3055 HP ≈ 83 HP

Effisiensi = $\frac{\text{HP blower}}{\text{HP shaft}}$ (Perry 5th ed., pers.6-35)

Effisiensi blower = 40% - 70% (Perry 5th ed., hal.6-21)

Diambil = 70%

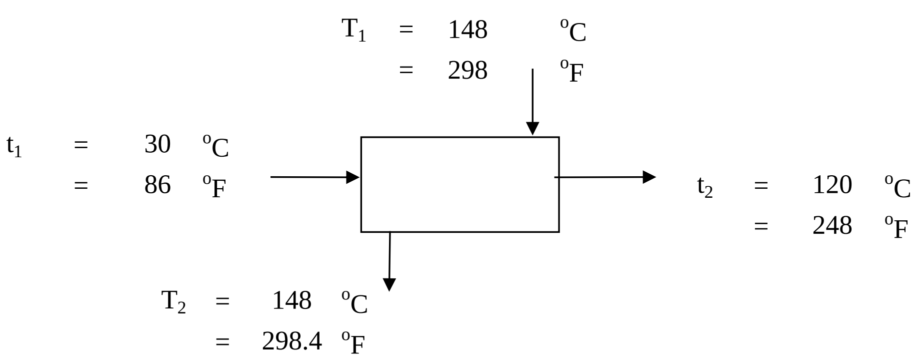
HP shaft = $\frac{83.3055}{0.7}$ = 119.008 HP ≈ 119 HP

Spesifikasi :

Fungsi	:	Memindahkan udara dari udara bebas ke Heater Udara
Tipe	:	Turbo blower
Kapasitas	:	100114.797 cuft/menit
HP shaft	:	119 hp
Power	:	83 hp
Bahan Konstruksi	:	Carbon Steel
Jumlah	:	1 buah

17. Preheater -2

Fungsi	:	Memanaskan udara dari suhu 30°C menjadi suhu 120°C
Tipe	:	Shell and Tube Heat Exchanger (Fixed Tube)
Dasar Pemilihan	:	Umum digunakan dan mempunyai range perpindahan panas yang besar
Kondisi Operasi	:	- P = 1 atm
		- T = 120 °C
		- Waktu operasi = Kontinyu



Perhitungan :

1. Heat balance

Q supply	=	1028739.583	kkal/jam	=	4079981	Btu/jam
W bahan masuk	=	197962.3080	kg/jam	=	436431.6634	Btu/jam
W steam masuk	=	2681.5137	kg/jam	=	5911.7188	Btu/jam

2. Penentuan ΔT_{LMTD}

hot fluid		cold fluid	diff.
298.4	higher temp.	248	50.4
298	lower temp.	86	212
0		162	162

$$\Delta t\ LMTD = \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t_1}{\Delta t_2}}$$

$$\Delta t\ LMTD = \frac{50 - 212}{\ln\ 50 / 212} = 112.6189\ ^oF$$

3. Tc dan tc

$$Tc = \frac{T_1 + T_2}{2} = \frac{298 + 298}{2}$$

$$= 298\ ^oF$$

$$tc = \frac{t_1 + t_2}{2} = \frac{86 + 248}{2}$$

$$= 167\ ^oF$$

Penentuan Tube = 5 - 50

Koefisien perpindahan panas U_D = 30 $\frac{BTU}{ft^2\ F}$ Kern Table 8

Luas perpindahan panas A = $\frac{Q}{U_D \times \Delta T\ LMTD}$

$= \frac{4079981.1880}{30 \times 112.6189}$

$= 1207.607\ ft^2$

$= 112.190\ m^2$

Kern Tabel 10 pg. 843

Pemilihan Design Tube

OD		=	1	in
BWG		=	16	
ID		=	0.8700	in
Flow area per tube	(a't)	=	0.5940	in^2
Outside surface per lin ft	(a")	=	0.2618	ft^2
Pitch		=	Square in	
Pitch Size		=	1 1/4	in
Asumsi Panjang Tube (L)		=	15	ft = 4.6 m

Jumlah Tube Nt = $\frac{A}{a'' \times L}$

$= \frac{1207.6074}{0.2618 \times 15} = 307.514$

Kern Table 9 pg 841

Phase = 2

ID Shell = 29 in

Jumlah Tube Standar = 326

Spesifikasi Heater

Fungsi	:	Menaikkan suhu Udara dari suhu 30^{O}C ke suhu 120^{O}C sebelum memasuki Rotary Dryer
Type	:	Shell and tube heat exchanger
Panjang Tube	:	15 ft
Diameter Tube (ID)	:	0.87 in
Diameter Tube (OD)	:	1 in
Jumlah Tube Standar	:	326 buah
Flow area per tube	:	0.594 in^2
Outside surface per lin ft	:	0.2618 ft^2
BWG	:	16
Pitch	:	Square in
Pitch Size	:	1.25 in
Phase	:	2
Diameter Shell	:	29 in
Jumlah	:	1 buah
Bahan konstruksi	:	Carbon Steel

18. Rotary Dryer

Fungsi : Mengeringkan pellet carbon dengan bantuan udara panas

Dasar pemilihan : Sesuai untuk pengeringan padatan

Kondisi operasi :
- Tekanan = 1 atm
- Suhu = 100 °C
- Waktu operasi = Time of passes

Komponen	Berat (Kg/jam)	Fraksi berat	ρ	Fraksi/ρ	ρ bahan (lb/cuft)
C	8837.5	0.9970	2.267	0.43978827	141.524276
H_2O	26.59227683	0.0030	1	0.003	62.428
Total	8864.0923	1.0000		0.4428	

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ komponen}}} \times 62.43 \text{ gr/ml}$$

$$= \frac{1.0000}{0.4428} \times 62.43 \frac{\text{lb/cuft}}{\text{gr/ml}}$$

$$= 140.9929 \text{ lb/cuft}$$

Kapasitas	=	8864.0923	kg/jam	=	19541.95512	lb/jam
Jumlah produk keluar	=	8864.0923	kg/jam	=	19541.9551	lb/jam
Besar air yang diuapkan	=	26.5923	kg/jam	=	58.6259	lb/jam
Kebutuhan udara pemanas	=	197962.3080	kg/jam	=	436431.6634	lb/jam

Diameter Rotary Dryer :

Diameter Rotary Dryer = 1 - 3 m (Ulrich, Tabel 4-10, Hal. 132)

Diambil D = 1.5 m = 4.92 ft = 59 in

Panjang Rotary Dryer :

L/D = 6-10 (Ulrich, Tabel 4-10, Hal. 132)

Diambil L/D = 6

L = 6 D

L = 6 x 2 = 9 m = 30 ft

Putaran Rotary Dryer :

Rotary dryer beroperasi pada peripheral speed : 60 - 75 ft/menit

Diambil Vp = 75 ft/menit (Perry 7th ed.,hal.12-54)

$$N = \frac{Vp}{3.14 \times D} = \frac{75}{3.14 \times 4.92} = 4.9 \text{ rpm}$$

Time of Passage :

Penentuan time of passage adalah untuk mengetahui lama material dalam rotary dryer

$$\theta = \frac{0.23 \times L}{S \times N^{0.9} \times D} \pm 0.6 \frac{B \times L \times G}{F}$$ (Perry 7th ed.,hal.12-55)

Keterangan :

e = time of passage, menit

L = panjang rotary dryer, ft

G = rate flue gas, lb/j ft^2

F = rate feed, lb material kering/jam

B = konstanta (tergantung dari sifat material)

S = slope, ft/ft

Rotary dryer beroperasi dengan sistem counter-current, maka :

$B = 5 (Dp)^{-0.5}$ (Perry 7th ed.,hal.12-55)

Diameter partikel = Dp = 0.125 - 0.5 in

Diambil : Dp = 0.5 in = 1.27 cm = 12700 μm

$B = 5 \times (12700)^{-0.5} = 0.0444$

Slope rotary dryer = S = 0 - 8 cm/m (Perry 7th ed.,hal.12-56)

Diambil : S = 3.00 cm/m = 0.098425 ft/ft

Rate flue gas = G = 0.5 - 5 $kg/s.m^2$

Diambil : G = 5 $kg/s.m^2$ = 0.032959 $lb/jam.ft^2$

Maka : tg α = 0.10

α = 5.71

$$\theta = \frac{0.23 \times L}{S \times N^{0.9} \times D} + 0.6 \frac{B \times L \times G}{F}$$

$$= \frac{0.23 \times 29.5276}{0.10 \times 5^{0.9} \times 4.9213} + 0.6 \frac{0.0444 \times 29.5 \times 0.03}{19541.9551}$$

= 3.3832 + 0.0000013

= 3.3832 menit = 202.9899 detik

Power Penggerak :

$$BHP = \frac{N \times (4.75dw + 0.1925\ DW + 0.33W)}{100000}$$ (Perry 7th ed.,hal.12 - 60)

Keterangan :

BHP = Brake Horse Power yang dibutuhkan

d = diameter shell, ft

D = diameter riding ring = (d+2), ft = 6.9213 ft

w = berat material, lb

W = berat total rotary dryer, lb
N = putaran rotary dryer, rpm

Perhitungan Tebal Shell Drum :
Rotary Drum memakai shell dari stainless steel AISI type316 dengan stress
allowable = 36000 psi (Perry 8ed, Tabel 25-11)
ρ = 140.9929 lb/cuft

Tekanan Vertikal Pada Tangki :

$$PB = \frac{r\rho_b\,(g/gc)}{2\,\mu'\,k'}\left(1 - e^{-2\mu' k' ZT/r}\right)$$ (Mc.Cabe, pers 26-24)

Keterangan :
P_B = Tekanan Vertikal pada dasar
ρ_B = Densitas bahan
μ' = Koefisien gesek (0,35-0,55) diambil = 0.45
k' = ratio tekanan normal
(Mc.Cabe, pers 26-17)

$$\frac{1 - \sin\alpha}{1 + \sin\alpha} = \frac{1 - \sin(30)}{1 + \sin(30)} = \frac{1 - 1}{1 + 1} = 0.33$$

Z_T = Tinggi total material dalam tangki, asumsi tinggi bahan
15% dari tinggi drum
15% x 4.92 = 0.7 ft (Ulrich, T.4-10, hal 132)
r = jari-jari tangki, ft ; r = D / 2 = 2.4606 ft

maka : $$PB = \frac{2.4606 \times 140.99 \times (32/32.174)}{2 \times 0.45 \times 0.33}\left[1 - e^{-2(0,45)(0,33)(0.5)/1,64}\right]$$

PB = 1154.5985 lb/ft^2
= 8.0180 psi

Tekanan Lateral P_L = k' P_B
= 2.6460 psi
P operasi = P_B + P_L
= 8.0180 + 2.6460
= 10.6640 psi
Untuk faktor keamanan 10% digunakan tekanan
P operasi = 1.1 x 10.6640
= 12.7304 psi

Tebal Shell digunakan ASME Code

$$t_{min} = \frac{P \times r}{fE - 0{,}6P} + C$$ (Brownell,pers. 13-1,hal 254)

dengan :
t_{min} = tebal shell minimum ; in
P = tekanan tangki ; psi
r = jari-jari tangki ; in (1/2 D)
C = faktor korosi ; in (digunakan 1/8 in)
E = faktor pengelasan, digunakan dobel welded E = 0.8
f = stress allowable, bahan konstruksi stainless steel AISI 316
f = 36000 psi (Perry 7ed, Tabel 28-11)

$$t_{min} = \frac{P \times r}{fE - 0{,}6P} + C$$

$$= \frac{12.7304 \times 29.528}{28800 - 7.6382} + \frac{1}{8}$$

$$= \frac{375.8976}{28792.3618} + 0.125$$

= 0.1381 in

digunakan t = 3/16 in

Sudut Rotary Dryer

Slope = 0.09843

tan α = 0.09843

Sudut = 5.71 °

Berat Total Rotary Dryer :

- Berat silinder :

$$Ws = \left(\frac{\pi}{4} D_2^2 - D_1^2\right) L \times \rho$$

Keterangan :

D_2 = diameter luar silinder shell

$$= 4.92 + \left(\frac{2 \times 0.25}{12}\right)$$

= 4.9629 ft

D_1 = diameter dalam silinder shell = 4.9213 ft

ρ = densitas steel = 489 lb/cuft (Perry 7th ed.,T. 2-118)

L = panjang rotary dryer = 29.5276 ft

$$Ws = \left(\frac{\pi}{4} 4.9629^2 - 4.9213^2\right) \times 29.5 \times 489$$

= 4668.0526 lb

- Berat isolasi :

$$Wt = \left(\frac{\pi}{4} D_3^2 - D_1^2\right) L \times \rho$$

Keterangan :

D_3 = diameter luar isolasi

$$= 4.92 + \left(\frac{2 \times 0.25}{12}\right)$$

= 4.9629 ft

ρ = densitas isolasi

= 115 lb/cuft (bahan : Alumina) (Perry 6th ed.,hal.3-260)

$$Wt = \left(\frac{\pi}{4} 4.9629^2 - 4.9213^2\right) \times 29.5 \times 115$$

= 1097.8038 lb

- **Berat flight :**

Wf = n x L x h x t x ρ

Keterangan :

n = jumlah flight = 0,6D - D (Perry 7th ed.,hal.12 - 56)

diambil : n = 0.8 D

= 0.8 x 4.9213 = 3.9370 ≈ 4 buah

h = tinggi flight = 1/8D - 1/12D (Perry 3th ed.,hal.832)

diambil : h = 1/10 x 4.92 = 5/10 ft

t = tebal flight = π D/12

$= \pi \dfrac{4.9213}{12} = 1.2877$ ft

Wf = 4 x 29.53 x 0.49 x 1.29 x 489

= 36024.9747 lb

- **Berat material :**

W = rate feed x e

$= 19541.9551 \times 3.38$ menit $\times \dfrac{1}{60}$

= 1101.8943 lb

- **Berat Gear :**

$$Wg = \frac{\pi}{4}\, b \left(D^2 - d^2 \quad \rho \right)$$

Keterangan :

b = lebar permukaan gear

= (2.38 Pc) + (0.25) (Hesse, tabel 15-6, hal.446)

Dimana Pc = circular = 1.75 - 2 in

Diambil Pc = 2 in

Jadi b = (2.38 x 2) + 0.25

= 5.01 in

d = diameter luar shell rotary dryer

= 4.9629 ft

ρ = densitas cast iron

= 450 lb/cuft (Perry 7th ed.,T. 2-118)

$$Wg = \frac{\pi}{4} \times \frac{5.01}{12} \times \left(6.92^2 - 4.9629^2 \times 450 \right)$$

= 3432.374918 lb

- **Berat riding ring :**

$$Wr = 2 \times \frac{\pi}{4} \times b\,(D^2 - d^2)\rho$$

Keterangan :

b = 5.01 in

d = 4.9629 ft

D = diameter riding ring (Perry 7th ed., hal 12-60)

= d + 2 = 4.96 + 2 = 6.96 ft

$$Wr = 2 \times \frac{\pi}{4} \times \frac{5.01}{12} \times \left(6.96^2 - 4.96^2 \times 450 \right)$$

= 7035.3887 lb

Jadi, berat total rotary dryer :

= 4668.0526 + 1097.8038 + 36024.975 + 1101.8943 + 3432.4

+ 7035.3887

= 53360.489 lb

Power Penggerak (BHP) :

$$BHP = \frac{4.85350318}{100000} \times \left(4.75 \times 4.96 \times 1101.89 \right) + \left(0.193 \times 6.96 \times 53360.5 \right) + \left(0.33 \times 53360.49 \right)$$

BHP = 5.5867 hp

Effisiensi motor = 80%

$$\text{Power Motor} = \frac{5.5867}{0.80} = 6.9834 = 7 \text{ Hp}$$

Spesifikasi :

Fungsi	:	Mengeringkan pellet carbon dengan bantuan udara panas
Tipe	:	Single Shell Direct Rotary Dryer
Kapasitas	:	19541.9551 lb/jam
Ukuran	:	Diameter = 4.9213 ft
		Panjang = 29.5276 ft
		Slope = 0.0984 ft/ft
Putaran	:	4.9 rpm
Kecepatan udara	:	0.03 lb/j ft^2
Kecepatan putaran	:	75 ft/menit
Time of passage	:	3.3832 menit
Jumlah flight	:	4 buah
Tinggi radial flight	:	0.4921 ft
Power	:	7 Hp
Jumlah	:	1 buah

19. Cooling Conveyor

Fungsi : Mendinginkan bahan sampai dengan 30˚C

Tipe : Plain spout of chutes.

Dasar Pemilihan : Umum digunakan untuk padatan dengan sistem tertutup.

Perhitungan :

Rate massa = 8864.0923 kg/jam = 8.8641 ton/jam

Berdasarkan kapasitas = 8.8641 ton/jam

Dari Perry 7 Ed. T 21-7 dan fig. 21-4 dipilih belt conveyor dengan spesifikasi :

Kapasitas maksimum = 32 ton/jam

hp tiap 10 ft (linier-ft) = 0.34 hp/ft

Asumsi :
- jarak belt conveyor = 25 ft
- tinggi belt = 10 ft

Slope = α

$$tg\ \alpha = \frac{10}{25}$$

tg α = 0.4

α = 21.8 °

Panjang belt = $\sqrt{25^2 + 10^2}$ = 26.9258 ft

Perhitungan Power :

hp / 10ft, lift = 0.34 hp/ft (Perry 7 Ed. T 21-7)

$$hp = \frac{26.9258}{10} \times 0.34 = 0.9155 \text{ hp}$$

Penambahan power untuk tripper = 2 hp (Perry 7 Ed. T 21-7)

Power Total = 2.9155 , hp = 3 hp

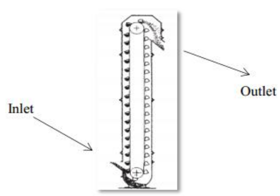
Spesifikasi :

Fungsi	:	Mendinginkan suhu carbon black hingga 30 C menuju Silo
Kapasitas	:	8.8641 ton/jam
Belt	:	Width = 14 in = 4.2672 m 14 ft
		Trough width = 9 in = 2.7432 m 9 ft
		Skirt seal = 2 in = 0.6096 m 2 ft
		Belt speed = $\frac{8.8641}{32}$ x 100 ft/min = 27.70029
		Panjang = 26.9258 ft
		Sudut = 21.8 °
Power	:	3 hp
Jumlah	:	1 buah

20. BUCKET ELEVATOR

Fungsi : Memindahkan karbon black dari Cooling conveyor

Tipe : *Continous bucket elevator*



Kondisi Operasi :

T = 30 ˚C

P = 1 atm

Perhitungan :

Rate massa = 8864.0923 kg/jam = 8.8641 ton/jam

ρ carbon = 141.5243 lb/cuft

Dari Perry 7 Ed. T 21-9 dipilih bucket elevator dengan spesifikasi :

Tinggi Bucket	=	17	ft
Putaran head shaft (kepala poros)	=	28	rpm
Kapasitas maksimum	=	35	ton/jam
Bucket linear speed	=	150	ft/min

Sehingga, untuk kapasitas 8.8641 ton/jam, maka :

Kecepatan bucket elevator = $\frac{8.8641}{35}$ x 150 ft/min

= 37.9889669 ft/min

Power pada head shaft = 1.8 hp

Power tambahan = 0.06 hp tiap ft

= 0.06 x 17

= 0.991466413 hp

Power total = 1.8 + 0.9914664

= 2.791 hp

Ukuran bucket = lebar x Proyeksi x kedalaman

= 8" x 5,5" x 7,75"

Bucket spacing = 8 in

Efisiensi motor = 80%

Maka, motor penggerak yang digunakan = $\frac{2.791}{80\%}$ = 3.4893 hp = 3.5 hp

Spesifikasi :

Fungsi = Memindahkan karbon black dari Cooling conveyor

Kapasitas = 8.8641 ton/jam
Bucket = Tinggi bucket = 16.524 ft
= Kecepatan bucket = 37.9890 ft/min
= Bucket spacing = 8 in
= Ukuran bucket = 8" x 5,5" x 7,75"
= Putaran head shaft = 28 rpm
Power = 3.5 hp
Jumlah = 1 buah

21. Tangki Penampung (Silo)

Fungsi : Menampung Carbon Black sebelum Packing
Type : Silinder dengan tutup bawah berbentuk conical posisi vertikal
Temperatur : 30 C

Komponen	Berat (Kg/jam)	Fraksi Berat	ρ bahan (gr/cm^3)	ρ bahan (lb/cuft)
C	8837.5000	0.9970	2.267	141.524276
H2O	26.5923	0.0030	1	62.428
Total	8864.0923	1		

r campuran :

$$= \frac{1}{\Sigma \frac{fraksi\ berat}{\rho\ komponen}} x\ 62{,}43 \frac{lb}{cuft} = \dots \frac{lb}{cuft} (1 \frac{gr}{cc} = 62.43 \frac{lb}{cuft})$$

r campuran : $= \dfrac{1}{\dfrac{0.997}{2.267} + \dfrac{0.003}{1}}$ X 62.3

= 27.5857 lb/cuft

Rate Massa = 8864.0923 kg/jam = 19541.77783 lb/jam

Rate Volumetrik = 708.402 cuft/jam
Asumsi proses = 1 jam
= 708.402 cuft/jam X 1 jam
= 708.402 cuft

* Untuk faktor keamanan, asumsi bahan mengisi 80% volume tanki

Maka volume tanki = $\left(\dfrac{100}{80}\right)$ x 708.4022
= 885.5028 Cuft

Menentukan ukuran tanki dan ketebalan :

Asumsi Dimension ratio : H/D = 2 (Ulrich : T.4-27)
Volume = ¼ π D2 H
885.5028 = ¼ π D^2 2D
885.5028 = 1.57 D^3
D^3 = 564.01 ft
D = 8.26 ft = 99 in
H = 16.52 ft = 198 in

Menentukan tebal minimum shell :

Tebal shell berdasarkan ASME Code untuk cylindrical tank :

$$t_{min} = \frac{P\ x\ ri}{fE\ - 0.6\ P} + C$$ **(brownell, pers.13-1, hal 254)**

dengan :
t.min = tebal shell minimum ; in

P	=	tekanan tangki ; psi
ri	=	jari - jari tangki ; in
C	=	faktor korosi ; in digunakan yaitu = 1/8 in
E	=	Faktor pengelasan, digunakan double we 0.8
f	=	Stress allowable, bahan konstruksi Carbon Steel SA-283 grade C, maka nilai f = **12650** psi [Brownell,T. 13-1]

Penentuan tekanan design pada tanki :

$$P_B = \frac{r\,\rho_B((\frac{g}{gc})}{2\mu k}\left[1 - e^{-2\mu k Zt/r}\right]$$ (Mc. Cabe, pers 26-24)

dimana :

P_B = tekanan vertikal dasar bejana

ρ_B = bulk densitas bahan, lb/cuft

μ = koefisien gesek = 0.35-0.55 dipilih = 0.45

K' = ratio tekanan normal

k' = $\frac{1 - \sin\alpha}{1 + \sin\alpha}$ = 0.334 (sudut=30°)

Z_T = Tinggi total material dalam tangki

= 16.52 x 80% = 13.22 ft

r = jari-jari bin

= $\frac{1}{2}$ x 8.26 = 4.1311 ft

$$P_B = \frac{r\,\rho_B\,(\frac{g}{gc})}{2\,\mu\,k'}\left[1 - e^{-2\mu k' Z_T/r}\right]$$

= 270.0001 lb/ft2 = 1.88 psi 1 psi = 144 lbf/ft2

Tekanan lateral,

P_L = k x PB (Mc.Cabe, hal 302)

P_L = 0.334 x 1.88 = 0.6 psi

P operasi = PB + PL = 1.875 + 0.6 = 2.5 psi

P design = 1.1 x 2.5 = 2.8 psi

(10% faktor keamanan)

r = 1/2 D = 4.131 ft

$$t_{min} = \frac{2.75137591 \times 4.1311101 \times 12}{(12650 \times 0.8) - (0.6 \times 2.7514)} + 0.125$$

= 0.1385 in digunakan t = 1/2 in

Untuk tebal tutup disamakan dengan tebal shell, karena bekerja pada tekanan atmosfer

Tutup bawah, conis :

Tebal conical = $\frac{P \times D}{2 \cos\alpha\,(fE - 0.6P)}$ + C (Brownell, hal 118)

dengan α = $\frac{1}{2}$ sudut conis = $\frac{30}{2}$ = 15° = cos 15° = 1

tc = $\frac{272.7897}{2 \cos\alpha \times 10118.349}$ + 0.125

= 0.1390 in = 1/2 inch

Tinggi conical :

$$h = \frac{tgn\ \alpha \times (D - m)}{2} \quad \text{(Hesse, pers 14-7)}$$

Keterangan :

α = 1/2 sudut conis; 15° = tgn 15° = 0.268

D = diameter tangki; ft

m = flat spot center; 12 in = 1 ft

maka, $h = \frac{1.95}{2}$ = 1.0 ft

Spesifikasi:

Fungsi	:	Menampung Carbon Black sebelum Packing
Type	:	Silinder dengan tutup bawah berbentuk conical posisi vertikal
Volume	:	885.503 cuft = 25 m^3
Diameter	:	8.3 ft
Tinggi	:	17 ft
Tebal Shell	:	1/2 in
Tebal tutup atas	:	1/2 in
Tebal tutup bawah	:	1/2 in
Tinggi tutup Conical	:	1.0 ft
Bahan Konstruksi	:	Carbon steel SA-283 grade C (Brownell : 253)
Jumlah	:	1 buah

d) Pengeluaran Produk (Tapping)

Interval waktu tapping ditetapkan 30 menit (Kirk&Othmer vol 2 hal 109)

jumlah tiap hole ditetapkan = 24 cm

Tinggi permukaan muatan = $\frac{\text{volume muatan}}{\text{luas crucible}}$

$$= \frac{542.30921}{0.25 \times 3.14 \times 2.0962^2}$$

= 157.2171609 m

Letak tiap hole = 1/3 x tinggi muatan

= 1/3 x 157.22

= 52.406 m

21. Burner Rotary Dryer

Fungsi : Untuk memanaskan udara bebas dengan bantuan fuel oil

Type : Thermal direct fired heater

Kondisi operasi :

Suhu udara masuk = 30 °c

Suhu gas masuk = 120 °c

Tekanan = 1 atm

Proses operasi = Continous

Rate massa udara masuk = 197962.308 kg/jam

= 436506.8891 lb/jam

Humidity pada 86°F = 0.022 lb H_2O uap/lb udara

Volume spesifik = 0,0405 x (460+T) x (0,622 + H)

= 12.7802 cuft/lb

$$\rho = \frac{1}{V}$$

$$= \frac{1}{12.7802}$$

= 0.0782 lb/cuft

$$\text{Rate volumetrik} = \frac{436506.89}{0.0782}$$

= 5578636.6138 cuft/jam

= 92977.2769 cuft/menit

Panas yang disupply ke rotary dryer = 306512.2764 kkal/jam

= 1215627.6881 btu/jam

Berdasarkan perry ed 5 halaman 9-33, Figure 9-28 mendapatkan dimensi burner :

A = 30 in

B = 27 in

C = 72 in

D = 30 in

Spesifikasi :

Fungsi = Untuk memanaskan udara bebas menggunakan fuel oil

Type = Thermal direct fired heater

Kondisi operasi

Tekanan	=	1 atm
Suhu operasi	=	120 °C
Proses operasi	=	Continous
Kapasitas	=	436506.89 lb/jam

Dimensi burner

A	=	30	in
B	=	27	in
C	=	72	in
D	=	30	in
Jumlah	=	1	buah

B. Diameter atomizer

Maksimum drop size atomizer : (Perry ed 6. p.20-57)

Jenis : Disk Atomizer

$X = (1920(\alpha)^{1/2}) / (Va \cdot \rho l) + 597 ((\mu / (\alpha \rho l)^{1/2})^{0,45} (1000\ Ql / Qa)^{1/5}$

Keterangan :

X	=	diameter drop, µm			
α	=	surface tension	=	1	
Va	=	relative velocity air and liquid, cuft/s			
ρl	=	liquid density, g/cm^3	=	23.9663	
µ	=	liquid viscosity	=	0.98	
Ql	=	liquid volumetric	=	1.42	cuft/s
Qa	=	air volumetrik	=	1.42	cuft/s

ρ campuran = 23.9663 lb/cuft

Rate bahan masuk = 18882.0018 kg/jam = 41634.8140 lb/jam

Volumetrik bahan = $\frac{\text{rate bahan}}{\rho \text{ bahan}} = \frac{41634.8140 \text{ lb/jam}}{23.9663 \text{ lb/cuft}}$

= 1737.224 cuft/jam

= 0.4826 cuft/detik

$X = (1920\ (1)^{1/2}) / (1,0136 \times 0,329) + 597\ ((0,98 / (1 \times 0,329)^{1/2})^{0,45}\ (1000 \times 1,42 / 1,42)^{1,5}$

X = 24002610.2 µm

0.04

13. COMPRESSOR

Fungsi : Memberi tekanan pada tangki CO_2 (F-310)

Type : Sliding-vane Rotary Compressor.

Dasar pemilihan : Sesuai dengan jenis bahan, effisiensi tinggi.

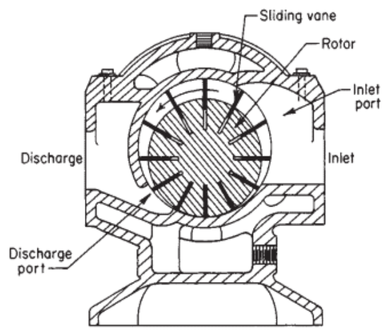


FIG. 10-81 Sliding-vane type of rotary compressor.

Perhitungan rate udara:

Rate massa udara = 189312.156 kg/jam = 417,433.30 lb/jam

BM udara standart = 28.95 kg/kmol

BM udara standart = kg/kmol

Menentukan densitas gas udara : [Himmelblau : 249]

pada P = 1 atm

T = 30 °C = 546 °R

Udara standart

T = 25 °C = 492 °R

P = 1 atm

$$\rho = \frac{T_{\text{udara standart}}}{T_{\text{gas CO2}}} \times \frac{P_{\text{gas CO2}}}{P_{\text{udara standart}}} \times \frac{BM_{\text{gas CO2}}}{BM_{\text{udara standart}}}$$

$$= \frac{492}{546} \times \frac{1}{1} \times \frac{28.95}{359}$$

= 0.0727 lb/cuft

ρ reference (air) = 62.43 lb/cuft

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\text{Densitas}}$$

$$= \frac{417,433.3}{0.0727}$$

= 5744411 cuft/jam

= 95740.185 cuft/menit

= 1595.6698 cuft/detik

Asumsi aliran turbulen

Di optimum untuk turbulen, NRe > 2100 digunakan persamaan (15)

Peters:

Diameter optimum = $3{,}9 \times q_f^{0,45} \times \rho^{0,13}$

Dengan: q_f = fluid flow rate ; cuft/dt

ρ = fluid density ; lb/cuft

Diameter pipa optimum = 76.624 in [Peters, 4ed, pers 15 hal 496]

Dipilih pipa 8 in sch 80

OD = 8.625 in [Mc Cabe 5[ed], appendix 5]

ID = 7.625 in = 0.6354 ft = 2.084802 m

A = 0.3171 ft^2

$$\text{Kecepatan aliran, } v = \frac{\text{Rate volumetrik}}{\text{Area pipa}} \quad \frac{\text{cuft/detik}}{\text{ft}^2}$$

$$= \frac{1595.6698}{0.3171}$$

$$= 5032.0711 \text{ ft/detik}$$

$$\text{Sg bahan} = \frac{\rho \text{ bahan}}{\rho \text{ reference } (H_2O)} \times \text{Sg reference}$$

$$= \frac{0.0727}{62.43} \times 1$$

$$= 0.0012$$

Berdasarkan Sg bahan

$$\mu \text{ reference} = 0.00085 \text{ lb/ft}$$

$$\mu \text{ bahan} = \frac{\text{Sg bahan}}{\text{Sg reference } (H_2O)} \times \mu \text{ reference}$$

$$= \frac{0.0012}{1} \times 0.00085$$

$$= 0.0000010 \text{ lb/ft.detik}$$

$$NRe = \frac{ID \; v \; \rho}{\mu}$$

$$= \frac{0.635 \times 5032.0711 \times 0.0727}{0.0000010}$$

$$= 234{,}844{,}169 > 2100 \quad \text{Asumsi turbulen benar}$$

Perhitungan power : [Perry 6[ed]; pers. 6-31b]

$$hp = 0.004 \; Q \times P_1 \times \ln \frac{P_2}{P_1}$$

dengan Q = rate volumetrik gas ; cuft/menit

P_1 = operating suction pressu ; 14.7 psi = 1 atm

P_2 = operating discharge pres ; psi

= 5 atm = 73.5 psi

$$P_2 = P_1 + \Delta P_{pipa} + \Delta P_{akhir}$$

$$= 14.7 + 2 + 73.5$$

$$= 90.2000 \text{ psi}$$

$$hp = 0.004 \; Q \times P_1 \times \ln \frac{P_2}{P_1}$$

$$= 0.004 \times 95740.185 \times 14.7 \times \ln \frac{90.2000}{14.7}$$

$$= 10212.9787 \text{ hp}$$

Dengan asumsi effisiensi motor ya = 80% maka:

$$hp = \frac{10212.9787}{80\%}$$

$= 12766$ hp

Adiabatic head = 15,000 $ft.lb_f/lb_m$ [Perry 6[ed], fig 6-35]

Spesifikasi :

Bahan	:	Commercial steel
Rate volumetrik	:	95740.185 cuft/menit
Adiabatic head	:	15,000 $ft.lb_f/lb_m$
Effisiensi motor	:	80%
Power	:	12766 hp
Jumlah	:	1 buah

n

kadar debu dalam udara
1 gr/1000 cuft
berat debu dalam udara

$\frac{1}{1000}$ x 95740.185 = 95.74018521 gr/menit

ukuran dry filter = 24 in x 24 in

kapasitas dry filter = 10000 cuft/menit

Menghitung jumlah filter udara

$$N = \frac{Q}{\text{Kapasitas Dry Filter}}$$

$$= \frac{95740.185}{10000} = 9.57401852 = 96 \text{ buah}$$

ɔke

m/detik

gga

l

APPENDIX D
PERHITUNGAN ANALISA EKONOMI

Kapasitas Produksi Carbon Black	=	70,000.0000	ton/tahun			
	=	8,838.3838	kg/jam			
Basis Bahan Baku Residual oil	=	1 ton/jam	=	1000	kg/jam	
Waktu Operasi	=	1 tahun	=	330	hari	
		1 hari	=	24	jam	

Dengan Bahan Baku :
Residual oil = 18882.0018 kg/jam

Menghasilkan Produk
Carbon Black = 8,838.3838 kg/jam

Faktor-Faktor yang perlu untuk ditinjau antara lain :
1. Laju pengembalian modal *(Rate of Return)*
2. Lama pengembalian modal *(Pay Back Periode)*
3. Titik impas *(Break Event Point)*

Untuk meninjau faktor-faktor diatas, perlu adanya penaksiran terhadap beberapa beberapa faktor, yaitu :
1. Penaksiran modal industri *(Total Capital Investment)* yang terdiri atas :
   a. Modal Tetap *(Fixed Capital Investment)*
   b. Modal Kerja *(Working Capital Investment)*
2. Penentuan biaya produksi total *(Production Cost)* yang terdiri atas :
   a. Biaya Pembuatan *(Manufacturing Cost)*
   b. Biaya Pengeluaran Umum *(General Expences)*
   c. Total Pendapatan

1. HARGA PERALATAN

Harga peralatan berubah menurut waktu resmi sesuai dengan kondisi ekonomi dunia. Untuk memperkirakan harga peralatan saat ini, digunakan indeks seperti pada persamaan sebagai berikut :

$$Cp = \frac{Ip}{Io} \times Co$$

Dimana : Cp = Harga alat pada tahun 2019

Co = Harga alat pada tahun data 2016
Ip = Cost Index pada tahun 2019
Io = Cost Index pada tahun data 2016

Perhitungan peralatan didasarkan pada Cost Equipment sedangkan Cost Indeks didasarkan pada Peters and Timmerhauss " Plant Design and Economic for Chemical Engineering ". Perhitungan Engineering berdasarkan Chemical Engineering Plant Cost Index (CEPCI), Chemical tabel D-1.

Tabel D.1. Indeks Harga Peralatan

Tahun	Indeks
2010	550.8
2011	585.7
2012	584.6
2013	567.3
2014	576.1
2015	556.8
2016	541.7
2017	567.5
2018	603.1

Sumber : CEPCI Tahun 2018 Annual Index

Dengan metode least square dan data-data pada tabel di atas dilakukan pendekatan atau penafsiran indeks harga peralatan pada awal tahun dimana data-data :
Keterangan :
Y = Indeks harga peralatan pada tahun ke-n
X = Tahun ke-n

n	X	Y	X^2	Y^2	XY
1	2010	550.8	4040100	303381	1107108
2	2011	585.7	4044121	343044	1177843
3	2012	584.6	4048144	341757	1176215
4	2013	567.3	4052169	321829	1141975
5	2014	576.1	4056196	331891	1160265
6	2015	556.8	4060225	310026	1121952
7	2016	541.7	4064256	293439	1092067
8	2017	567.5	4068289	322056	1144648
9	2018	603.1	4072324	363730	1217056
	18,126	5,133.60	36505824	2931154	10339129

Jumlah Data (n) = 9

Persamaan 17-21, Peters and Timmerhauss :

$\sum(\bar{x} - x)^2 = \sum x^2 - \frac{(\sum x)^2}{n} =$ 60.0000

$\sum(\bar{y} - y)^2 = \sum y^2 - \frac{(\sum y)^2}{n} =$ 2,948.3400

Persamaan 20, Peters and Timmerhauss :

$$\sum(\bar{x} - x)(\bar{y} - y) = \sum xy - \frac{\sum x \cdot \sum y}{n} = \quad 58.3000$$

$$b = \frac{\sum(\bar{x} - x)(\bar{y} - y)}{\sum(\bar{x} - x)^2} = \quad 0.9717$$

Rata-rata y = ∑y / n = a = 570.4000
Rata-rata x = ∑x / n = c = 2014

y = a + b (x-c)
= 570.4000 + 0.9717 (x - 2014)
= 570.4000 + 0.9717 x - 1956.9367
= -1386.5367 + 0.9717 x

Dari persamaan di atas diperoleh indeks harga pada tahun 2019 sebesar :
y = -1386.5367 + 0.9717 x
= 575.2583

Kurs dollar pada tahun 2019
$1 = Rp 14,255 (Maret 2019)

Contoh Perhitungan Harga Peralatan :
Tangki Penampung
Harga Pada Tahun 2016 = $ 1,000
Indeks Harga Tahun 2016 = 541.7

Dari **Peters and Timmerhauss 4^ed Page 164 :**

$$\text{Harga Pada Tahun 2019} = \frac{\text{Indeks harga th 2019}}{\text{Indeks harga th 2016}} \times \text{Harga Alat pada th 2016}$$

$$= \frac{575.2583}{541.7} \times \$ \; 1{,}000$$

= $ 1,061.9500

= Rp 15,138,098

Contoh perhitungan harga peralatan :

Harga belt conveyor tahun 2016 US $ = $ 2,600 **(www.alibaba.com)**

Indeks harga tahun 2016 = 541.7000

Indeks harga tahun 2019 = 575.2583

$$\text{Harga alat pada tahun 2018} = \frac{575.2583}{541.7000} \times \$ \; 2{,}600$$

= $ 2,761.0701

= Rp 39,359,054

Tabel D.2 Hasil Perhitungan Harga Peralatan Proses

No	Kode	Nama Alat	Harga per unit (US$)		Jumlah	Harga Total US $
			2016	2019		
1	F-110	Storage tank	6000	6372	3	19115
2	L-112	Pompa(Feed)	2254	2394	1	2394
3	E-114	Heater-1	35000	37168	3	111505
4	H-120	Filter Udara -1	1500	1593	1	1593
5	G-121	Turbo Blower-1	7500	7965	1	7965
6	Q-210	Furnace	120000	127434	1	127434
7	D-220	Quenching Tower	93000	98761	1	98761
8	H-222	Cyclone-1	17440	18520	1	18520
9	H-223	Cyclone-2	17440	18520	1	18520
10	J-224	Screw Conveyor-1	26000	27611	1	27611
11	J-225	Bucket Elevator-1	12500	13274	1	13274
12	F-226	Bin	16843	17886	1	17886
13	S-310	Pelletizer	33000	35044	1	35044
14	J-311	Screw Conveyor-2	26000	27611	1	27611
15	H-321	Filter Udara -2	1500	1593	1	1593
16	H322	turbo Blower-2	7500	7965	1	7965
17	E-325	Heater-2	35000	37168	1	37168
18	B-320	Rotary Dryer	130000	138054	1	138054
19	J-328	Cooling Conveyor	7500	7965	1	7965
20	J-329	Bucker Elevator-2	10600	11257	1	11257

21	F-330	Tangki penampung (Silo)	16843	17886	1	17886
		Total			22	712,013.07

Tabel D.3 Hasil Perhitungan Harga Peralatan Utilitas

No	Nama Alat	Harga per unit (US $)		Jumlah	Harga Total
		2016	2018		US $
1	Pompa Air Sungai	2000	2124	5	10620
2	Bak Penampung Air Sungai	7500	7965	3	23894
3	Pompa Bak koagulasi	2000	2124	4	8496
4	Tangki Koagulasi	12500	13274	1	13274
5	Pompa Tangki Flokulasi	2000	2124	1	2124
6	Tangki Flokulasi	15000	15929	1	15929
7	Clarifier	12500	13274	1	13274
8	Bak penampung flok	7500	7965	1	7965
9	Pompa air bersih	2000	2124	1	2124
10	Bak air bersih	7500	7965	1	7965
11	pompa cooling tower	2000	2124	1	2124
12	Sand Filter	24000	25487	2	50974
13	Pompa sand filter	2000	2124	1	2124
14	Bak Penampung Air Bersih	7500	7965	1	7965
15	Pompa ke bak sanitasi	2000	2124	1	2124
16	Pompa bak air pendingin	2000	2124	1	2124
17	Bak Penampung Air Sanitasi	7500	7965	1	7965
18	Bak air pendingin	7500	7965	1	7965
19	Pompa recycle Air Pendingin	2000	2124	1	2124
20	Tangki Kation Exchanger	24000	25487	1	25487
21	Pompa Tangki Kation Exchanger	2000	2124	1	2124
22	Tangki Anion Exchanger	24000	25487	1	25487
23	Pompa Tangki Anion Exchanger	2000	2124	1	2124
24	Bak penampung Air Umpan Boile	7500	7965	1	7965
25	Boiler	186000	197523	5	987614
26	Generator Set	85000	90266	1	90266
27	Tangki Bahan Bakar	15600	16566	1	16566
28	pompa cooling tower	2000	2124	1	2124
29	Cooling Tower	136000	144425	1	144425

Total	1495331.84

Total Harga Peralatan	=	Harga Peralatan Proses	+	Harga Peralatan Utilitas	
	=	$ 712,013.07	+	$	1,495,331.84
	=	$ 2,191,415.66	x	Rp	14,255
	=	Rp 31,238,630,304.45			

D.4 Harga Bahan Baku

1.Residual oil

Jumlah Kebutuhan = 18882.0018 kg/jam = 18.8820 ton/jam

Harga Residual oil = $300 /ton **(Alibaba.com)**

= Rp 4,276,500 /ton **=** Rp 4,276.500

Biaya Pertahun = Rp 4,276,500 x 18.8820 x 24 x 330

= Rp 639,531,136,364

Total Biaya Bahan Baku = Rp 639,531,136,364

D.5 Harga Jual Produk

1. Produk Carbon Black

Jumlah Hasil Produksi = 8,838.3838 kg/jam = 8.8384 ton/jam

Harga Carbon Black = $1,200 /ton **(Alibaba.com)**

= Rp 17,106,000 **=** Rp 17,106.000

Harga Pertahun = Rp 17,106,000 x 8.8384 x 24 x 330

= **Rp 1,198,118,495,000**

Harga gas H2 = $ 4 /kg

= Rp 57,020.00 x 1.55 x 24 x 330

= **Rp 698,495,000.00**

D.6 Biaya Pengemasan Produk

Carbon Black

Produk yang dihasilkan	=	70,000,000.00	kg/tahun
(Produk dikemas dalam bag 50 kg)			
Kebutuhan Bag	=	1,400,000.00	Bag/jam
Harga 1 Bag	=	1,500.00	/Bag
Biaya pengemasan per tahun	=	**2,100,000,000.00**	
Biaya pendukung (10% pengemasan)	=	Rp 210,000,000.0	+
Total Biaya Pengemasan Per Tahun		Rp 2,310,000,000	
Total Harga Jual Produk	=	Rp 1,198,118,495,000	+

		Rp	**1,200,428,495,000**	
Harga Bahan Baku 1 Bulan	=	Rp	53,294,261,364	
Harga Produk 1 Bulan	=	Rp	100,035,707,917	+
		Rp	153,329,969,280	
Harga Jual Produk + Pengemasan	**=**	**Rp**	**1,200,428,495,000.00**	

D.7 Gaji Karyawan

A. Gaji Pokok

No	Jabatan	Gaji/bulan	Jumlah	Gaji/tahun
1	Direktur Utama	Rp 60,000,000	1	Rp 720,000,000
2	Direktur Produksi & Teknik	Rp 45,000,000	1	Rp 540,000,000
3	Direktur Keuangan & Administrasi	Rp 45,000,001	1	Rp 540,000,012
4	Sekretaris Direktur	Rp 9,000,000	3	Rp 324,000,000
5	Staff Ahli	Rp 13,000,000	4	Rp 624,000,000
6	Kepala Bagian Produksi	Rp 11,000,000	1	Rp 132,000,000
7	Kepala Bagian Teknik	Rp 11,000,001	1	Rp 132,000,012
8	Kepala Bagian Pemasaran	Rp 11,000,002	1	Rp 132,000,024
9	Kepala Bagian Umum	Rp 11,000,003	1	Rp 132,000,036
10	Kepala Bagian Keuangan	Rp 11,000,004	1	Rp 132,000,048
11	Kasi Proses	Rp 8,000,000	1	Rp 96,000,000
12	Kasi Riset & Pengembangan	Rp 8,000,000	1	Rp 96,000,000
13	Kasi Utilitas & Energi	Rp 8,000,000	1	Rp 96,000,000
14	Kasi Pemeliharaan & Perbaikan	Rp 8,000,000	1	Rp 96,000,000
15	Kasi Pembelian	Rp 8,000,000	1	Rp 96,000,000
16	Kasi Gudang	Rp 8,000,000	1	Rp 96,000,000
17	Kasi Pemasaran & Penjualan	Rp 8,000,000	1	Rp 96,000,000
18	Kasi Administrasi	Rp 8,000,000	1	Rp 96,000,000
19	Kasi Personalia & Kesejahteraan	Rp 8,000,000	1	Rp 96,000,000
20	Kasi Keamanan	Rp 8,000,000	1	Rp 96,000,000
21	Karyawan Bagian Proses(Kepala)	Rp 7,000,000	4	Rp 336,000,000
22	Karyawan Bagian Proses(Regu)	Rp 6,000,000	28	Rp 2,016,000,000
23	Karyawan Bagian Laboratorium	Rp 6,000,000	15	Rp 1,080,000,000
24	Karyawan Bagian Utilitas	Rp 6,000,001	20	Rp 1,440,000,240
25	Karyawan Bagian Personalia	Rp 6,000,001	5	Rp 360,000,060
26	Karyawan Bagian Pemasaran	Rp 6,000,002	10	Rp 720,000,240
27	Karyawan Bagian Administrasi	Rp 6,000,002	5	Rp 360,000,120

28	Karyawan Bagian Pembelian	Rp 6,000,003	5	Rp 360,000,180
29	Karyawan Bagian Pemeliharaan	Rp 4,250,000	8	Rp 408,000,000
30	Karyawan Bagian Gudang	Rp 4,250,000	8	Rp 408,000,000
31	Karyawan Bagian Keamanan	Rp 4,250,001	15	Rp 765,000,180
32	Karyawan Bagian Kebersihan	Rp 4,250,001	12	Rp 612,000,144
33	Dokter	Rp 9,000,000	2	Rp 216,000,000
34	Perawat	Rp 4,000,000	5	Rp 240,000,000
35	Supir	Rp 3,400,000	4	Rp 163,200,000
36	Satpam	Rp 3,700,000	10	Rp 444,000,000
Total			181	Rp 14,296,201,296

D.8 Kebutuhan Utilitas

A. Air

Kebutuhan air tiap hari = 5,821.2022 m^3/hari

Biaya air tiap hari = 5,821.2022 x 2500

= 14,553,005.50

Biaya pengolahan per tahun = Rp 4,802,491,814.23

B. Kebutuhan Penunjang Pengolahan Air

1 Kebutuhan $Al_2(SO_4)_3$ = 41,493.53 kg/tahun

Harga $Al_2(SO_4)_3$ = Rp 5,000 /kg **(www.bukalapak.com)**

Biaya tawas per tahun = Rp 207,467,646

2 Kebutuhan PAC = 6224.5273 kg/tahun

Harga PAC = Rp 15,000 /kg **(www.bukalapak.com)**

Biaya PAC per tahun = Rp 93,367,910

3 Kebutuhan HCl = 10,042.9521 liter/tahun

Harga HCl = Rp 13,500 / liter **(www.bukalapak.com)**

Biaya HCl per tahun = Rp 135,579,854

4 Kebutuhan Dowex Anion = 52379.6788 kg/tahun

Harga Dowex Anion = Rp 27,320 / kg **(www.tokopedia.com)**

Biaya Dowex Anion/tahun = Rp 1,431,012,824

5 Kebutuhan NaOH = 3953.1833 kg/tahun

	Harga NaOH	=	Rp	20,000 / kg	**(www.tokopedia.com)**
	Biaya NaOH per tahun	=	Rp	79,063,666.04	
6	Kebutuhan Dowex Kation	=		65886.3884 kg/tahun	
	Biaya Dowex Kation	=	Rp	12,500 / kg	
	Biaya Dowex Kation/tahun	=	Rp	823,579,855	
7	Kebutuhan Chlorine	=		2803.6800 kg/tahun	
	Harga Chlorine	=	Rp	31,000 /kg	**(francisumatmuslim.blogspot.com)**
	Biaya Chlorine per tahun	=	Rp	86,914,080	

C. Bahan Bakar

1 Diesel Oil

Kebutuhan bahan bakar tiap hari	=		25841.32 liter/jam	
	=		620191.5775 liter/hari	
Harga bahan bakar/liter	=	Rp	11,900	**(www.liputan6.com)**
Biaya bahan bakar tiap tahun	=	Rp	7,380,279,772.1	

D. Listrik

Kebutuhan listrik/jam	=		59.700 kWh/jam	
	=		1432.800 kWh/hari	
Biaya listrik per kWh	=	Rp	1,645	**(www.liputan6.com)**
Biaya listrik tiap tahun	=	Rp	777,568,524	

Jadi total biaya utilitas pertahun = Rp 15,817,325,944.68

D.8 Luas Tanah dan Bangunan

Luas Tanah	=		20000 m^2	
Harga tanah/m^2	=	Rp	3,000,000	**(http://www.Rumahku.com/)**
Total harga tanah	=	Rp	60,000,000,000	
Luas bangunan pabrik	=		8100 m^2	
Harga bangunan pabrik per m^2	=	Rp	4,000,000	**(http:///www.urbanindo.com/)**
Harga bangunan pabrik total	=	Rp	32,400,000,000	
Luas bangunan gedung	=		4750 m^2	

Harga bangunan gedung = Rp 4,200,000 **(http://rumah.mitula.co.id/)**
Harga bangunan gedung total = Rp 19,950,000,000
Harga bangunan total = Rp 52,350,000,000
Total harga tanah dan bangunan = Rp 112,350,000,000

Rp 558,587,358,636