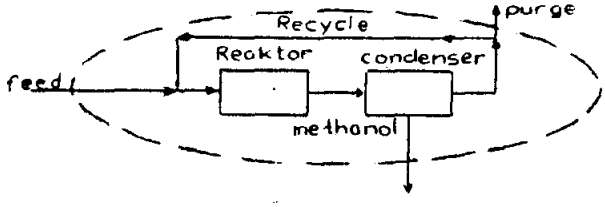
APPENDIX A
PERHITUNGAN NERACA MASSA

Kapasitas : 15 000 kg DME
1 tahun : 330 hari
satuan massa : kilogram (kg)
satuan waktu : hari

A.1 Perhitungan dengan Basis

Untuk reactor 1



Basis : Feed masuk terdiri atas 300 mol CH_4 dan 150 mol O_2

X = (mol CH_4 + mol O_2) pada recycle
Y = (mol CH_4 + mol O_2) pada purge

asumsi : pada cooler methanol terkondensasi seluruhnya

Feed masuk terdiri atas :

1.Gas alam, dengan komposisi: (Hermadi, 2000)

metana = 300 kmol = 300 x 16 = 4800 kg

etana $= \frac{13.09\,\%}{71.01\,\%} \times 300$ = 55.3021 kmol = 55.3021 x 30 = 1659.0621 kg

propana $= \frac{7.91\,\%}{71.01\,\%} \times 300$ = 33.4178 kmol = 33.4178 x 44 = 1470.3845 kg

$$\text{i-butana} = \frac{1.68\,\%}{71.01\,\%} \times 300 = 7.0976 \text{ kmol} = 7.0976 \times 58 = 411.6603 \text{ kg}$$

$$\text{n-butana} = \frac{2.09\,\%}{71.01\,\%} \times 300 = 8.8297 \text{ kmol} = 8.8297 \times 58 = 512.1251 \text{ kg}$$

$$\text{i-pentana} = \frac{1.17\,\%}{71.01\,\%} \times 300 = 4.9430 \text{ kmol} = 4.9430 \times 72 = 355.8935 \text{ kg}$$

$$\text{n-pentana} = \frac{1.12\,\%}{71.01\,\%} \times 300 = 4.7317 \text{ kmol} = 4.7317 \times 72 = 350.1924 \text{ kg}$$

$$\text{heksana} = \frac{1.93\,\%}{71.01\,\%} \times 300 = 8.1538 \text{ kmol} = 8.1538 \times 86 = 701.2252 \text{ kg}$$

2. Udara, dengan komposisi :

oksigen = 150 kmol = 150 x 32 = 4800 kg

$$\text{nitrogen} = \frac{79\,\%}{21\,\%} \times 150 = 64.2857 \text{ kmol} = 564.2857 \times 28 = 15800 \text{ kg}$$

Total = 30860.5431 kg

Bagian masuk reactor 1 = Feed + Recycle :

~ CH_4 = (300 + 2/3 X) kmol
~ O_2 = (150 + 1/3 X) kmol
+
450 + X

asumsi : mol inerts masuk reactor 1 = 10 x (mol CH_4 + mol O_2) masuk reactor
~ inerts = 10 (450 + X) kmol

$$2\,CH_4 + O_2 \longrightarrow 2\,CH_3OH \quad \text{konversi 70 \%}$$
(Bhatt,1990)

M	300 + 2/3 X	150 + 1/3 X	
R	0.7 (300 + 2/3 X)	0.7 (150 + 1/3 X)	0.7 (300 + 2/3 X)
S	0.3 (300 + 2/3 X)	0.3 (150 + 1/3 X)	0.7 (300 + 2/3 X)

Bagian keluar reactor 1

~ CH_4 = 0.3 (300 + 2/3 X) kmol
~ O_2 = 0.3 (150 + 1/3 X) kmol

0.3 (450 + X)
~ inerts = 10 (450 + X) kmol
~ CH_3OH = 0.7 (300 + 1/3 X) kmol

$$\frac{mol\ inerts\ keluar\ reactor\ 1}{(mol\ CH_4 + mol\ O_2)\ keluar\ reactor\ 1} = \frac{10.(450+X)}{0.3.(450+X)} = 33.3333$$

$$\frac{mol\ inerts\ purge}{(mol\ CH_4 + mol\ O_2)\ purge} = \frac{mol\ inerts\ keluar\ reactor\ 1}{(mol\ CH_4 + mol\ O_2)\ keluar\ reactor\ 1} = 33.3333$$

$$\frac{mol\ inerts\ purge}{Y} = 33.333$$

$$mol\ inerts\ purge = 33.3333\ Y$$

$$mol\ inerts\ Feed = mol\ inerts\ purge$$

$$686.7614 = 33.3333\ Y$$

$$Y = 20.6029$$

$$mol\ CH_4\ keluar\ reactor\ 1 = mol\ CH_4\ recycle + mol\ CH_4\ purge$$

$$0.3\,(300 + 2/3\,X) = 2/3\,X + 2/3\,Y$$

$$90 + 0.2\,X = 2/3\,X + 2/3\,(20.6029)$$

$$76.2647 = (2/3 - 0.2)X$$

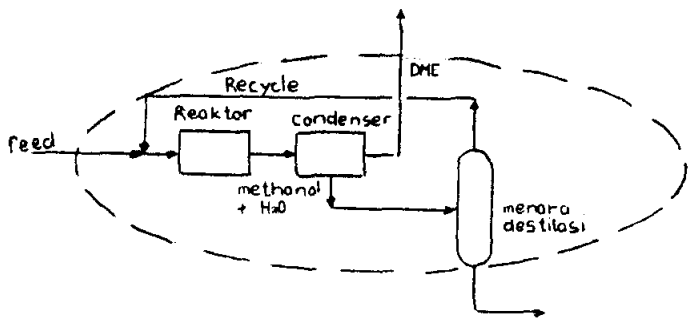
$$X = 163.4244$$

maka :

* Bagian masuk reactor 1
~ CH_4 = (300 + 2/3 X) = 408.9496 kmol = 6543.1936 kg
~ O_2 = (150 + 1/3 X) = 204.4748 kmol = 6543.1936 kg

* Bagian keluar reactor 1 :
~ metana = 0.3 (300 + 2/3 X) = 122.6849 kmol = 1962.9581 kg
~ oksigen = 0.3 (150 + 1/3 X) = 61.3424 kmol = 1962.9581 kg
~ methanol = 0.7 (300 + 2/3 X) = 286.2647 kmol = 9160.4710 kg

Untuk reactor 2



Feed methanol masuk = hasil dari reactor 1 = 286.2647 kmol

X = jumlah kmol recycle = hasil atas menara destilasi D-220
Y = hasil bawah menara destilasi D-220

Asumsi : Pada cooler, methanol dan H_2O terkondensasi seluruhnya
Destilat terdiri atas 99% methanol
Bottom terdiri atas 1 % methanol

Bagian masuk reactor 2:
~ methanol : 286.2647 + 0.99 X
~ H_2O : 0.01 X

$$2\ CH_3OH \rightarrow CH_3OCH_3 + H_2O$$ konversi 80% (Wang S., 2001)

M	286.2647 + 0.99 X		0.01 X
R	0.8(286.2647 + 0.99 X)	0.4(286.2647 + 0.99 X)	0.4 (286.2647 + 0.99 X)
S	0.2(286.2647 + 0.99 X)	0.4(286.2647 + 0.99 X)	0.4 (286.2647 + 0.99 X)+0.01X

Feed = Product DME + Bottom Product
286.2647 = 0.4 (286.2647 + 0.99 X) + Y
171.7588 = 0.396 X + Y .....(1)

methanol keluar reactor 2 = methanol pada destilat + methanol pada bottom
0.2 (286.2647 + 0.99 X) = 0.99 X + 0.01 Y
57.2529 = 0.792 X + 0.01 Y .....(2)

dari persamaan 1 dan 2 diperoleh
X = 70.4727 kmol
Y = 143.8516 kmol

Maka pada bagian masuk reactor 2:
Methanol = 286.2647 + 0.99 X = 356.0327 kmol = 11393.0464 kg
H_2O = 0.01 X = 0.7047 kmol = 12.6851 kg
total = 11405.7315 kg

Bagian keluar reactor 2
Methanol = 0.2 (286.2647 + 0.99 X) = 71.2065 kmol = 2278.6080 kg
H_2O = 0.4 (286.2647 + 0.99 X)+0.01X = 142.4131 kmol = 2576.1204 kg
DME = 0.4 (286.2647 + 0.99 X) = 143.1178 kmol = 6551.0026 kg
total = 11405.731 kg

Dengan basis 300 mol CH_4 dan 150 mol O_2 pada feed, diperoleh DME sebanyak 6551.0026 kg

Maka untuk memperoleh DME sebanyak 15000 kg dibutuhkan feed masuk

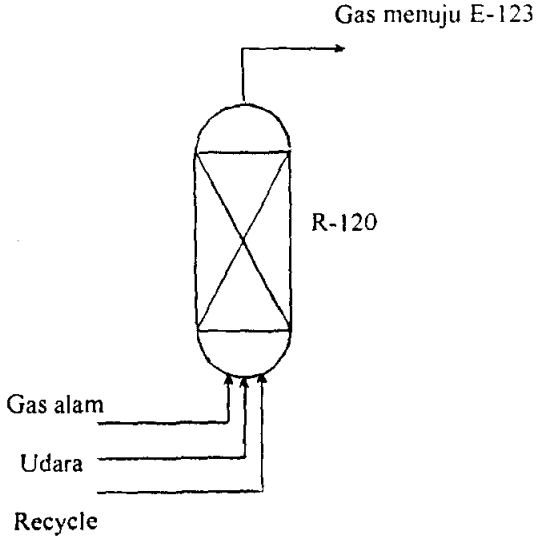
~ $CH_4 = 300 \times \frac{15000}{6551.0026} = 686.9178$ kmol ≈ 700 kmol

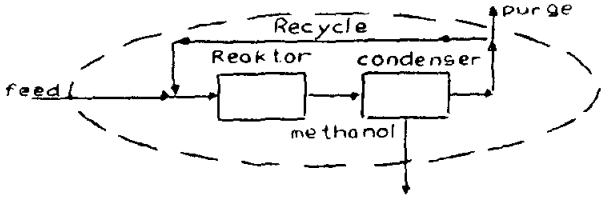
~ $O_2 = 150 \times \frac{15000}{6551.0026} = 343.4589$ kmol ≈ 350 kmol

untuk perhitungan neraca massa dengan kapasitas 15000 kg DME dapat dilihat pada App A.2

A.2 Perhitungan Neraca Massa dengan kapasitas 15000 kg DME

I. Reaktor (R – 120)





X = (mol CH_4 + mol O_2) pada recycle
Y = (mol CH_4 + mol O_2) pada purge
mol CH_4 : mol O_2 = 2 : 1

asumsi : pada cooler methanol terkondensasi seluruhnya
Feed masuk terdiri atas :

1.Gas alam, dengan komposisi: (Hermadi, 2000)

metana = 700 kmol = 700 x 16 = 11200 kg

etana $= \frac{13.09\ \%}{71.01\ \%}$ x 700 = 129.0382 kmol = 129.0382 x 30 = 3871.1449 kg

propana $= \frac{7.91\ \%}{71.01\ \%}$ x 700 = 77.9749 kmol = 77.9749 x 44 = 3430.8971 kg

i-butana $= \frac{1.68\ \%}{71.01\ \%}$ x 700 = 16.5610 kmol = 15.5610 x 58 = 960.5408 kg

n-butana $= \frac{2.09\ \%}{71.01\ \%}$ x 700 = 20.6027 kmol = 20.6027 x 58 = 1194.9585 kg

i-pentana $= \frac{1.17\ \%}{71.01\ \%}$ x 700 = 11.5336 kmol = 11.5336 x 72 = 830.4183 kg

n-pentana $= \frac{1.12\ \%}{71.01\ \%}$ x 700 = 11.0407 kmol = 11.0407 x 72 = 794.9303 kg

heksana $= \frac{1.93\ \%}{71.01\ \%}$ x 700 = 19.0255 kmol = 19.0255 x 86 = 1636.1921 kg

2. Udara, dengan komposisi :

oksigen = 350 kmol = 350 x 32 = 11200 kg

nitrogen $= \frac{79\ \%}{21\ \%}$ x 350 = 1316.6667 kmol = 1316.6667 x 28 = 36866.6667 kg

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Total = 71985.7485 kg

Dari komposisi diatas didapat
~ mol N_2 : mol gas alam tanpa CH_4 = 4.6073 : 1
~ komposisi gas alam tanpa CH_4:

etana	45.15 %
propana	27.29 %
i-butana	5.8 %
n-butana	7.21 %
i-pentana	4.04 %
n-pentana	3.86 %
heksana	6.66 %

Bagian masuk reactor = Feed + Recycle :

~ CH_4 = (700 + 2/3 X) kmol
~ O_2 = (350 + 1/3 X) kmol

1050 + X

asumsi : mol inerts masuk reactor = 10 x (mol CH_4 + mol O_2) masuk reactor
~ inerts = 10 (1050 + X) kmol

	$2\,CH_4$	+	O_2	→	$2\,CH_3OH$	konversi 70 % (Bhatt,1990)
M	700 + 2/3 X		350 + 1/3 X			
R	0.7 (700 + 2/3 X)		0.7 (350 + 1/3 X)		0.7 (700 + 2/3 X)	
S	0.3 (700 + 2/3 X)		0.3 (350 + 1/3 X)		0.7 (700 + 2/3 X)	

Bagian keluar reactor

~ CH_4 = 0.3 (700 + 2/3 X) kmol
~ O_2 = 0.3 (350 + 1/3 X) kmol

0.3 (1050 + X)
~ inerts = 10 (1050 + X) kmol
~ CH_3OH = 0.7 (700 + 1/3 X) kmol

$$\frac{mol\ inerts\ keluar\ reactor}{(mol\ CH_4 + mol\ O_2)\ keluar\ reactor} = \frac{10.(1050+X)}{0.3.(1050+X)} = 33.3333$$

$$\frac{mol\ inerts\ purge}{(mol\ CH_4 + mol\ O_2)\ purge} = \frac{mol\ inerts\ keluar\ reactor}{(mol\ CH_4 + mol\ O_2)\ keluar\ reactor} = 33.3333$$

$$\frac{mol\ inerts\ purge}{Y} = 33.333$$

$$mol\ inerts\ purge = 33.3333\ Y$$

$$mol\ inerts\ Feed = mol\ inerts\ purge$$

$$1602.4433 = 33.3333\ Y$$

$$Y = 48.0733$$

$$mol\ CH_4\ keluar\ reactor = mol\ CH_4\ recycle + mol\ CH_4\ purge$$

$$0.3\,(700 + 2/3\,X) = 2/3\,X + 2/3\,Y$$

$$210 + 0.2\,X = 2/3\,X + 2/3\,(48.0733)$$

$$177.9511 = (2/3 - 0.2)X$$

$$X = 381.3239$$

* Bagian masuk reactor

~ CH_4 = (700 + 2/3 X) = 954.2157 kmol = 15267.4517 kg

~ O_2 = (350 + 1/3 X) = 477.1079 kmol = 15267.4517 kg

~ N_2 = $\frac{4.6073}{5.6073}$ x 10.(1050 + 381.3239) = 11760.6285 kmol = 329297.5982 kg

~ etana = 45.15 % x $\frac{1}{5.6073}$ x 10.(1050 + 381.3239)
= 1152.5022 kmol = 34575.0672 kg

~ propana = 27.29 % x $\frac{1}{5.6073}$ x 10.(1050 + 381.3239)
= 696.6066 kmol = 30650.6886 kg

~ i-butana = 5.8 % x $\frac{1}{5.6073}$ x 10.(1050 + 381.3239)
= 148.0512 kmol = 8586.9713 kg

~ n-butana = 7.21 % x $\frac{1}{5.6073}$ x 10.(1050 + 381.3239)
= 184.0430 kmol = 10674.4936 kg

~ i-pentana = 4.04 % x $\frac{1}{5.6073}$ x 10.(1050 + 381.3239)

= 103.1253 kmol = 7425.0244 kg

~ n-pentana = 3.86 % x $\frac{1}{5.6073}$ x 10.(1050 + 381.3239)

= 98.5306 kmol = 7094.2065 kg

~ heksana = 6.66 % x $\frac{1}{5.6073}$ x 10.(1050 + 381.3239)

= 170.0037 kmol = 14620.3141 kg

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total = 473459.2674 kg

* Bagian keluar reactor :

~ metana = 0.3 (700 + 2/3 X)	= 286.2647 kmol	=	4580.2355 kg
~ oksigen = 0.3 (350 + 1/3 X)	= 143.1324 kmol	=	4580.2355 kg
~ methanol = 0.7 (700 + 2/3 X)	= 667.9510 kmol	=	21374.4324 kg
~ etana = etana masuk reactor	= 1152.5022 kmol	=	34575.0672 kg
~ propana = propane masuk reactor	= 696.6066 kmol	=	30650.6886 kg
~ i-butana = i-butana masuk reactor	= 148.0512 kmol	=	8586.9713 kg
~ n-butana = n-butana masuk reactor	= 184.0430 kmol	=	10674.4936 kg
~ i-pentana = i-pentana masuk reactor	= 103.1253 kmol	=	7425.0244 kg
~ n-pentana = n-pentana masuk reactor	= 98.5306 kmol	=	7094.2065 kg
~ heksana = heksana masuk reactor	= 170.0037 kmol	=	14620.3141 kg
~ nitrogen = nitrogen masuk reactor	=11760.6285 kmol	=	329297.5982 kg

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total = 473459.2674 kg

$$bagian\ yang\ direcycle = \frac{X}{X+Y} = \frac{381.3239}{381.3239+48.0733} = 0.888$$

$$bagian\ yang\ dipurge = 1 - 0.888 = 0.112$$

* Bagian recycle :

~ metana = 0.888 x	286.2647 =	254.2031 kmol =	4067.2491 kg
~ oksigen = 0.888 x	143.1324 =	127.1079 kmol =	4067.2491 kg
~ etana = 0.888 x	1152.5022 =	1023.4220 kmol =	30702.6597 kg
~ propana = 0.888 x	696.6066 =	618.5866 kmol =	27217.8115 kg
~ i-butana = 0.888 x	148.0512 =	131.4695 kmol =	7625.2305 kg
~ n-butana = 0.888 x	184.0430 =	163.4302 kmol =	9478.9503 kg
~ i-pentana = 0.888 x	103.1253 =	91.5753 kmol =	6593.4217 kg
~ n-pentana = 0.888 x	98.5306 =	87.4952 kmol =	6299.6554 kg

~ heksana = 0.888 x 170.0037 = 150.9632 kmol = 12982.8390 kg
~ nitrogen = 0.888 x 11760.6285 = 10443.4381 kmol = 292416.2672 kg

total = 401473.5189 kg

* Bagian purge :

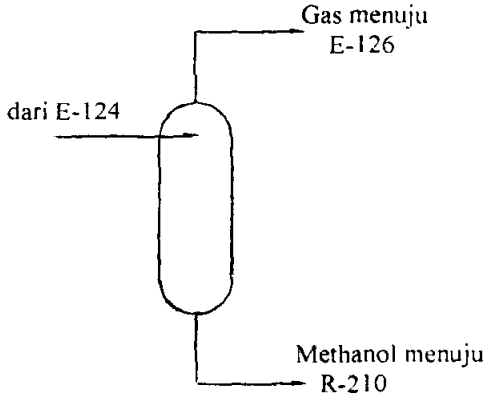
~ metana = 0.112 x 286.2647 = 32.0616 kmol = 512.9864 kg
~ oksigen = 0.112 x 143.1324 = 16.0308 kmol = 512.9864 kg
~ etana = 0.112 x 1152.5022 = 129.0803 kmol = 3872.4075 kg
~ propana = 0.112 x 696.6066 = 78.0199 kmol = 3432.8771 kg
~ i-butana = 0.112 x 148.0512 = 16.5817 kmol = 961.7408 kg
~ n-butana = 0.112 x 184.0430 = 20.6128 kmol = 1195.5433 kg
~ i-pentana = 0.112 x 103.1253 = 11.5500 kmol = 831.6027 kg
~ n-pentana = 0.112 x 98.5306 = 11.0354 kmol = 794.5511 kg
~ heksana = 0.112 x 170.0037 = 19.0404 kmol = 1637.4752 kg
~ nitrogen = 0.112 x 11760.6285 = 1317.1904 kmol = 36881.3310 kg

total = 50611.3161 kg

Ringkasan Neraca massa reactor R-120

Masuk (kg)		Keluar (kg)	
~ Feed :		**~ Gas menuju cooler E-124 :**	
# Gas alam dari storage tank F-110		methanol	21374.4324
metana	11200	metana	4580.2355
etana	3871.1449	etana	34575.0672
propana	3430.8971	propana	30650.6886
i-butana	960.5408	i-butana	8586.9713
n-butana	1194.9585	n-butana	10674.4936
i-pentana	830.4183	i-pentana	7425.0244
n-pentana	794.9303	n-pentana	7094.2065
heksana	1636.1921	heksana	14620.3141
	23919.0818	oksigen	4580.2355
# Udara		nitrogen	329297.5982
oksigen	11200		
nitrogen	36866.6667		
	48066.6667		
	71985.7485		
~ Recycle			
metana	4067.2491		
etana	30702.6597		
propana	27217.8115		
i-butana	7625.2305		
n-butana	9478.9503		
i-pentana	6593.4217		
n-pentana	6299.6554		
heksana	12982.8390		
oksigen	4067.2491		
nitrogen	292416.2672		
	401473.5189		
Total	473459.2674	Total	473459.2674

II. Drum Separator (H – 125)



Pada bagian masuk
~ komponen masuk = komponen keluar cooler E-124 :
~ terdiri atas :

metana	=	286.2647 kmol	=	4580.2355 kg
etana	=	1152.5022 kmol	=	34575.0672 kg
propana	=	696.6066 kmol	=	30650.6886 kg
i-butana	=	148.0512 kmol	=	8586.9713 kg
n-butana	=	184.0430 kmol	=	10674.4936 kg
i-pentana	=	103.1253 kmol	=	7425.0244 kg
n-pentana	=	98.5306 kmol	=	7094.2065 kg
heksana	=	170.0037 kmol	=	14620.3141 kg
oksigen	=	143.1324 kmol	=	4580.2355 kg
nitrogen	=	11760.6285 kmol	=	329297.5982 kg
methanol	=	667.9510 kmol	=	21374.4324 kg
			total =	473459.2674 kg

Pada bagian keluar terdiri atas :
~ komposisi bagian keluar
// Gas menuju devider M-126

metana	=	286.2647 kmol	=	4580.2355 kg
etana	=	1152.5022 kmol	=	34575.0672 kg
propana	=	696.6066 kmol	=	30650.6886 kg
i-butana	=	148.0512 kmol	=	8586.9713 kg

n-butana	=	184.0430 kmol	= 10674.4936 kg
i-pentana	=	103.1253 kmol	= 7425.0244 kg
n-pentana	=	98.5306 kmol	= 7094.2065 kg
heksana	=	170.0037 kmol	= 14620.3141 kg
oksigen	=	143.1324 kmol	= 4580.2355 kg
nitrogen	=	11760.6285 kmol	= 329297.5982 kg
			452084.8350 kg

Liquid menuju reactor R-210

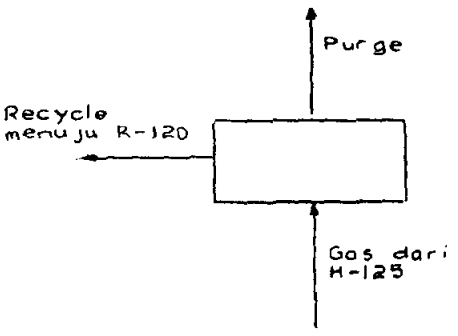
methanol = 667.9510 kmol = 21374.4324 kg

total = 473459.2674 kg

Ringkasan Neraca massa Drum Separator H-125

Masuk (kg)		**Keluar (kg)**	
Dari Cooler E-124:		**~ Gas menuju devider M-126:**	
metana	4580.2355	metana	4580.2355
etana	34575.0672	etana	34575.0672
propan	30650.6886	propan	30650.6886
i-butan	8586.9713	i-butan	8586.9713
n-butan	10674.4936	n-butan	10674.4936
i-pentan	7425.0244	i-pentan	7425.0244
n-pentan	7094.2065	n-pentan	7094.2065
heksana	14620.3141	heksana	14620.3141
oksigen	4580.2355	oksigen	4580.2355
nitrogen	329297.5982	nitrogen	329297.5982
methanol	21374.4324		452084.8350
		~ Liquid menuju Reaktor R-210:	
		methanol	21374.4324
Total	473459.2674	Total	473459.2674

III. Devider (M – 126)



Pada bagian masuk devider
~ komponen masuk devider = gas keluar H-125 :

~ terdiri atas :

metana	=	286.2647 kmol	=	4580.2355 kg
etana	=	1152.5022 kmol	=	34575.0672 kg
propana	=	696.6066 kmol	=	30650.6886 kg
i-butana	=	148.0512 kmol	=	8586.9713 kg
n-butana	=	184.0430 kmol	=	10674.4936 kg
i-pentana	=	103.1253 kmol	=	7425.0244 kg
n-pentana	=	98.5306 kmol	=	7094.2065 kg
heksana	=	170.0037 kmol	=	14620.3141 kg
oksigen	=	143.1324 kmol	=	4580.2355 kg
nitrogen	=	11760.6285 kmol	=	329297.5982 kg
				452084.8350 kg

dari perhitungan sebelumnya diperoleh
X = 381.3239
Y = 48.0733

Maka:

$$\textit{bagian yang direcycle} = \frac{X}{X+Y} = \frac{381.3239}{381.3239+48.0733} = 0.888$$

$$\textit{bagian yang dipurge} = 1 - 0.888 = 0.112$$

Sehingga bagian keluar devider terdiri atas :

* Recycle, dari perhitungan sebelumnya diperoleh:

metana	=	254.2031 kmol	=	4067.2491 kg
etana	=	1023.4220 kmol	=	30702.6597 kg
propana	=	618.5866 kmol	=	27217.8115 kg
i-butana	=	131.4695 kmol	=	7625.2305 kg
n-butana	=	163.4302 kmol	=	9478.9503 kg
i-pentana	=	91.5753 kmol	=	6593.4217 kg
n-pentana	=	87.4952 kmol	=	6299.6554 kg
heksana	=	150.9632 kmol	=	12982.8390 kg
oksigen	=	127.1079 kmol	=	4067.2491 kg
nitrogen	=	10443.4381 kmol	=	292416.2672 kg
				401473.5189 kg

* Purge, dari perhitungan sebelumnya diperoleh:

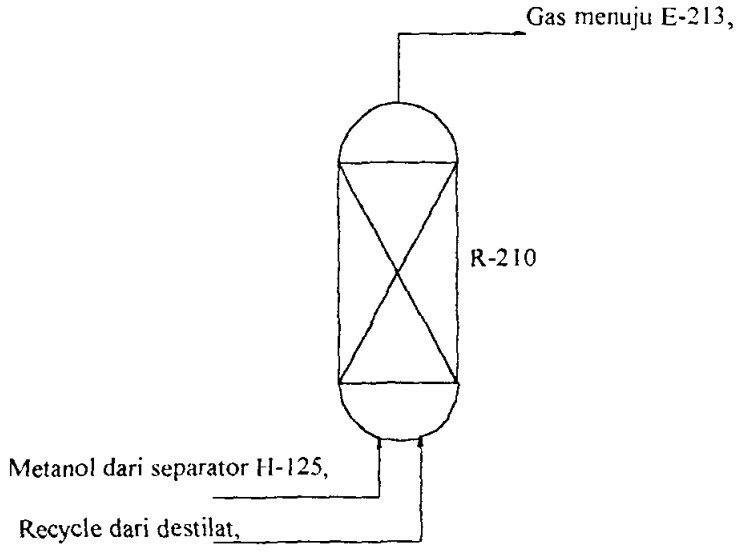
metana	=	32.0616 kmol	=	512.9864 kg
etana	=	129.0803 kmol	=	3872.4075 kg
propana	=	78.0199 kmol	=	3432.8771 kg
i-butana	=	16.5817 kmol	=	961.7408 kg
n-butana	=	20.6128 kmol	=	1195.5433 kg
i-pentana	=	11.5500 kmol	=	831.6027 kg
n-pentana	=	11.0354 kmol	=	794.5511 kg
heksana	=	19.0404 kmol	=	1637.4752 kg
oksigen	=	16.0308 kmol	=	512.9864 kg
nitrogen	=	1317.1904 kmol	=	36881.3310 kg
				50611.3161 kg

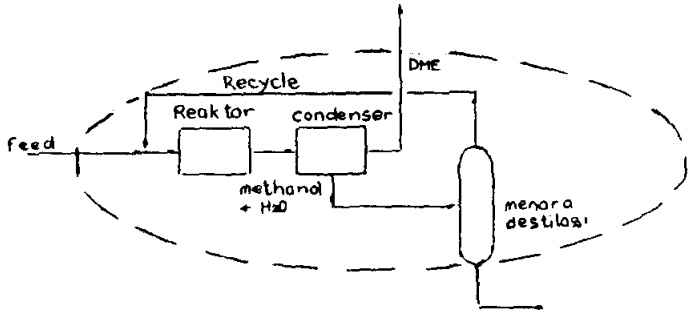
total = 452084.8350 kg

Ringkasan Neraca massa Devider M-126

Masuk (kg)		Keluar (kg)	
~ Gas dari H-125:		**~ Recycle menuju Reaktor R-120 :**	
metana	4580.2355	metana	4067.2491
etana	34575.0672	etana	30702.6597
propan	30650.6886	propana	27217.8115
i-butan	8586.9713	i-butana	7625.2305
n-butan	10674.4936	n-butana	9478.9503
i-pentan	7425.0244	i-pentana	6593.4217
n-pentan	7094.2065	n-pentana	6299.6554
heksana	14620.3141	heksana	12982.8390
oksigen	4580.2355	oksigen	4067.2491
nitrogen	329297.5982	nitrogen	292416.2672
			401473.5189
		~ Purge menuju ke unit LPG:	
		metana	512.9864
		etana	3872.4075
		propana	3432.8771
		i-butana	961.7408
		n-butana	1195.5433
		i-pentana	831.6027
		n-pentana	794.5511
		heksana	1637.4752
		oksigen	512.9864
		nitrogen	36881.3310
			50611.3161
Total	452084.8350	Total	452084.8350

IV. Reaktor (R-210)





Feed methanol masuk = dari separator H-125 = 667.9510 kmol

X = jumlah kmol recycle = hasil atas menara destilasi D-220
Y = hasil bawah menara destilasi D-220

Asumsi : Pada cooler, methanol dan H_2O terkondensasi seluruhnya
Destilat terdiri atas 99% methanol
Bottom terdiri atas 1 % methanol

Bagian masuk reactor:
- ~ methanol : 667.9510 + 0.99 X
- ~ H_2O : 0.01 X

$$2\ CH_3OH \rightarrow CH_3OCH_3 + H_2O$$ konversi 80% (Wang S., 2001)

M	667.9510 + 0.99 X		0.01 X
R	0.8 (667.9510 + 0.99 X)	0.4 (667.9510 + 0.99 X)	0.4 (667.9510 + 0.99 X)
S	0.2 (667.9510 + 0.99 X)	0.4 (667.9510 + 0.99 X)	0.4 (667.9510 + 0.99 X)+0.01X

Feed = Product DME + Bottom Product

667.9510 = 0.4 (667.9510 + 0.99 X) + Y

400.7706 = 0.396 X + Y .....(1)

methanol keluar reactor = methanol pada destilat + methanol pada bottom

0.2 (667.9510 + 0.99 X) = 0.99 X + 0.01 Y

113.5902 = 0.792 X + 0.01 Y .....(2)

dari persamaan 1 dan 2 diperoleh

X = 164.4364 kmol

Y = 335.6542 kmol

Maka pada bagian masuk :

Metanol = 667.9510 + 0.99 X = 830.7430 kmol = 830.7430 x 32 = 26583.7749 kg

H_2O = 0.01 X = 1.6444 kmol = 1.6444 x 18 = 29.5986 kg

total = 26613.3735 kg

Bagian keluar reaktor

Methanol = 0.2 (667.9510 + 0.99 X) = 166.1485 kmol = 5316.7520 kg

H_2O = 0.4 (667.9510 + 0.99 X)+0.01X = 333.9415 kmol = 6010.9476 kg

DME = 0.4 (667.9510 + 0.99 X) = 332.2972 kmol = 15285.6739 kg

total = 26613.3735 kg

Hasil atas (Destilat) terdiri atas:

Methanol = 0.99 X = 162.7920 kmol = 5209.3425 kg

H_2O = 0.01 X = 1.6444 kmol = 29.5986 kg

total = 5238.9411 kg

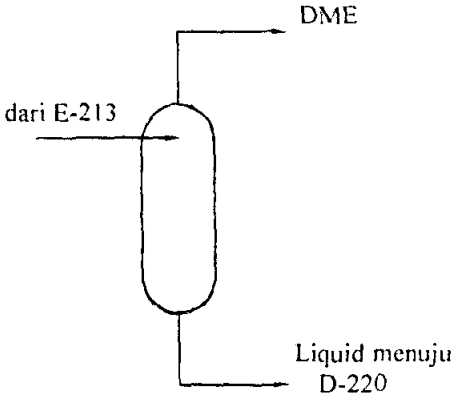
Hasil bawah (Bottom) terdiri atas:

Methanol	= 0.01 Y	= 3.357 kmol	= 107.4095 kg
H_2O	= 0.99 Y	= 332.2972 kmol	= 5981.3490 kg
		total	= 6088.7585 kg

Ringkasan Neraca massa Reactor R-210

Masuk (kg)		Keluar (kg)	
~ Dari H-125		**~ Gas menuju cooler E-213:**	
methanol	21374.4324	Methanol	5316.752
		H_2O	6010.9476
~ Recycle dari Destilat D-220		DME	15285.6739
Methanol	5209.3425		
H_2O	29.5986		
	5238.9411		
Total	26613.3735	Total	26613.3735

V. Drum Separator (H-214)



Bagian masuk :

~ komponen masuk = komponen keluar cooler E-213

~ terdiri atas:

Methanol	= 166.1485 kmol	= 5316.752 kg
H_2O	= 333.9415 kmol	= 6010.9476 kg
DME	= 332.2972 kmol	= 15285.6739 kg
	total	= 26613.3735 kg

Bagian keluar

~ komponen keluar

Liquid menuju menera destilasi

Methanol = 166.1485 kmol = 5316.752 kg

H_2O = 333.9415 kmol = 6010.9476 kg

11327.6996

Gas sebagai produk

DME = 332.2972 kmol = 15285.6739 kg

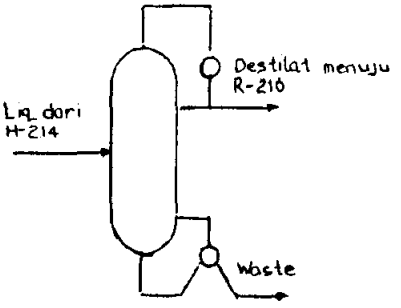
---

total = 26613.3735 kg

Ringkasan Neraca massa Drum Separator H-214

Masuk (kg)		Keluar (kg)	
Dari cooler E-213		**~ Liquid menuju menara destilasi D-220:**	
Methanol	5316.752	Methanol	5316.752
H_2O	6010.9476	H_2O	6010.9476
DME	15285.6739		11327.6996
		~ Gas sebagai Produk	
		DME	15285.6739
Total	26613.3735	Total	26613.3735

VI. Menara Destilasi (D-220)



Bagian masuk menara destilasi :

~ komponen masuk menara destilasi = Liquid keluar H-214

~ terdiri atas:

Methanol = 166.1485 kmol = 5316.7520 kg

H_2O = 333.9415 kmol = 6010.9476 kg

11327.6996

Bagian keluar

Dari perhitungan sebelumnya diperoleh :

~ Destilat:

Methanol = 162.7920 kmol = 5209.3425 kg

H_2O = 1.6444 kmol = 29.5986 kg

5238.9411 kg

~ Bottom :

Methanol = 3.357 kmol = 107.4095 kg

H_2O = 332.2972 kmol = 5981.3490 kg

6088.7585 kg

---

total = 11327.6996 kg

Ringkasan Neraca Massa Menara Destilasi D-220

Masuk (kg)		Keluar (kg)	
~ Liquid dari H-214:		**~ Destilat menuju reactor R-210:**	
Methanol	5316.7520	Methanol	5209.3425
H_2O	6010.9476	H_2O	29.5986
			5238.9411
		~ Bottom	
		Methanol	107.4095
		H_2O	5981.3490
			6088.7585
Total	11327.6996	Total	11327.6996

APPENDIX B

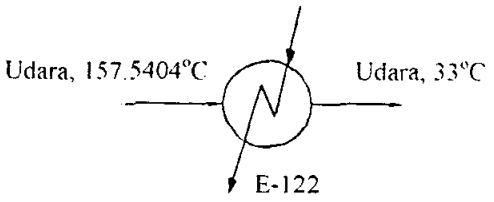
PERHITUNGAN NERACA PANAS

APPENDIX B

PERHITUNGAN NERACA PANAS

Kapasitas : 15 000 kg DME
1 tahun : 330 hari
satuan panas : kilojoule (kJ)
satuan waktu : hari
Suhu reference : 25^0C

1. Cooler (E – 113)



Cp dihitung dengan persamaan

$$Cp = a + \frac{b}{2}(T_1 + T_2) + \frac{c}{3}(T_2^2 + T_1.T_2 + T_1^2) + \frac{d}{4}(T_2^2 + T_1^2)(T_1 + T_2)$$

Komponen	T	A	$b.10^2$	$c.10^5$	$d.10^9$
O_2	C	29.1000	1.1580	-0.6076	1.3110
N_2	C	29.0000	0.2199	0.5723	-2.8710

T_1 = T ref = 25^0C
T2 = suhu feed masuk ataupun suhu keluar

Menghitung enthalpy udara masuk cooler

Q = m Cp ΔT
= m Cp (T_{udara} – 25) , dimana T_{udara} = 157.5404^{0}C

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
O_2	350.0000	30.0989	1396262.086
N_2	1316.6667	29.2534	5105055.623
		Total	6501317.709

Menghitung enthalpy udara keluar cooler

$Q = m\ Cp\ \Delta T$

$= m\ Cp\ (T_{udara} - 25)$, dimana $T_{udara} = 33^0C$

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
O_2	350.0000	29.4139	51474.2722
N_2	1316.6667	29.0648	191342.9522
		Total	242817.2245

Menghitung Q serap dan Q hilang

Q masuk = Q keluar + Q serap + Q hilang

Q serap + (5% Q serap) = Q masuk - Q keluar

1.05 Q serap = 6258500.485

Q serap = 5960476.652 kJ

Q hilang = 5% Q serap = 298023.8326 kJ

Jumlah air pendingin :

asumsi : air pendingin masuk pada 30^0C dan keluar pada 45^0C

Cp air pendingin = 4.1815 kJ / kg K (Geankoplis, 1997)

$Q = m\ Cp\ \Delta T$

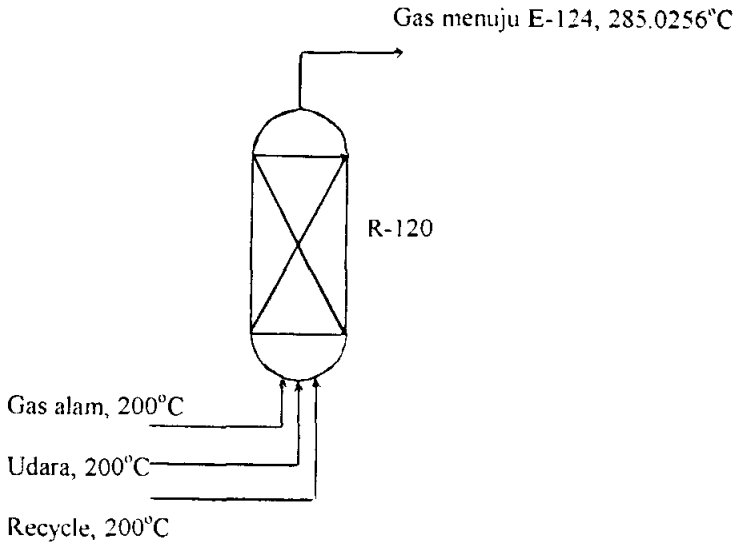
$5960476.652 = m\ 4.1815\ (45 - 30)$

$m = 95029.3221$ kg

Ringkasan Neraca panas Cooler E-113

Masuk (kJ)		**Keluar (kJ)**	
~ Udara, pada 157.5404^{0}C		**~ Udara , pada 33^{0}C**	
oksigen	1396262.086	oksigen	51474.2722
nitrogen	5105055.623	nitrogen	191342.9522
			242817.2245
		~ Q serap	5960476.652
		~ Q hilang	298023.8326
Total	6501317.709	**Total**	6501317.709

II. Reaktor (R – 120)



~Data data yang diperlukan untuk menghitung Cp (Himmelbau, 1991)

Komponen	*T*	*A*	$b.10^2$	$c.10^5$	$d.10^9$
Metana	C	34.3100	5.4690	0.3661	-11.0000
Etana	C	49.3700	13.9200	-5.8160	7.2800
Propane	C	68.0320	22.5900	-13.1100	31.7100
i-butane	C	82.8800	25.6400	-17.2700	50.5000
n-butane	C	92.3000	27.8800	-15.4700	34.9800
i-pentane	C	110.5027	33.4086	-20.4556	47.7271
n-pentane	C	114.8000	34.0900	-18.0900	42.2600
Hexane	C	137.4400	40.8500	-23.9200	57.6600
O_2	C	29.1000	1.1580	-0.6076	1.3110
N_2	C	29.0000	0.2199	0.5723	-2.8710
metanol (gas)	C	42.9300	8.3010	-1.8700	-8.0300
Methanol (liq)	K	-259.25	0.003358	-1.1639	14052

Cp dihitung dengan persamaan

$$Cp = a + \frac{b}{2}(T_1 + T_2) + \frac{c}{3}(T_2^2 + T_1 T_2 + T_1^2) + \frac{d}{4}(T_2^2 + T_1^2)(T_1 + T_2)$$

dimana T_1 = T ref = 25°C

T2 = suhu feed masuk ataupun suhu keluar

Menghitung enthalpy masuk reaktor

~ Enthalpy feed

$Q = m\ Cp\ \Delta T$

$= m\ Cp\ (T_{feed} - 25)$, dimana $T_{feed} = 200^0C$

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
Metana	700.0000	40.4932	4960412.8337
Etana	129.0382	64.1621	1448888.3580
Propane	77.9749	91.5244	1248906.5667
i-butane	16.5610	109.2139	316521.9686
n-butane	20.6027	121.3922	437676.9390
i-pentane	11.5336	145.0855	292837.2501
n-pentane	11.0407	150.4966	290777.8915
Hexane	19.0255	179.8902	598937.2696
O_2	350.0000	30.3133	1856692.0754
N_2	1316.6667	29.3279	6757628.6882
		Total	18209279.8409

~ Enthalpy recycle

$Q = m\ Cp\ \Delta T$

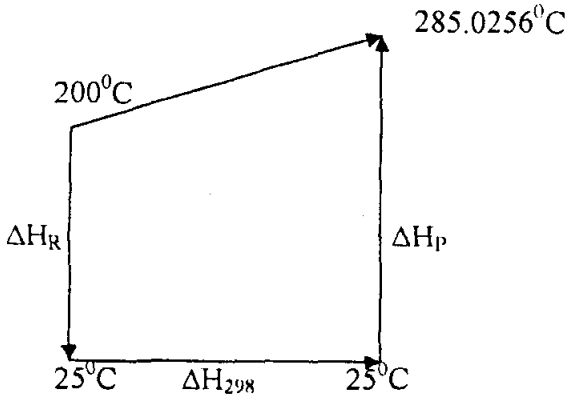
$= m\ Cp\ (T_{recycle} - 25)$, dimana $T_{recycle} = 200^0C$

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
Metana	254.2031	40.4932	1801360.4566
Etana	1023.4220	64.1621	11491361.7750
Propane	618.5866	91.5244	9907759.2761
i-butane	131.4695	109.2139	2512702.4329
n-butane	163.4302	121.3922	3471851.6769
i-pentane	91.5753	145.0855	2325092.7445
n-pentane	87.4952	150.4966	2304353.2788
Hexane	150.9632	179.8902	4752439.4814
O_2	127.1079	30.3133	674252.4223
N_2	10443.4381	29.3279	53599653.3481
		Total	92840826.8926

~ Enthalpy masuk reactor = enthalpy feed + enthalpy recycle

= 111050106.7335 kJ

Menghitung Panas Reaksi



~ Enthalpy Reaktan

$Q = m\ Cp\ \Delta T$

$= m\ Cp\ (25 - T_{reaktan\ masuk})$, dimana $T_{reaktan} = 200^0C$

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
CH_4	954.2157	40.4932	-6761862.5777
O_2	477.1079	30.3133	-2530978.4487
		Total	-9292841.0264

~ $\Delta H_{R\ 298}$

data (Himmelblau, 1991) : $\Delta H_f\ CH_4\ (g) = -74.84$ kJ / mol

$\Delta H_f\ O_2\ (g) = 0$

$\Delta H_f\ CH_3OH\ (g) = -201.25$ kJ / mol

$$\Delta H_{R\ 298} = \text{mol}\ CH_3OH \times \Delta H_f\ CH_3OH - \text{mol}\ CH_4 \times \Delta H_f\ CH_4$$

$$= ((667.9510 \times -201.25) - (667.9510 \times -74.84)) \times 1000$$

$$= -84435684.6459\ \text{kJ}\ (\text{eksoterm})$$

~ Enthalpy Produk

$Q = m\ Cp\ \Delta T$

$= m\ Cp\ (T_{produk\ keluar} - 25)$, dimana $T_{produk} = 285.0256^0C$

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
CH_4	286.2647	42.5520	3045283.8786
O_2	143.1324	30.6761	1097685.9539

Untuk methanol :

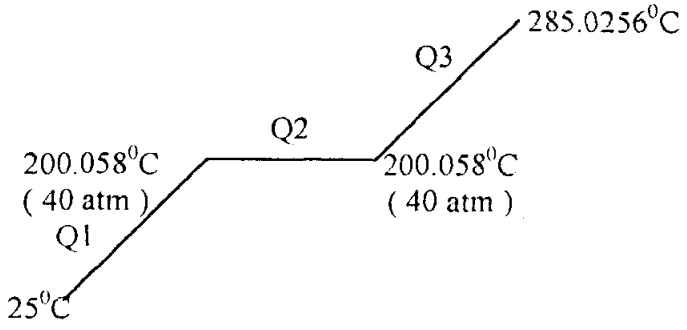
data (Himmelblau, 1991) : A = 18.5875
B = 3626.55
C = -34.29
Hv = 35.3 kJ / mol
Tc = 513.2 K
Tdidih pada 1 atm = 337.9 K

titik didih pada 40 atm (30400 mmHg)

$$T = \frac{B}{A - \ln(P)} - C = 473.058 \text{ K} = 200.058^0\text{C}$$

Hv pada 473.058 K

$$\frac{Hv_2}{Hv_1} = \left(\frac{1 - \frac{T_2}{Tc}}{1 - \frac{T_1}{Tc}} \right)^{0.38} \rightarrow Hv_2 = 20.1607 \text{ kJ / mol}$$



$Q_{metanol}\,1 = m\ Cp_{liq}\ (200.058 - 25)$
$= 667.9510 \times 56.3214 \times (200.058 - 25)$
$= 6585670.6603$ kJ

$Q_{metanol}\,2 = m\ Hv$
$= 667.9510 \times 20.1607 \times 1000$
$= 13466347.09$ kJ

$Q_{metanol}\,3 = m\ Cp_{gas}\ (285.0256 - 200.058)$
$= 667.9510 \times 44.06 \times (285.0256 - 200.058)$
$= 2205537.144$ kJ

$Q_{metanol} = Q_{metanol}\,1 + Q_{metanol}\,2 + Q_{metanol}\,3$
$= 22257554.8976$ kJ

Enthalpy produk = Q metana + Q Oksigen + Q methanol
= 26400524.7301 kJ

~ Panas Reaksi

Panas reaksi = enthalpy reaktan + $\Delta H_{R\ 298}$ + enthalpy produk
= -67328000.9422 kJ (eksoterm)

Menghitung enthalpy keluar reaktor

$Q = m\ Cp\ \Delta T$
$= m\ Cp\ (T_{keluar} - 25)$, dimana $T_{keluar} = 285.0256^{0}C$

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
Metana	286.2647	40.4932	3045286.3089
Etana	1152.5022	64.1621	19788496.1485
Propane	696.6066	91.5244	17147977.8923
i-butane	148.0512	109.2139	4324707.6029
n-butane	184.0430	121.3922	5982941.7454
i-pentane	103.1253	145.0855	4001792.4889
n-pentane	98.5306	150.4966	3969902.2395
Hexane	170.0037	179.8902	8177896.6518
O_2	143.1324	30.3133	1097687.4370
N_2	11760.6285	29.3279	86652329.1946

Untuk methanol :

Dari perhitungan diatas diperoleh Q = 22257554.8976 kJ

total = 176446572.6073 kJ

Menghitung Q serap dan Q hilang

Q masuk + Panas reaksi = Q keluar + Q serap + Q hilang
(Q feed + Q recycle) + Panas reaksi = Q keluar + Q serap + (5% Q serap)
1.05 Q serap = 1931535.0684
Q serap = 1839557.208 kJ
Q hilang = 5% Q serap = 91977.8604 kJ

Jumlah air pendingin :

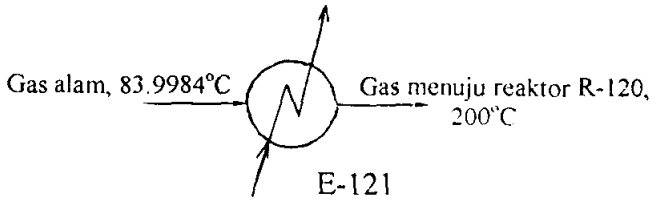
Air pendingin masuk pada $30^{0}C$ dan keluar pada $45.2355^{0}C$
Cp air pendingin = 4.1815 kJ / kg K (Geankoplis, 1997)

$Q = m\ Cp\ \Delta T$
$1839557.208 = m\ 4.1815\ (45.2355 - 30)$
m = 29328.50585 kg

Ringkasan Neraca panas reactor R-120

Masuk (kJ)		Keluar (kJ)	
~ Feed :		**~ Gas menuju cooler E-124, pada 285.0256^{0}C**	
# Gas alam dari storage tank F-110, pada 200^{0}C		methanol	22257554.8976
metana	4960412.8337	metana	3045286.3089
etana	1448888.3580	etana	19788496.1485
propana	1248906.5667	propana	17147977.8923
i-butana	316521.9686	i-butana	4324707.6029
n-butana	437676.9390	n-butana	5982941.7454
i-pentana	292837.2501	i-pentana	4001792.4889
n-pentana	290777.8915	n-pentana	3969902.2395
heksana	598937.2696	heksana	8177896.6518
	9594959.0773	oksigen	1097687.4370
# Udara, pada 200^{0}C		nitrogen	86652329.1946
oksigen	1856692.0754		176446572.6073
nitrogen	6757628.6882		
	8614320.7636	**~ Q serap**	1839557.208
	18209279.8409	**~ Q hilang**	91977.8604
~ Recycle, pada 200^{0}C			
metana	1801360.4566		
etana	11491361.7750		
propana	9907759.2761		
i-butana	2512702.4329		
n-butana	3471851.6769		
i-pentana	2325092.7445		
n-pentana	2304353.2788		
heksana	4752439.4814		
oksigen	674252.4223		
nitrogen	53599653.3481		
	92840826.8926		
~ Panas Reaksi	67328000.9422		
Total	178378107.6757	Total	178378107.6757

III. Heater (E – 121)



Cp dihitung dengan persamaan

$$Cp = a + \frac{b}{2}(T_1 + T_2) + \frac{c}{3}(T_2^2 + T_1.T_2 + T_1^2) + \frac{d}{4}(T_2^2 + T_1^2)(T_1 + T_2)$$

Dimana: nilai konstanta a, b, c, dan d dapat dilihat pada table diatas
T_1 = T ref = 25^0C
T2 = suhu feed masuk ataupun suhu keluar

Menghitung enthalpy gas alam masuk heater

Q = m Cp ΔT
= m Cp (T_{gas} – 25) , dimana T_{gas} = 83.9984^0C

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
Metana	700.0000	37.3002	1540456.2643
Etana	129.0382	56.7682	432178.8518
Propane	77.9749	79.9226	367675.5862
i-butane	16.5610	96.3011	94093.4501
n-butane	20.6027	106.9973	130058.2873
i-pentane	11.5336	128.0532	87135.4910
n-pentane	11.0407	132.7978	86502.3321
Hexane	19.0255	158.9351	178400.4767
		Total	2916500.7396

Menghitung enthalpy gas alam keluar heater

Q = m Cp ΔT
= m Cp (T_{gas} – 25) , dimana T_{gas} = 200^0C

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
Metana	700.0000	40.4932	4960412.8337
Etana	129.0382	64.1621	1448888.3580
Propane	77.9749	91.5244	1248906.5667
i-butane	16.5610	109.2139	316521.9686
n-butane	20.6027	121.3922	437676.9390

i-pentane	11.5336	145.0855	292837.2501
n-pentane	11.0407	150.4966	290777.8915
Hexane	19.0255	179.8902	598937.2696
		Total	9594959.0773

Menghitung Q suplay dan Q hilang

Q gas alam masuk + Q suplay = Q gas alam keluar + Q hilang

Q suplay – Q hilang = Q gas alam keluar – Q gas alam masuk

Q suplay – (5% Q suplay) = Q gas alam keluar – Q gas alam masuk

0.95 Q suplay = 6678458.3377

Q suplay = 7029956.1449 kJ

Q hilang = 5% Q suplay = 351497.8072 kJ

Jumlah Steam yang dibutuhkan :

asumsi: steam yang digunakan adalah steam superheated pada 45 bar, 400^0 C

data (Geankoplis, 1997) : $H_{sat\ vapor}$ = 2513.9251 kJ/kg

H_{liq} = 1032.9435 kJ/kg

$H_{sup\ vap}$ = 2878.7895 kJ/kg

maka $\lambda = H_{sat\ vapor} - H_{liq}$

= 1480.9816 kJ/kg

$Q = m\lambda + m.\ (H_{sup\ vapor} - H_{sat\ vapor})$

7029956.1449 = m 1480.9816 + m (2878.7895 – 2513.9435)

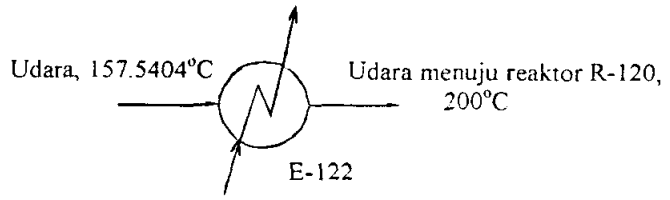
7029956.1449 = m 1845.8276

m = 3808.5659 kg

Ringkasan Neraca panas Heater E-121

Masuk (kJ)		**Keluar (kJ)**	
~ Gas Alam, pada 83.9984^{0}C		**~ Gas alam menuju R-120, pada 200^{0}C**	
metana	1540456.2642	metana	4960412.8337
etana	432178.8518	etana	1448888.3580
propana	367675.5862	propana	1248906.5667
i-butana	94093.4501	i-butana	316521.9686
n-butana	130058.2873	n-butana	437676.9390
i-pentana	87135.4910	i-pentana	292837.2501
n-pentana	86502.3321	n-pentana	290777.8915
heksana	178400.4767	heksana	598937.2696
	2916500.7396		9594959.0773
~ Q suplay	7029956.1449	**~ Q hilang**	351497.8072
Total	9946456.8845	Total	9946456.8845

IV. Heater (E – 122)



Cp dihitung dengan persamaan

$$Cp = a + \frac{b}{2}(T_1 + T_2) + \frac{c}{3}(T_2^2 + T_1.T_2 + T_1^2) + \frac{d}{4}(T_2^2 + T_1^2)(T_1 + T_2)$$

Dimana: nilai konstanta a, b, c, dan d dapat dilihat pada table diatas
T_1 = T ref = 25^0C
T2 = suhu feed masuk ataupun suhu keluar

Menghitung enthalpy udara masuk heater

Q = m Cp ΔT
= m Cp (T_{udara} – 25) , dimana T_{udara} = 157.5404^{0}C

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
O_2	350.0000	30.0989	52673.1132
N_2	1316.6667	29.2534	192585.0251
		Total	245258.1383

Menghitung enthalpy udara keluar heater

Q = m Cp ΔT
= m Cp (T_{udara} – 25) , dimana T_{udara} = 200^{0}C

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
O_2	350.0000	30.3133	1856692.0754
N_2	1316.6667	29.3279	6757628.6882
		Total	8614320.7636

Menghitung Q suplay dan Q hilang

Q gas alam masuk + Q suplay = Q gas alam keluar + Q hilang
Q suplay – Q hilang = Q gas alam keluar – Q gas alam masuk
Q suplay – (5% Q suplay) = Q gas alam keluar – Q gas alam masuk
0.95 Q suplay = 8369062.6253

Q suplay = 8809539.606 kJ
Q hilang = 5% Q suplay = 440476.9803 kJ

Jumlah Steam yang dibutuhkan :
asumsi : steam yang digunakan adalah steam superheated pada 45 bar, 400^0C
data (Geankoplis, 1997) : $H_{sat\ vapor}$ = 2513.9251 kJ/kg
H_{liq} = 1032.9435 kJ/kg
$H_{sup\ vap}$ = 2878.7895 kJ/kg

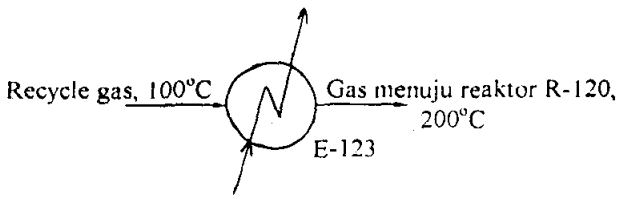
maka $\lambda = H_{sat\ vapor} - H_{liq}$
= 1480.9816 kJ/kg

$$Q = m\lambda + m.\ (H_{sup\ vapor} - H_{sat\ vapor})$$
$$8809539.606 = m\ 1480.9816 + m\ (2878.7895 - 2513.9435)$$
$$8809539.606 = m\ 1845.8276$$
$$m = 4772.6774\ kg$$

Ringkasan Neraca panas Heater E-122

Masuk (kJ)		Keluar (kJ)	
~ Udara, pada 157.5404^{0}C		**~ Udara menuju R-120, pada 200^{0}C**	
oksigen	52673.1132	oksigen	1856692.0754
nitrogen	192585.0251	nitrogen	6757628.6882
	245258.1383		8614320.7636
~ Q suplay	8809539.606	**~ Q hilang**	440476.9803
Total	9054797.7439	Total	9054797.7439

V. Heater (E – 123)



Cp dihitung dengan persamaan

$$Cp = a + \frac{b}{2}(T_1 + T_2) + \frac{c}{3}(T_2^2 + T_1.T_2 + T_1^2) + \frac{d}{4}(T_2^2 + T_1^2)(T_1 + T_2)$$

Dimana: nilai konstanta a, b, c, dan d dapat dilihat pada table diatas
T_1 = T ref = 25^0C
T2 = suhu feed masuk ataupun suhu keluar

Menghitung enthalpy gas masuk heater

Q = m Cp ΔT
= m Cp (T_{udara} – 25) , dimana T_{udara} = 100^0C

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
Metana	254.2031	37.7405	719531.2076
Etana	1023.4220	57.8180	4437913.4711
Propane	618.5866	81.5877	3785180.0980
i-butane	131.4695	98.1662	967939.6424
n-butane	163.4302	109.0598	1336774.8934
i-pentane	91.5753	130.5040	896320.6128
n-pentane	87.4952	135.3288	888046.8213
Hexane	150.9632	161.9439	1833567.6448
O_2	127.1079	29.7976	284063.3037
N_2	10443.4381	29.1615	22840991.5277
		Total	37990329.2227

Menghitung enthalpy gas keluar heater

Q = m Cp ΔT'
= m Cp ($T_{recycle}$ – 25) , dimana $T_{recycle}$ = 200^0C

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
Metana	254.2031	40.4932	1801360.4566
Etana	1023.4220	64.1621	11491361.7750
Propane	618.5866	91.5244	9907759.2761
i-butane	131.4695	109.2139	2512702.4329
n-butane	163.4302	121.3922	3471851.6769
i-pentane	91.5753	145.0855	2325092.7445
n-pentane	87.4952	150.4966	2304353.2788
Hexane	150.9632	179.8902	4752439.4814
O_2	127.1079	30.3133	674252.4223
N_2	10443.4381	29.3279	53599653.3481
		Total	92840826.8926

Menghitung Q suplay dan Q hilang

Q gas alam masuk + Q suplay = Q gas alam keluar + Q hilang
Q suplay – Q hilang = Q gas alam keluar – Q gas alam masuk
Q suplay – (5% Q suplay) = Q gas alam keluar – Q gas alam masuk
0.95 Q suplay = 54850497.6699
Q suplay = 57737365.9683 kJ
Q hilang = 5% Q suplay = 2886868.2984 kJ

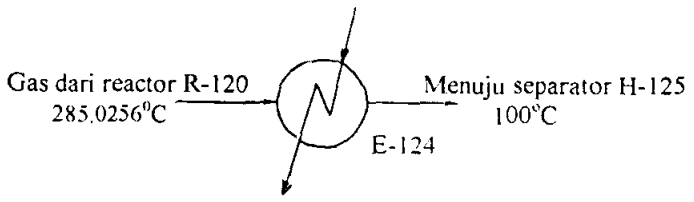
Jumlah Steam yang dibutuhkan :
asumsi : steam yang digunakan adalah steam superheated pada 45 bar,400^{0}C
data (Geankoplis, 1997) : $H_{sat\ vapor}$ = 2513.9251 kJ/kg
H_{liq} = 1032.9435 kJ/kg
$H_{sup\ vap}$ = 2878.7895 kJ/kg

maka $\lambda = H_{sat\ vapor} - H_{liq}$
= 1480.9816 kJ/kg
$Q = m\lambda + m.\ (H_{sup\ vapor} - H_{sat\ vapor})$
57737365.9683 = m 1480.9816 + m (2878.7895 – 2513.9435)
57737365.9683 = m 1845.8276
m = 31279.9343 kg

Ringkasan Neraca panas Heater E-123

Masuk (kJ)		**Keluar (kJ)**	
~ Recycle gas, pada 100^{0}C		**~ Gas menuju R-120, pada 200^{0}C**	
metana	719531.2076	metana	1801360.4566
etana	4437913.4711	etana	11491361.7750
propana	3785180.0980	propana	9907759.2761
i-butana	967939.6424	i-butana	2512702.4329
n-butana	1336774.8934	n-butana	3471851.6769
i-pentana	896320.6128	i-pentana	2325092.7445
n-pentana	888046.8213	n-pentana	2304353.2788
heksana	1833567.6448	heksana	4752439.4814
oksigen	284063.3037	oksigen	674252.4223
nitrogen	22840991.5277	nitrogen	53599653.3481
	37990329.2227		92840826.8926
~ Q suplay	57737365.9683	**~ Q hilang**	2886868.2984
Total	95727695.1910	Total	95727695.1910

VI. Cooler (E – 124)



Cp dihitung dengan persamaan

$$Cp = a + \frac{b}{2}(T_1 + T_2) + \frac{c}{3}(T_2^2 + T_1.T_2 + T_1^2) + \frac{d}{4}(T_2^2 + T_1^2)(T_1 + T_2)$$

Dimana: nilai konstanta a, b, c, dan d dapat dilihat pada table diatas

T_1 = T ref = 25°C

T2 = suhu feed masuk ataupun suhu keluar

Menghitung enthalpy masuk cooler

Q = m Cp ΔT

= m Cp (T_{keluar} – 25) , dimana T_{keluar} = 285.0256°C

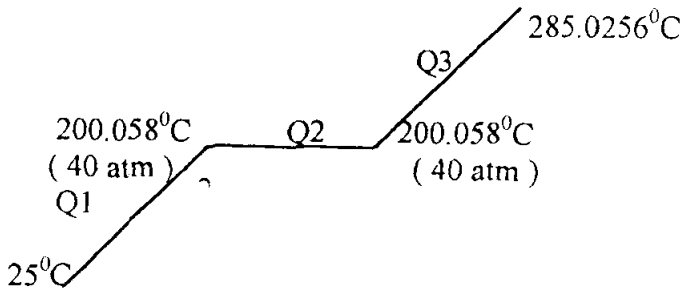
Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
Metana	286.2647	40.4932	3045286.3089
Etana	1152.5022	64.1621	19788496.1485
Propane	696.6066	91.5244	17147977.8923
i-butane	148.0512	109.2139	4324707.6029
n-butane	184.0430	121.3922	5982941.7454
i-pentane	103.1253	145.0855	4001792.4889
n-pentane	98.5306	150.4966	3969902.2395
Hexane	170.0037	179.8902	8177896.6518
O_2	143.1324	30.3133	1097687.4370
N_2	11760.6285	29.3279	86652329.1946

Untuk methanol :

dari perhitungan diatas diperoleh:

~ titik didih pada 40 atm = 473.058 K = 200.058°C

~ Hv pada 473.058 K = 20.1607 kJ / mol



$Q_{metanol}\,1 = m\,Cp_{liq}\,(200.058 - 25)$
$= 667.9510 \times 56.3214 \times (200.058 - 25)$
$= 6585670.6603$ kJ

$Q_{metanol}\,2 = m\,Hv$
$= 667.9510 \times 20.1607 \times 1000$
$= 13466347.09$ kJ

$Q_{metanol}\,3 = m\,Cp_{gas}\,(285.0256 - 200.058)$
$= 667.9510 \times 44.06 \times (285.0256 - 200.058)$
$= 2205537.144$ kJ

$Q_{metanol} = Q_{metanol}\,1 + Q_{metanol}\,2 + Q_{metanol}\,3$ = 22257554.8976 kJ

total = 176446572.6073 kJ

Menghitung enthalpy keluar cooler

$Q = m\,Cp\,\Delta T$
$= m\,Cp\,(T_{keluar} - 25)$, dimana $T_{keluar} = 100^0C$

Komponen	M (kmol)	Cp (J / mol K)	Q (kJ)
Metana	286.2647	37.7405	810282.7435
Etana	1152.5022	57.8180	4997650.0787
Propane	696.6066	81.5877	4262590.6194
i-butane	148.0512	98.1662	1090021.8346
n-butane	184.0430	109.0598	1505376.9848
i-pentane	103.1253	130.5040	1009369.6891
n-pentane	98.5306	135.3288	1000052.4158
Hexane	170.0037	161.9439	2064829.5997
O_2	143.1324	29.7976	319875.1802
N_2	11760.6285	29.1615	25721837.3257
		Total	42781886.4714

Untuk methanol :

$Q_{metanol} = m\,Cp_{liq}\,(100 - 25)$
$= 667.9510 \times 43.5964 \times (100 - 25)$ = 2184019.4232 kJ

Menghitung Q serap dan Q hilang

$$Q \text{ masuk} = Q \text{ keluar} + Q \text{ serap} + Q \text{ hilang}$$
$$Q \text{ serap} + (5\% \, Q \text{ serap}) = Q \text{ masuk} - Q \text{ keluar}$$
$$1.05 \, Q \text{ serap} = 131480666.7127$$
$$Q \text{ serap} = 125219682.5835 \text{ kJ}$$
$$Q \text{ hilang} = 5\% \, Q \text{ serap} = 6260984.1292 \text{ kJ}$$

Jumlah air pendingin :

asumsi : air pendingin masuk pada 30^0C dan keluar pada 45^0C

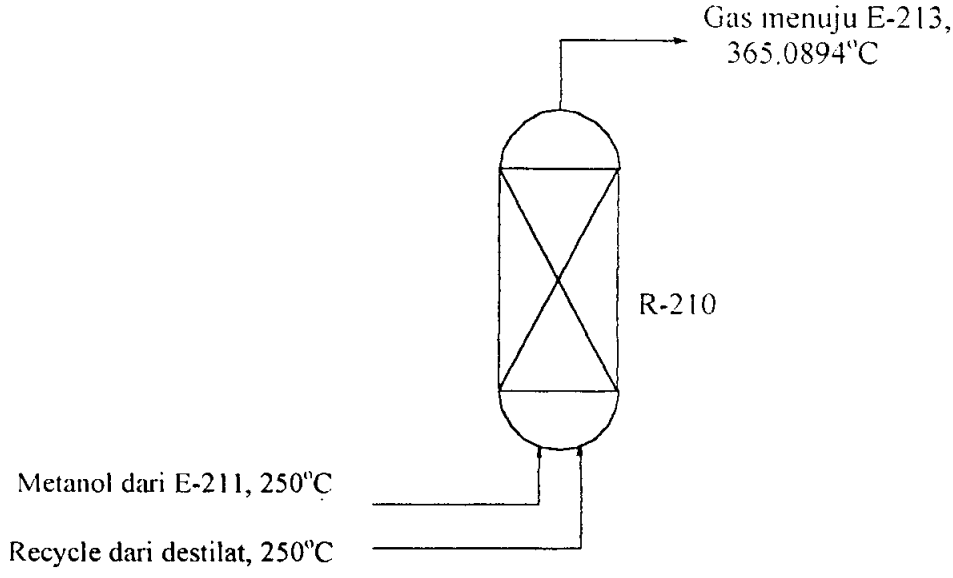
Cp air pendingin = 4.1815 kJ / kg K (Geankoplis, 1997)

$$Q = m \, Cp \, \Delta T$$
$$125219682.5835 = m \; 4.1815 \, (45 - 30)$$
$$m = 1996407.701 \text{ kg}$$

Ringkasan Neraca panas Cooler E-124

Masuk (kJ)		Keluar (kJ)	
~ Gas dari R-120, pada 285.0256^{0}C		**~ Gas menuju H-125, pada 100^{0}C**	
methanol	22257554.8976	metana	810282.7435
metana	3045286.3089	etana	4997650.0787
etana	19788496.1485	propana	4262590.6194
propana	17147977.8923	i-butana	1090021.8346
i-butana	4324707.6029	n-butana	1505376.9848
n-butana	5982941.7454	i-pentana	1009369.6891
i-pentana	4001792.4889	n-pentana	1000052.4158
n-pentana	3969902.2395	heksana	2064829.5997
heksana	8177896.6518	oksigen	319875.1802
oksigen	1097687.4370	nitrogen	25721837.3257
nitrogen	86652329.1946		----------
			42781886.4714
		~ Liq menuju separator H-125 :	
		methanol	2184019.4232
		~ Q serap	
		125219682.5835	
		~ Q hilang	6260984.1292
Total	176446572.6073	Total	176446572.6073

VII. Reaktor (R-210)



~Data data yang diperlukan untuk menghitung Cp (Himmelbau, 1991)

Komponen	*T*	*A*	$b.10^2$	$c.10^5$	$d.10^9$
Methanol (gas)	C	42.9300	8.3010	-1.8700	-8.0300
Methanol (liq)	K	-259.25	0.003358	-1.1639	14052
H_2O (gas)	C	33.46	0.688	0.7604	-3.593
H_2O (liq)	K	18.2964	47.212	-133.88	1314.2

Cp dihitung dengan persamaan

$$Cp = a + \frac{b}{2}(T_1 + T_2) + \frac{c}{3}(T_2^2 + T_1.T_2 + T_1^2) + \frac{d}{4}(T_2^2 + T_1^2)(T_1 + T_2)$$

Menghitung enthalpy masuk reaktor

Untuk methanol :

data (Himmelblau, 1991) :

A = 18.5875
B = 3626.55
C = -34.29
Hv = 35.3 kJ / mol
Tc = 513.2 K
Tdidih pada 1 atm = 337.9 K

titik didih pada 15 atm (11400 mmHg)

$$T = \frac{B}{A - \ln(P)} - C = 426.5135 \text{ K} = 153.5135\ ^{0}\text{C}$$

Hv pada 153.5135 K

$$\frac{Hv_2}{Hv_1} = \left(\frac{1 - \frac{T_2}{Tc}}{1 - \frac{T_1}{Tc}} \right)^{0.38} \rightarrow \quad Hv_2 = 27.0121 \text{ kJ / mol}$$

Untuk H_2O :

data (Himmelblau, 1991) :

A = 18.3036
B = 3816.4400
C = -46.1300
Hv = 40.65 kJ / mol
Tc = 647.4 K
Tdidih pada 1 atm = 373.16 K

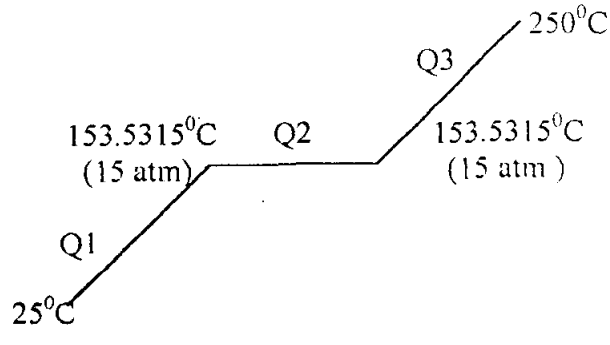
titik didih pada 15 atm (11400 mmHg)

$$T = \frac{B}{A - \ln(P)} - C = 471.9659 \text{ K} = 198.9659^{0}\text{C}$$

Hv pada 471.9659 K

$$\frac{Hv_2}{Hv_1} = \left(\frac{1 - \frac{T_2}{Tc}}{1 - \frac{T_1}{Tc}} \right)^{0.38} \rightarrow \quad Hv_2 = 34.3032 \text{ kJ / mol}$$

~ methanol hasil dari reactor R-120



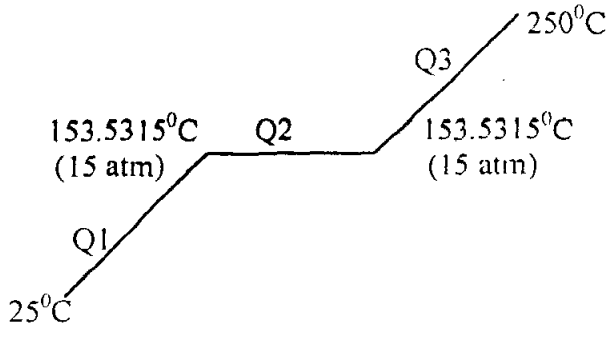
$Q_{metanol}\,1 = m\,Cp_{liq}\,(153.5135 - 25)$
$= 667.9510 \times 54.3247 \times (153.5135 - 25)$
$= 4663271.4073\ kJ$

$Q_{metanol}\,2 = m\,Hv$
$= 667.9510 \times 27.0121 \times 1000$
$= 18042791.8812\ kJ$

$Q_{metanol}\,3 = m\,Cp_{gas}\,(250 - 153.5135)$
$= 667.9510 \times 46.3789 \times (250 - 153.5135)$
$= 2989039.1349\ kJ$

$Q_{metanol} = Q_{metanol}\,1 + Q_{metanol}\,2 + Q_{metanol}\,3$
$= 25695102.4235\ kJ$

~ Recycle dari destilat
untuk methanol



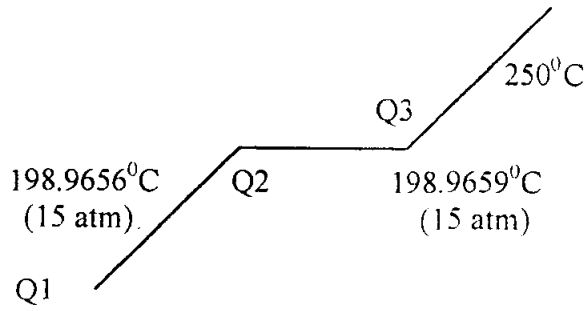
$Q_{metanol}\,1 = m\,Cp_{liq}\,(153.5135 - 25)$
$= 162.792 \times 54.3247 \times (153.5135 - 25)$
$= 1136525.4022\ kJ$

$Q_{metanol}\,2 = m\,Hv$
$= 162.792 \times 27.0121 \times 1000$
$= 4397361.7465\ kJ$

$Q_{metanol}\,3 = m\,Cp_{gas}\,(250 - 153.5135)$
$= 162.792 \times 46.3789 \times (250 - 153.5135)$
$= 728348.1617\ kJ$

$Q_{metanol} = Q_{metanol}\,1 + Q_{metanol}\,2 + Q_{metanol}\,3$
$= 6262235.3104\ kJ$

untuk H_2O



$Q_{H2O}1 = m\ Cp_{liq}\ (198.9659 - 25\ )$
$= 1.6444 \times 77.0678 \times (198.9659 - 25\ )$
$= 9448.0330$ kJ

$Q_{H2O}2 = m\ Hv$
$= 1.644 \times 34.3032 \times 1000$
$= 24173.43918$ kJ

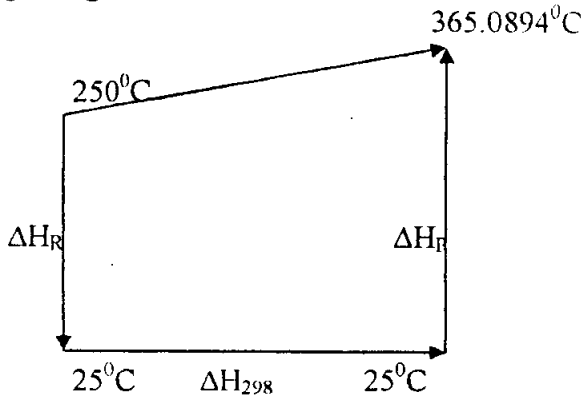
$Q_{H2O}3 = m\ Cp_{gas}\ (\ 250 - 198.9659\ )$
$= 1.6444 \times 35.3483 \times (\ 250 - 198.9659\ )$
$= 1271.2554$ kJ

$Q_{H2O} = Q_{H2O}1 + Q_{H2O}2 + Q_{H2O}3$
$= 34892.7276$ kJ

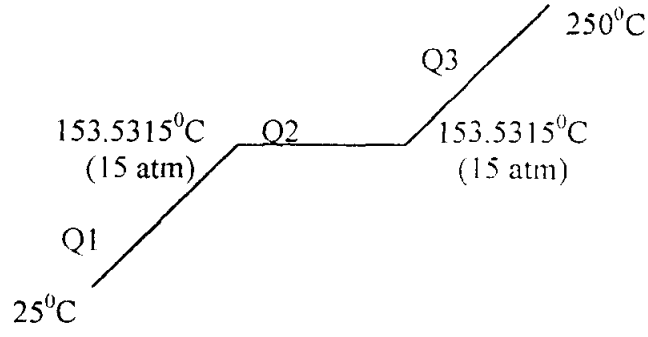
$Q_{recycle} = Q_{H2O} + Q_{methanol} = 6297128.0380$ kJ

Q masuk = Q methanol dari reactor R-120 + Q recycle
$= 31992230.4614$ kJ

Menghitung Panas Reaksi



~ Enthalpy Reaktan
untuk methanol



$Q_{metanol}\,1 = m\,Cp_{liq}\,(153.5135 - 25)$
$= 830.7430 \times 54.3247 \times (25 - 153.5135)$
$= -5799796.8103$ kJ

$Q_{metanol}\,2 = m\,Hv$
$= 830.743 \times -27.0121 \times 1000$
$= -22440112.9954$ kJ

$Q_{metanol}\,3 = m\,Cp_{gas}\,(250 - 153.5135)$
$= 830.743 \times 46.3789 \times (153.5135 - 250)$
$= -3750394.9631$ kJ

enthalpy reaktan = $Q_{metanol} = Q_{metanol}\,1 + Q_{metanol}\,2 + Q_{metanol}\,3$
$= -31957337.7339$ kJ

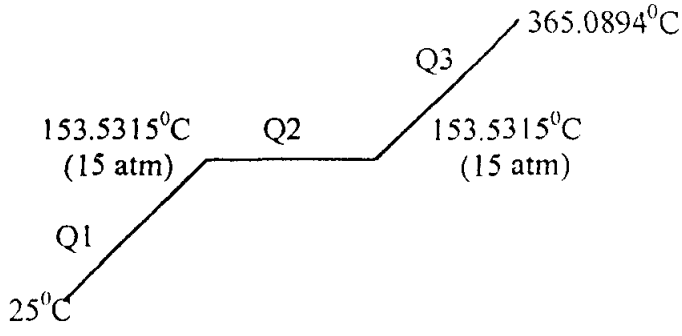
~ $\Delta H_{R\,298}$

data (Himmelblau, 1991) : ΔH_f DME (g) = -183.0000 kJ / mol
ΔH_f H_2O (g) = -241.8260 kJ/mol
ΔH_f CH_3OH (g) = -201.25 kJ / mol

$\Delta H_{R\,298} = (\text{mol DME} \times \Delta H_f\ \text{DME} + \text{mol } H_2O \times \Delta H_f\ H_2O) - (\text{mol } CH_3OH \times \Delta H_f\ CH_3OH)$
$= ((332.2972 \times -201.25 + 332.2972 \times -241.8260) - (664.5944 \times -201.25)) \times 1000$
$= -7418867.2872$ kJ (eksoterm)

~ Enthalpy Produk

untuk methanol



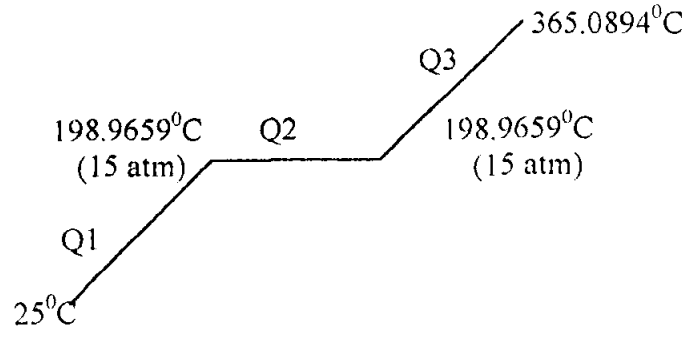
$Q_{metanol}\,1 = m\,Cp_{liq}\,(153.5135 - 25)$
$= 166.1485 \times 54.3247 \times (153.5135 - 25)$
$= 1159958.6638$ kJ

$Q_{metanol}\,2 = m\,Hv$
$= 166.1485 \times 27.0121 \times 1000$
$= 4488028.024$ kJ

$Q_{metanol}\,3 = m\,Cp_{gas}\,(365.0894 - 153.5135)$
$= 166.1485 \times 46.9687 \times (365.0894 - 153.5135)$
$= 1650253.4504$ kJ

$Q_{metanol} = Q_{metanol}\,1 + Q_{metanol}\,2 + Q_{metanol}\,3$
$= 7298240.1385$ kJ

untuk H_2O



$Q_{H2O}\,1 = m\,Cp_{liq}\,(198.9659 - 25)$
$= 333.9415 \times 77.0678 \times (198.9659 - 25)$
$= 4478087.8148$ kJ

$Q_{H2O}\,2 = m\,Hv$
$= 333.9415 \times 34.3032 \times 1000$
$= 11455249.8092$ kJ

$Q_{H2O}3 = m\ Cp_{gas}\ (\ 365.0894 - 198.9659\ )$
$= 333.9415 \times 35.9348 \times (\ 365.0894 - 198.9659\ )$
$= 1992018.1990$ kJ
$Q_{H2O} = Q_{H2O}1 + Q_{H2O}2 + Q_{H2O}3$
$= 17925355.8229$ kJ

untuk DME
$Cp_{gas} = 49.1304$ J /mol K (Ulmann, 1991)
$Q = m\ Cp_{gas}\ (\ 365.0894 - 25\ )$
$= 332.2972 \times 49.1304 \times (\ 365.0894 - 25\ )$
$= 5550804.081$ kJ
enthalpy produk = Q methanol + Q H_2O + Q DME
= 30774400.0421 kJ

~ Panas Reaksi
Panas reaksi = enthalpy reaktan + $\Delta H_{R\ 298}$ + enthalpy produk
= -8601804.9789 kJ (eksoterm)

Menghitung enthalpy keluar reaktor
dari perhitungan di atas didapat
$Q_{metanol}$ = 7298240.1385 kJ
Q_{H2O} = 17925355.8229 kJ
Q_{DME} = 5550804.081 kJ
---
total = 30774400.0421 kJ

Menghitung Q serap dan Q hilang

Q masuk + Panas reaksi = Q keluar + Q serap + Q hilang
(Q feed + Q recycle) + Panas reaksi = Q keluar + Q serap + (5% Q serap)
1.05 Q serap = 71368435.4825
Q serap = 9352033.7123 kJ
Q hilang = 5% Q serap = 467601.6856 kJ

Jumlah air pendingin :
air pendingin masuk pada 30^0C dan keluar pada 45.4567^0C
Cp air pendingin = 4.1815 kJ / kg K (Geankoplis, 1997)

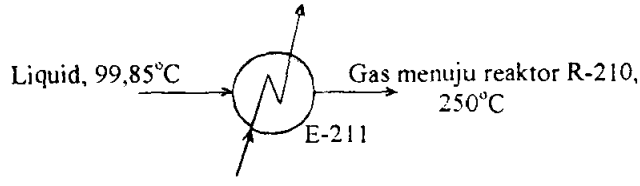
$Q = m\ Cp\ \Delta T$
$9352033.7123 = m\ \ 4.1815\ (\ 45.4567 - 30\ )$
$m = 149101.7372$ kg

Ringkasan Neraca panas reactor R-210

Masuk (kJ)		Keluar (kJ)	
~ Gas dari E-211, pada 250^{0}C		**~ Gas menuju E-213, pada 365.0894^{0}C**	
methanol	25695102.4235	Methanol	7298240.1385
		H_2O	17925355.8229
		DME	5550804.0810
~ Gas dari E-212, pada 250^{0}C			----------
Methanol	6262235.3104		30774400.0421
H_2O	34892.7276		
	----------	**~ Q serap**	9352033.7123
	6297128.0380		

	31992230.4614		
		~ Q hilang	467601.6856
~ Panas Reaksi	8601804.9789		
Total	40594035.4404	Total	40594035.4404

VIII. Heater (E-211)



Cp dihitung dengan persamaan

$$Cp = a + \frac{b}{2}(T_1 + T_2) + \frac{c}{3}(T_2^2 + T_1.T_2 + T_1^2) + \frac{d}{4}(T_2^2 + T_1^2)(T_1 + T_2)$$

Dimana: nilai konstanta a, b, c, dan d dapat dilihat pada table diatas

Menghitung enthalpy methanol masuk heater

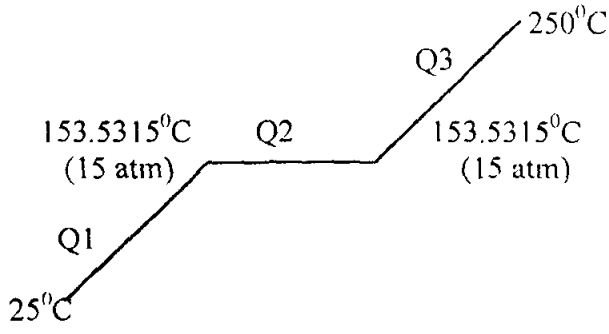
Q = m Cp ΔT

= m Cp_{liq} (T – 25) , dimana T = 99,85^{0}C

= 667,9510 x 53,6175 x (99,85 – 25)

= 2686039,7057 kJ

Menghitung enthalpy methanol keluar heater



$Q_{metanol}\,1 = m\ Cp_{liq}\ (\ 153.5135 - 25\ )$
$= 667.9510 \times 54.3247 \times (153.5135 - 25\ )$
$= 4663271.4073$ kJ

$Q_{metanol}\,2 = m\ Hv$
$= 667.9510 \times 27.0121 \times 1000$
$= 18042791.8812$ kJ

$Q_{metanol}\,3 = m\ Cp_{gas}\ (\ 250 - 153.5135\ )$
$= 667.9510 \times 46.3789 \times (\ 250\text{-}153.5135\ )$
$= 2989039.1349$ kJ

$Q_{metanol} = Q_{metanol}\,1 + Q_{metanol}\,2 + Q_{metanol}\,3$
$= 25695102.4235$ kJ

Menghitung Q suplay dan Q hilang

Q masuk + Q suplay = Q keluar + Q hilang
Q suplay – Q hilang = Q keluar – Q masuk
Q suplay – (5% Q suplay) = Q keluar – Q masuk
0.95 Q suplay = 23009030.0437
Q suplay = 24220066.0188 kJ
Q hilang = 5% Q suplay = 1211003.3009 kJ

Jumlah Steam yang dibutuhkan :
asumsi : steam yang digunakan adalah steam superheated pada 45 bar, 400^{0}C
data (Geankoplis, 1997) : $H_{sat\ vapor} = 2513.9251$ kJ/kg
$H_{liq} = 1032.9435$ kJ/kg
$H_{sup\ vap} = 2878.7895$ kJ/kg

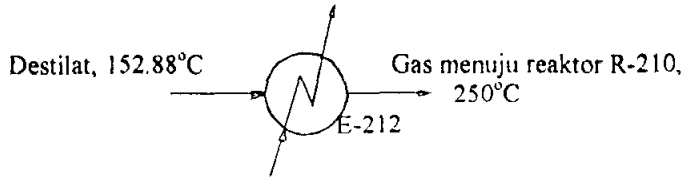
maka $\lambda = H_{sat\ vapor} - H_{liq}$
$= 1480.9816$ kJ/kg

$$Q = m\,\lambda + m.\,(H_{sup\ vapor} - H_{sat\ vapor})$$
$$24220066.0188 = m\ 1480.9816 + m\,(2878.7895 - 2513.9435)$$
$$24220066.0188 = m\ 1845.8276$$
$$m = 13121.5212\ kg$$

Ringkasan Neraca panas Heater E-211

Masuk (kJ)		Keluar (kJ)	
~ Liquid pada suhu 99,85^{0}C		**~ Gas menuju E-210, pada 250^{0}C**	
methanol	2686039.7057	Methanol	25695102.4235
~ Q suplay	24220066.0188	**~ Q hilang**	1211003.3009
Total	26906105.7244	Total	26906105.7244

IX. Heater (E-212)



Cp dihitung dengan persamaan

$$Cp = a + \frac{b}{2}(T_1 + T_2) + \frac{c}{3}(T_2^2 + T_1.T_2 + T_1^2) + \frac{d}{4}(T_2^2 + T_1^2)(T_1 + T_2)$$

Dimana: nilai konstanta a, b, c, dan d dapat dilihat pada table diatas

Menghitung enthalpy masuk heater

untuk methanol

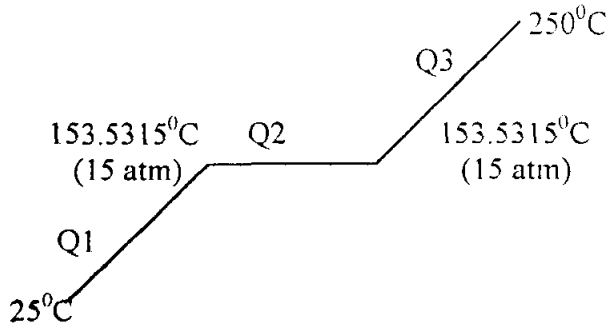
$Q_{metanol} = m\ Cp_{liq}\,(152.88 - 25)$
$= 162.792 \times 53.9795 \times (152.88 - 25)$
$= 1123736.6461\ kJ$

untuk H_2O

$Q_{H2O}\ l = m\ Cp_{liq}\,(152.88 - 25)$
$= 1.6444 \times 74.2597 \times (152.88 - 25)$
$= 15615.76578\ kJ$

$Q_{masuk} = Q_{H2O} + Q_{methanol} = 1139352.4119\ kJ$

Menghitung enthalpy keluar heater
untuk methanol



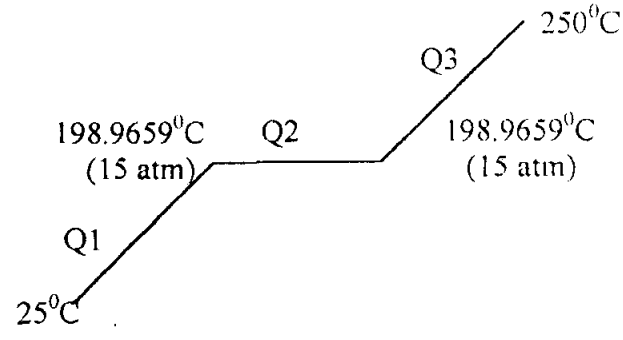
$Q_{metanol}\,1 = m\,Cp_{liq}\,(153.5135 - 25)$
$= 162.792 \times 54.3247 \times (153.5135 - 25)$
$= 1136525.4022$ kJ

$Q_{metanol}\,2 = m\,Hv$
$= 162.792 \times 27.0121 \times 1000$
$= 4397361.7465$ kJ

$Q_{metanol}\,3 = m\,Cp_{gas}\,(250 - 153.5135)$
$= 162.792 \times 46.3789 \times (250 - 153.5135)$
$= 728348.1617$ kJ

$Q_{metanol} = Q_{metanol}\,1 + Q_{metanol}\,2 + Q_{metanol}\,3$
$= 6262235.3104$ kJ

untuk H_2O



$Q_{H2O}\,1 = m\,Cp_{liq}\,(198.9659 - 25)$
$= 1.6444 \times 77.0678 \times (198.9659 - 25)$
$= 9448.0330$ kJ

$Q_{H2O}\,2 = m\,Hv$
$= 1.644 \times 34.3032 \times 1000$
$= 24173.43918$ kJ

$$Q_{H2O}3 = m\ Cp_{gas}\ (\ 250 - 198.9659\ )$$
$$= 1.6444 \times 35.3483 \times (\ 250 - 198.9659\ )$$
$$= 1271.2554\ kJ$$
$$Q_{H2O} = Q_{H2O}1 + Q_{H2O}2 + Q_{H2O}3$$
$$= 34892.7276\ kJ$$
$$Q_{keluar} = Q_{H2O} + Q_{methanol} = 6297128.0380\ kJ$$

Menghitung Q suplay dan Q hilang

$$Q\ masuk + Q\ suplay = Q\ keluar + Q\ hilang$$
$$Q\ suplay - Q\ hilang = Q\ keluar - Q\ masuk$$
$$Q\ suplay - (\ 5\%\ Q\ suplay\ ) = Q\ keluar - Q\ masuk$$
$$0.95\ Q\ suplay = 5157775.6261$$
$$Q\ suplay = 5429237.5012\ kJ$$
$$Q\ hilang = 5\%\ Q\ suplay = 271461.8751\ kJ$$

Jumlah Steam yang dibutuhkan :

asumsi : steam yang digunakan adalah steam superheated pada 45 bar, 400^0 C

data (Geankoplis, 1997) : $H_{sat\ vapor} = 2513.9251$ kJ/kg

$H_{liq} = 1032.9435$ kJ/kg

$H_{sup\ vap} = 2878.7895$ kJ/kg

maka $\lambda = H_{sat\ vapor} - H_{liq}$

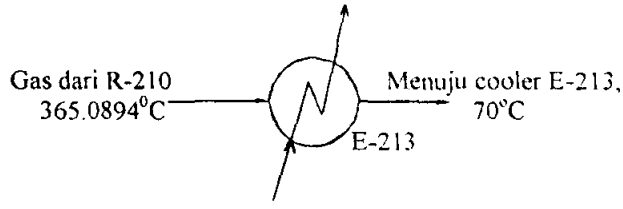
$= 1480.9816$ kJ/kg

$$Q = m\ \lambda + m.\ (\ H_{sup\ vapor} - H_{sat\ vapor}\ )$$
$$5429237.5012 = m\ 1480.9816 + m\ (\ 2878.7895 - 2513.9435\ )$$
$$5429237.5012 = m\ 1845.8276$$
$$m = 2941.3568\ kg$$

Ringkasan Neraca panas heater E-212

Masuk (kJ)		**Keluar (kJ)**	
~ Destilat dari D-220, pada 152.88^0C		**~ Gas menuju E-210, pada 250^0C**	
Methanol	1123736.6461	Methanol	6262235.3104
H_2O	15615.76578	H_2O	34892.7276
	---		---
-	1139352.4119		6297128.0380
~ Q suplay	5429237.5012	**~ Q hilang**	271461.8751
Total	6568589.9131	Total	6568589.9131

X. Cooler (E-213)

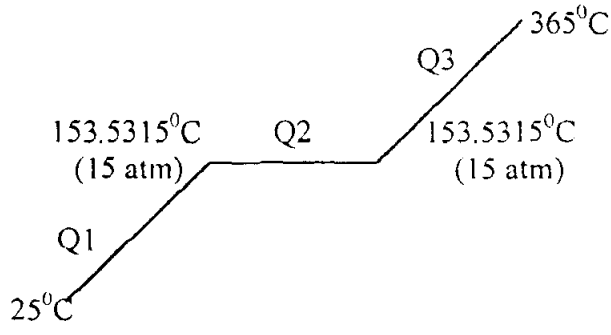


Cp dihitung dengan persamaan

$$Cp = a + \frac{b}{2}(T_1 + T_2) + \frac{c}{3}(T_2^2 + T_1.T_2 + T_1^2) + \frac{d}{4}(T_2^2 + T_1^2)(T_1 + T_2)$$

Dimana: nilai konstanta a, b, c, dan d dapat dilihat pada table diatas

Menghitung enthalpy masuk cooler
untuk methanol



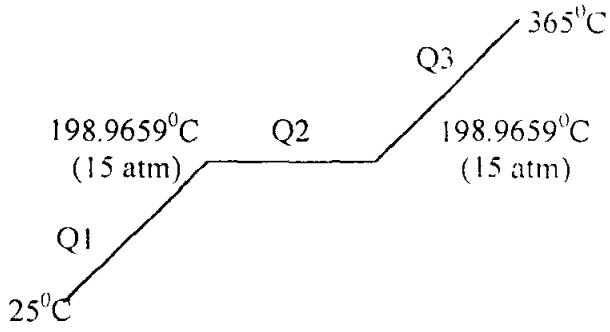
$Q_{metanol}\,1$ = m Cp_{liq} (153.5135 – 25)
= 166.1485 x 54.3247 x (153.5135 – 25)
= 1159958.6638 kJ

$Q_{metanol}\,2$ = m Hv
= 166.1485 x 27.0121 x 1000
= 4488028.024 kJ

$Q_{metanol}\,3$ = m Cp_{gas} (250 – 153.5135)
= 166.1485 x 46.9687 x (365-153.5135)
= 1650253.4504 kJ

$Q_{metanol}$ = $Q_{metanol}\,1$ + $Q_{metanol}\,2$ + $Q_{metanol}\,3$
= 7298240.1385 kJ

untuk H_2O



$Q_{H2O}\,1 = m\ Cp_{liq}\ (198.9659 - 25)$
$= 333.9415 \times 77.0678 \times (198.9659 - 25)$
$= 4478087.8148$ kJ

$Q_{H2O}\,2 = m\ Hv$
$= 333.9415 \times 34.3032 \times 1000$
$= 11455249.8092$ kJ

$Q_{H2O}\,3 = m\ Cp_{gas}\ (250 - 198.9659)$
$= 333.9415 \times 35.9348 \times (250 - 198.9659)$
$= 1992018.1990$ kJ

$Q_{H2O} = Q_{H2O}\,1 + Q_{H2O}\,2 + Q_{H2O}\,3$
$= 17925355.8229$ kJ

untuk DME

$Q = m\ Cp_{gas}\ (365 - 25)$
$= 332.2972 \times 49.1304 \times (365 - 25)$
$= 5550804.081$ kJ

Q masuk = Q methanol + Q H_2O + Q DME
$= 30774400.0421$ kJ

Menghitung enthalpy keluar cooler

$Q_{metanol} = m\ Cp_{liq}\ (70 - 25)$
$= 166.1485 \times 52.6447 \times (70 - 25)$
$= 393607.7072$ kJ

$Q_{H2O} = m\ Cp_{liq}\ (70 - 25)$
$= 333.9415 \times 75.6189 \times (70 - 25)$
$= 1136353.0002$ kJ

$Q_{DME} = m\ Cp_{gas}\ (70 - 25)$
$= 332.2972 \times 49.1304 \times (70 - 25)$
$= 734665.2460$ kJ

Q keluar = Q methanol + Q H_2O + Q DME
= 2264625.9534 kJ

Menghitung Q serap dan Q hilang

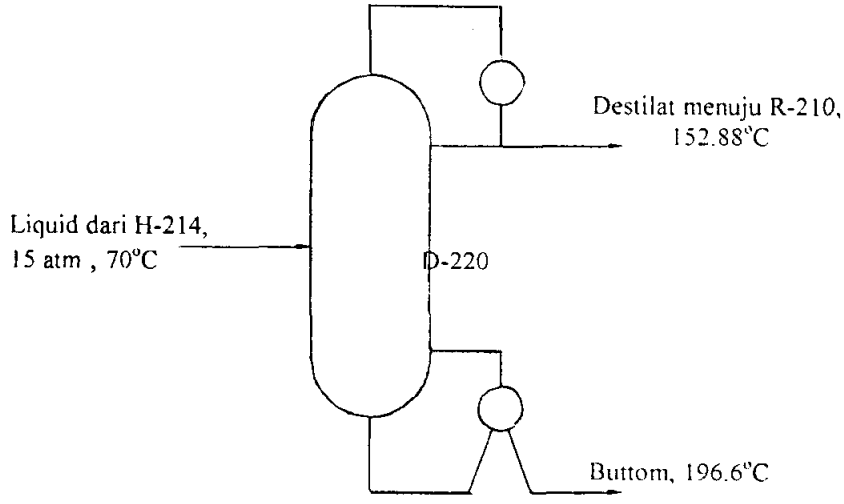
Q masuk = Q keluar + Q serap + Q hilang
Q serap + (5% Q serap) = Q keluar - Q masuk
1.05 Q serap = 28509774.0890
Q serap = 27152165.7990 kJ
Q hilang = 5% Q serap = 1357608.2900 kJ

Jumlah air pendingin :
asumsi : air pendingin masuk pada 30^{0}C dan keluar pada 45^{0}C
Cp air pendingin = 4.1815 kJ / kg K (Geankoplis, 1997)
Q = m Cp ΔT
27152165.7990 = m 4.1815 (45 - 30)
m = 432893.5517 kg

Ringkasan Neraca panas cooler E-213

Masuk (kJ)		**Keluar (kJ)**	
~ Gas dari R-210, pada 365.0894^{0}C		**~ Liquid menuju H-214, pada 70^{0}C**	
Methanol	7298240.1385	Methanol	393607.7072
H_2O	17925355.8229	H_2O	1136353.0002
DME	5550804.0810		1529960.7074
		~ Gas menuju H-214, pada 70^{0}C	
		DME	734665.2460
			2264625.9534
		~ Q serap	27152165.7990
		~ Q hilang	1357608.2900
Total	30774400.0424	Total	30774400.0424

XI. Menara Destilasi (D-220)



Menghitung enthalpy masuk menara destilasi

$Q_{metanol}$ = m Cp_{liq} (70 – 25)
= 166.1485 x 52.6447 x (70 – 25)
= 393607.7072 kJ

Q_{H2O} = m Cp_{liq} (70 – 25)
= 333.9415 x 75.6189 x (70 – 25)
= 1136353.0002 kJ

Q masuk = Q methanol + Q H_2O
= 1529960.7074 kJ

Kondisi pada feed

~ mencari T dew

P = 15 atm

Trial T dew = 173,4 ^{O}C

Komponen	Kmol	Y_F	Psat, mmHg	K = Psat / P	$X_F = Y_F / K$
Metanol	166.1485	0.3322	24550.8080	1.3204	0.2516
H_20	333.9415	0.6678	10539.4460	0.8925	0.7482
				Total	0.9998

→ trial cocok

~ mencari T bubble

P = 15 atm

Trial T bubble = 173 ^{O}C ~~0.3702 0.4459~~

Komponen	Kmol	X_F	Psat, mmHg	K = Psat / P	$Y_F = X_F . K$
Metanol	166.1485	0.3322	24280.6880	1,3144	0.4366
H_20	333.9415	0.6678	10485.7181	0.8439	0.5636
				Total	1.0002

→ trial cocok

jadi Feed yang berupa Subcooled Liquid

Kondisi pada puncak

~ mencari T dew

P = 15 atm

Trial T dew = 152.88^{O}C

Komponen	Kmol	Yd	Psat, mmHg	K = Psat / P	Xd = Yd/K
Metanol	162.7920	0.99	22011.3482	0.9987	0.9913
H_20	1.6444	0.01	9882.0721	1.1236	0.0089
				Total	1.0002

→ trial cocok

~ mencari T buble

P = 15 atm

Trial T dew = 152.88^{O}C

Komponen	Kmol	Xd	Psat, mmHg	K = Psat / P	Yd=Xd.K
Metanol	162.7920	0.99	22011.3482	0.9987	0.9887
H_20	1.6444	0.01	9882.0721	1.1236	0.0112
				Total	0.9999

→ trial cocok

Kondisi pada buttom

~ mencari T dew

P = 15 atm

Trial T dew = 196.86^{O}C

Komponen	Kmol	Yd	Psat, mmHg	K = Psat / P	Xd =Yd / K
Metanol	3.357	0.01	28698.8354	2.6043	0.0038
H_20	332.2972	0.99	11059.7523	1.0036	0.9854
				Total	0.9992

→ trial cocok

~ mencari T buble

P = 15 atm

Trial T buble = 196.6^{O}C

Komponen	Kmol	Xd	Psat, mmHg	K = Psat / P	Yd = Xd .K
Metanol	3.357	0.01	28468.1288	2.5833	0.02583
H_20	332.2972	0.99	10843.2374	0.9840	0.97412
				Total	0.99995

→ trial cocok

Mencari R min dan R op

Data keetimbangan methanol air (Perry 3ed)

X	0	0.02	0.06	0.1	0.15	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Y	0	0.134	0.304	0.418	0.517	0.579	0.665	0.729	0.825	0.87	0.915	0.958	0.978	1

~ menentukan q line

* $H_F = Cp\ (T_F - T_{Ref})$

$H_{F\ methanol}$ = 52.6447 (70-25)

= 2369.0115 J/mol

$H_{F\ H2O}$ = 75.6189 (70-25)

= 3402.8505 J/mol

$H_F = \Sigma X_{Fi}\ H_{F\,1}$ = 2544.3506 J/mol

* $H_L = Cp\ (T_L - T_{Ref})$

$H_{L\ methanol}$ = 56.4732 (173-25)

= 8369.3282 J/mol

$H_{L\ H2O}$ = 77.0678 (173-25)

= 11421.4476 J/mol

$H_L = \Sigma X_{Fi}\ H_{L\,1}$ = 8886.9677 J/mol

* $H_v = R.T_c.T_{b,r}\left(\frac{3.978\,T_{b,r} - 3.938 + 1.555 \ln P_c}{1.07 - T_{b,r}}\right)$

methanol

T_c = 512.6 K

P_c = 80.97 bar = 79.912 atm

R = 1.987 kal/ mol K

T_b = 173.4 °C = 446.4 K

$T_{b,r} = \frac{T_b}{T_c} = \frac{446.4}{512.6} = 0.8709$

Maka $H_{v\ methanol}$ = 28240.8734 kal/mol
= 118611.6683 J/mol

H_2O

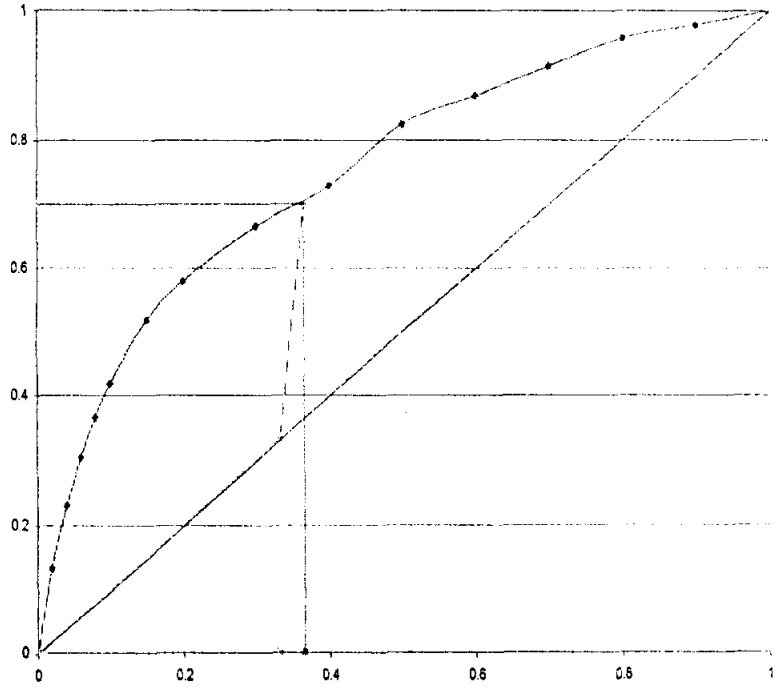
T_c = 647.1 K
P_c = 220.55 bar = 217.666 atm
R = 1.987 kal/ mol K
T_b = 173.4 °C = 446.4 K

$$T_{b,r} = \frac{T_b}{T_c} = \frac{446.4}{647.1} = 0.6898$$

Maka $H_{v\ H2O}$ = 16471.5185 kal/mol
= 70314.3771 J/mol
$H_v = \Sigma X_{Fi} H_{vi}$ = 110420.3766 J/mol

$$\rightarrow q = \frac{H_V - H_F}{H_V - H_L} = 1.1624$$

$$\rightarrow slope = \frac{q}{1-q} = 7.1576$$



Xd = 0.99
Xw = 0.01
Xf = 0.3322

Dari kurva kesetimbangan diperoleh:

x' = 0.365

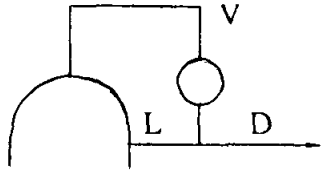
y' = 0.7

maka $\frac{R\min}{R\min+1} = \frac{Xd - y'}{Xd - x'}$

Rmin = 0.8657

Rop = 1.2 Rmin

= 1.0388



D = 164,4364 kmol

L = R op x D

= 170,8165 kmol, terdiri atas : methanol = 169,1084 kmol

H_2O = 1,7081 kmol

V = D + L

= 335,2529 kmol terdiri atas : methanol = 331,9004 kmol

H_2O = 3,3525 kmol

Menghitung enthalpy destilat

$Q_{metanol}$ = m Cp_{liq} (152.88 – 25)

= 162.792 x 53.9795 x (152.88 – 25)

= 1123736.6461 kJ

Q_{H2O} = m Cp_{liq} (152.88 – 25)

= 1.6444 x 74.2597 x (152.88 – 25)

= 15615.7658 kJ

$Q_{destilat} = Q_{H2O} + Q_{methanol}$ = 1139352.4119 kJ

Menghitung enthalpy buttom

$Q_{metanol}$ = m Cp_{liq} (196.6 – 25)

= 3.357 x 56.3589 x (196.6 – 25)

= 32466.1756 kJ

Q_{H2O} = m Cp_{liq} (196.6 – 25)
= 332.2972 x 76.5197 x (196.6 – 25)
= 4363321.6006 kJ
$Q_{buttom} = Q_{H2O} + Q_{methanol}$ = 4395787.7762 kJ

Menghitung beban kondenser

~ Hv

$Q_{metanol}$ = m Cp_{liq} (152.88 – 25) + m Hv
= 331.9004 x 53.9795 x (152.88 – 25) + 331.9004 x 21860.1846
= 8087951.728 kJ

Q_{H2O} = m Cp_{liq} (152.88 – 25) + m Hv
= 3.3525 x 74.2597 x (152.88 – 25) + 3.3525 x 14484.0849
= 68111.5737 kJ

Hv = $Q_{H2O} + Q_{methanol}$ = 8156063.302 kJ

~ Hl

$Q_{metanol}$ = m Cp_{liq} (152.88 – 25)
= 331.9004 x 53.9795 x (152.88 – 25)
= 1941040.514 kJ

Q_{H2O} = m Cp_{liq} (152.88 – 25)
= 3.3525 x 74.2597 x (152.88 – 25)
= 26972.4273 kJ

Hl = $Q_{H2O} + Q_{methanol}$ = 1968017.941 kJ

~ Beban condenser (Qc)

Qc = Hv – Hl
= 6188050.361 kJ

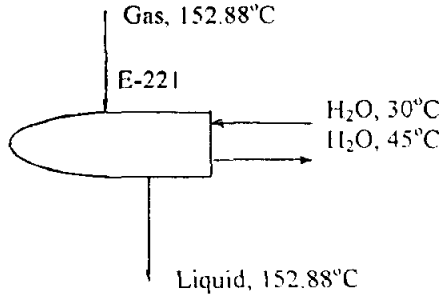
Menghitung beban reboiler (Qr)dan Q hilang

Q masuk + Qr = Q destilat + Q buttom + Q c + Q hilang
Qr - Q hilang = Q destilat + Q buttom + Q c - Q masuk
Qr – (5 % Qr) = 10193229.84
Qr = 10729715.62 kJ
Q hilang = 5% Qr = 536485.7811 kJ

Ringkasan Neraca panas Menara Destilasi D-220

Masuk (kg)		Keluar (kg)	
~ Liquid dari H-214, pada 152.88^{0}C:		**~ Destilat, pada 152.88^{0}C :**	
Methanol	393607.7072	Methanol	1123736.6461
H_2O	1136353.0002	H_2O	15615.7658
	1529960.7074		1139352.4119
		~ Buttom, pada 196.6^{0}C	
~ Beban reboiler		Methanol	32466.1756
Qr	10729715.6226	H_2O	4363321.6006
			4395787.7762
		~ Beban condenser	
		Qc	6188050.3609
		~ Q hilang	536485.7811
Total	12259676.3300	Total	12259676.3300

XII. Kondenser (E-221)



Menghitung enthalpy masuk kondenser

$Q_{metanol}$ = m Cp_{liq} (152.88 – 25) + m Hv
= 331.9004 x 53.9795 x (152.88 – 25) + 331.9004 x 21860.1846
= 8087951.728 kJ

Q_{H2O} = m Cp_{liq} (152.88 – 25) + m Hv
= 3.3525 x 74.2597 x (152.88 – 25) + 3.3525 x 14484.0849
= 68111.5737 kJ

Q masuk = Q_{H2O} + $Q_{methanol}$ = 8156063.302 kJ

Menghitung enthalpy keluar kondenser

$Q_{metanol}$ = m Cp_{liq} (152.88 – 25)
= 331.9004 x 53.9795 x (152.88 – 25)
= 1941040.514 kJ

Q_{H2O} = m Cp_{liq} (152.88 – 25)
= 3.3525 x 74.2597 x (152.88 – 25)
= 26972.4273 kJ

Q keluar = Q_{H2O} + $Q_{methanol}$ = 1968017.941 kJ

Menghitung Q serap

Dari perhitungan diatas diperoleh :
Beban condenser (Qc) = 6188050.361 kJ

Q serap = Qc
= 6188050.361 kJ

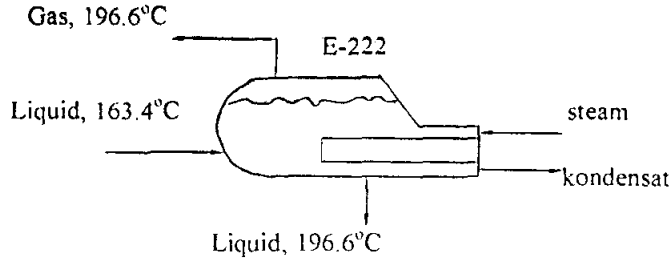
Jumlah air pendingin :
asumsi : air pendingin masuk pada 30^0C dan keluar pada 45^0C
Cp air pendingin = 4.1815 kJ / kg K (Geankoplis, 1997)

$$Q = m\ Cp\ \Delta T$$
$$6188050.361 = m\ 4.1815\ (45 - 30)$$
$$m = 98657.5848\ kg$$

Ringkasan Neraca panas condenser E-221

Masuk (kJ)		Keluar (kJ)	
~ Gas, pada 152.88°C		**~ Liq, pada 152.88°C**	
Methanol	8087951.7283	Methanol	1941040.5140
H_2O	68111.5737	H_2O	26972.4273
			1968012.9413.
		~ Q serap	6188050.3610
Total	8156063.3020		21129648.5363

XIII. Reboiler (E-222)



Menentukan suhu masuk reboiler

Jumlah yang masuk:

Methanol = 166.1645 + 169.1084 = 335.2729

H_2O = 33.9415 + 1.7081 = 35.6496

Trial T = 163.4°C

Komponen	Kmol	Xd	Psat	K = Psat / P	Yd = Xd .K
Metanol	335.2729	0.8991	23361.2723	1.0599	0.9530
H_20	35.6496	0.1009	10323.1145	0.4684	0.0473
				Total	1.0003

→ trial cocok

Dari perhitungan diatas diperoleh

beban reboiler (Q r) = 10729715.6226 kJ

Jumlah Steam yang dibutuhkan :

Asumsi: steam yang digunakan adalah steam superheated pada 45 bar, 400°C

data (Geankoplis, 1997) : $H_{sat\ vapor}$ = 2513.9251 kJ/kg

H_{liq} = 1032.9435 kJ/kg

$H_{sup\ vap}$ = 2878.7895 kJ/kg

maka $\lambda = H_{sat\ vapor} - H_{liq}$

= 1480.9816 kJ/kg

$$Q = m\,\lambda + m.\,(H_{sup\ vapor} - H_{sat\ vapor})$$

$$10729715.6226 = m\ 1480.9816 + m\,(2878.7895 - 2513.9435)$$

$$10729715.6226 = m\ 1845.8276$$

$$m = 5812.9565 \text{ kg}$$

H steam = $m\ H_{sup\ vapor}$

= 5812.9565 x 2878.7895 = 16734278.25 kJ

H kondensat = $m\ H_{liq}$

= 5812.9565 x 1032.9435 = 6004455.6320 kJ

Ringkasan Neraca panas reboiler E-222

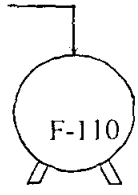
Masuk (kJ)		Keluar (kJ)	
~ **Steam, pada 400°C**	16734278.2550	~ **Beban reboiler** Qr	10729715.6226
		~ **Kondensat, pada 256.6912°C**	6004455.6324
Total	16734278.2550	Total	16734278.2550

APPENDIX C

PERHITUNGAN SPESIFIKASI PERALATAN

APPENDIX C
PERHITUNGAN SPESIFIKASI PERALATAN

1. STORAGE TANK (F-110)



Fungsi : menyimpan gas alam

Type : bola

Perhitungan :

Direncanakan: T penyimpanan = 30°C = 303 K

P penyimpanan = 20 atm

$BM_{camp} = \Sigma X_i.BMi$

=(0,7101.16)+(0,1309.30)+(0,0791.44)+(0,0377.58)+(0,0229.72)+(0,0193.86)

= 24,2642 lb/lbmol

$$\rho_{camp} = \frac{BM_{camp}}{V_o}.\frac{P}{P_o}.\frac{T_o}{T}$$

$$= \frac{24,2642}{359}.\frac{20}{1}.\frac{273}{303} = 1,2179 \text{ lb/ft}^3$$

Kebutuhan gas alam = 23919,0818 kg/hari = 52732,0077 lb/hari

= 43297,4856 ft^3/hari

Waktu penyimpanan = 15 hari

Maka, volume gas = 649462,284 ft^3 = 18390.8235 m^3

Jika digunakan 2 tangki, maka volume masing-masing tangki = 9196 m^3

$$9195.4117 = \frac{4}{3}.\pi.\left(\frac{1}{2}.D\right)^3$$

$$D^3 = 17570.8505$$

$$D = 26 \text{ m}$$

$$r = 13 \text{ m}$$

Tebal dinding

$$t_{shell} = \frac{P.r}{1{,}8.f - 0{,}2.P} + c \qquad \text{(Ulrich, p.250)}$$

dimana:

$f_{allow} = f_u.f_m.f_s.f_a.f_r$

f_u = 75000 psia (untuk SA-240 grade S tipe 304)

f_m = 0,92 (untuk bahan kualitas C → *structure steel*)

f_a = 1,0 (tidak dikenakan *radiograph*)

f_r = 1,0 (tidak dikenakan *stress relief*)

$f_{allow} = f_u.f_m.f_s.f_a.f_r$ = 17250 psi

Maka,

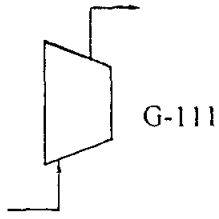
$$t_{shell} = \frac{(20.14{,}696).(13.39{,}37)}{1{,}8.17250 - 0{,}2.(20.14{,}696)} + 0{,}1$$

$$= 2.85\text{"} \approx 3\text{"}$$

1. Spesifikasi Storage Tank (F-110)

Fungsi	: menyimpan gas alam
Type	: Bola
Dasar pemilihan	: tekanan penyimpanan tinggi
Kapasitas	: 9196 m^3
Diameter	: 26 m
Suhu penyimpanan	: 30°C
Tekanan penyimpanan	: 20 atm
Tebal dinding	: 3"
Bahan konstruksi	: Carbon stell
Jumlah	: 2 buah

2. KOMPRESOR (G-111)



Fungsi : memberi tekanan pada gas alam

Type : Reciprocal

Gas masuk pada kompresor pada suhu 30°C.

ratio compression $= \frac{P_2}{P_1} = \frac{40}{20} = 2$

$\gamma \approx 1.31$

$$-Ws = \frac{\gamma}{\gamma - 1}\frac{R.T_1}{BM}\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

$$= \frac{1.31}{1.31-1}\frac{8314.3.(273+30)}{24.2642}\left[\left(\frac{40}{2}\right)^{\frac{1.31-1}{1.31}} - 1\right]$$

$= 78204.6556$ J/kg

gas alam yang disuplay = 23919.0818 kg/hari ≈ 23920 kg/hari

= 0.2768 kg/sec

Jika digunakan kompresor dengan efisiensi 80 %,

Maka $Hp = \frac{-Ws.m}{\eta 1000} = \frac{(78204.6556\ J/kg)\ (0.2768\ kg/sec)}{0.8\ 1000}$

= 27.0588 kJ/sec = 37 Hp

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

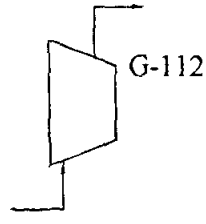
$$\frac{T_2}{303} = (2)^{\frac{1.31-1}{1.31}}$$

$T_2 = 356.9984$ K $= 83.9984\ ^0$C

2. Spesifikasi Kompresor (G-111)

Fungsi	: memberi tekanan pada gas alam
Type	: Reciprocal
Dasar pemilihan	: Ratio kompresi yang dibutuhkan tinggi
Kapasitas	: 23920 kg/hari
Suhu operasi	: 30°C
Ratio kompresi	: 2
Power	: 37 Hp
Efisiensi	: 80%
Bahan konstruksi	: Carbon Stell
Jumlah	: 1 buah

3. KOMPRESOR (G-112)



Fungsi : memberi tekanan pada udara

Type : Reciprocal

Udara masuk pada kompresor pada suhu 33°C.

$$\text{ratio compression} = \frac{P_2}{P_1} = \frac{3.42}{1} = 3.42$$

$\gamma \approx 1.4$

$$-Ws = \frac{\gamma}{\gamma - 1}\frac{R.T_1}{BM}\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

$$= \frac{1.4}{1.4-1}\frac{8314,3.(273+33)}{28.84}\left[(3.42)^{\frac{1.4-1}{1.4}} - 1\right]$$

$$= 128698.0388 \text{ J/kg}$$

udara yang disuplay = 38066.6667 kg/hari ≈ 38067 kg/hari

= 0.4406 kg/sec

Jika digunakan kompresor dengan efisiensi 80 %,

$$\text{Maka } Hp = \frac{-Ws.m}{\eta 1000} = \frac{(128698.0388 \text{ J/kg})(0.4406 \text{kg/sec})}{0.8\ 1000}$$

= 70.8804 kJ/sec = 95 Hp

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

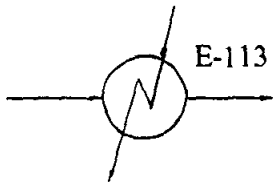
$$\frac{T_2}{308} = (3.42)^{\frac{1.4-1}{1.4}}$$

T_2 = 430.5404 K = 157.5404 ^{0}C

3. Spesifikasi Kompresor (G-112)

Fungsi	: memberi tekanan pada udara
Type	: Reciprocal
Dasar pemilihan	: Ratio kompresi yang dibutuhkan tinggi
Kapasitas	: 38067 kg/hari
Suhu operasi	: 35^{o}C
Ratio kompresi	: 3,42
Power	: 95 Hp
Efisiensi	: 80%
Bahan Konstruksi	: Carbon Stell
Jumlah	: 3 buah

4. COOLER (E-113)

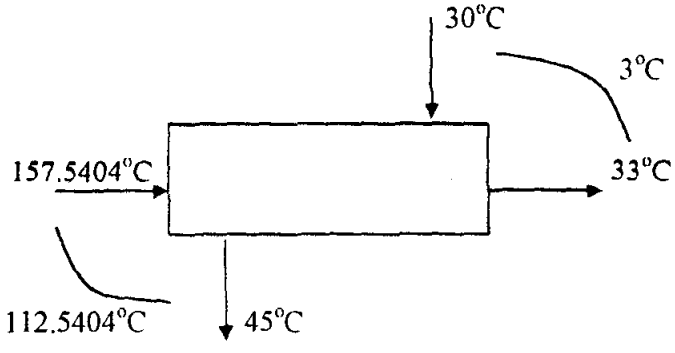


Fungsi : untuk menurunkan suhu udara sebelum masuk kompresor

Type : Shell and Tube Heat Exchanger (STHE)

Dari perhitungan sebelumnya didapat:

- oksigen	=	15267,4517 kg/hari	= 1402,4427	lb/jam
- nitrogen	=	329297,5982 kg/hari	= 30248,7285	lb/jam
		Total	= 31651,1712	lb/jam
Q	=	5960476.652 kJ/hari	= 233064.1834	Btu/jam
Massa air	=	95029.3221 kg/hari	= 8877.3225	lb/jam



1. $\Delta T_{LMTD} = \dfrac{112.5404 - 3}{\ln\left(\dfrac{112.5404}{3}\right)} = 34,5359\ ^{\circ}C = 94,1646\ ^{\circ}F$

2. $T_c = \dfrac{157.5404 + 33}{2} = 96.2702\ ^{\circ}C = 205.2864\ ^{\circ}F$

$t_c = \dfrac{30 + 45}{2} = 37,5^{\circ}C = 67,5^{\circ}F$

3. Asumsi :

U_D = 30 Btu/(hr).(ft^2).(^oF)

$Q = U_D.A.\Delta T$

$$A = \frac{Q}{U_D.(T_c - t_c)}$$

$$= \frac{233064.1834}{30.(205{,}2864 - 67{,}5)}$$

$= 56.3830\ ft^2$

Dipilih ukuran pipa:

1½" OD, 16 BWG, 1⅞" triangular pitch, L = 8 ft

$$N_t = \frac{A}{a''.L}$$

$$= \frac{56{,}3830}{0{,}3925.8}$$

$= 17.9564$

Dari table 9, Kern diperoleh:

ID = 12"

N_t = 18

Passes = 1

U_D koreksi

$A = Nt.a''.L$

$= 18.0{,}3925.8$

$= 56.5\ ft^2$

$Q = U_D.A.\Delta T$

$$U_D = \frac{233064{,}1834}{56{,}5.(205{,}2864 - 67{,}5)}$$

$= 29{,}9273 \approx 30$ Btu/(hr).(ft^2).(^oF)

Bagian shell: udara	**Bagian tube: air pendingin**
4. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ $= 1\frac{7}{8} - 1\frac{1}{2} = 0{,}375$ $B = 5"$ $= 12.\frac{0{,}375.5}{144.1\frac{7}{8}}$ $= 0{,}0833\ ft^2$	4'. $a'_t = 1{,}47\ ft^2$ [table 10] $a_t = \frac{N_t.a'_t}{144.n} = \frac{18.1{,}47}{144.1}$ $= 0{,}1838\ ft^2$
5. $G_s = \frac{w}{a_s} = \frac{31651{,}1712}{0{,}0833}$ $= 379793.1003\ lb/(hr).(ft^2)$	5'. $G_t = \frac{w}{a_t} = \frac{8877{,}3225}{0{,}1838}$ $= 48311.9592\ lb/(hr).(ft^2)$ $v = \frac{G_t}{3600.\rho} = \frac{48311.9592}{3600.62{,}4}$ $= 2.151\ fps$
6. Pada $T_c = 205.2864\ ^oF$ $\mu_{udara} = 0{,}023$ [fig.15] $= 0{,}023\ cp \times 2{,}42$ $= 0{,}0557\ lb/(ft).(hr)$ $De = \frac{1{,}08}{12} = 0{,}09\ ft$ [fig 28] $Re_s = \frac{D_e.G_s}{\mu} = \frac{0{,}09.379793{,}1003}{0{,}0557}$ $= 613669.2823$	6'. Pada $t_c = 67{,}5^oF$ $\mu_{air} = 1\ cp \times 2{,}42$ $= 2{,}42\ lb/(ft).(hr)$ $D = \frac{1{,}37}{12} = 0{,}1142\ ft$ [table 10] $Re_t = \frac{D.G_t}{\mu} = \frac{48311.9592.0{,}1142}{2{,}42}$ $= 2279.8453$
7. $j_H = 500$ [fig.28] $k_{udara} = 0{,}01895\ Btu/(hr).(ft^2).(^oF/ft)$ [table 5] $c_{udara} = 0{,}25\ Btu/(lb).(^oF)$ [fig 3]	8'. $h_i = 450\ Btu/(hr).(ft^2).(^oF)$ [fig.25] 9'. $h_{io} = h_i.\frac{ID}{OD}$ $= 450.\frac{1{,}37}{1{,}5}$ $= 411\ Btu/(hr).(ft^2).(^oF)$
8'. $h_o = j_H.\frac{k}{D}.\left(\frac{c.\mu}{k}\right)^{1/3}$ $= 500.\frac{0{,}01895}{0{,}09}.\left(\frac{0{,}25.0{,}0557}{0{,}01895}\right)^{1/3}$ $= 95.0084\ Btu/(hr).(ft^2).(^oF)$	

10. $U_C = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{411.95{,}0084}{411+95{,}0084}$

$= 77.1696$ Btu/(hr).(ft^2).(^{o}F)

$R_D = \frac{U_C-U_D}{U_C.U_D} = \frac{77{,}1696-30}{77{,}1696.30}$

$= 0{,}0204$ (hr).(ft^2).(^{o}F)/Btu > 0,003

Pressure Drop

Bagian Shell: udara	**Bagian Tube: air pendingin**
1. $Re_s = 613669.2823$ $f = 0{,}0009$ ft^2/in^2 [fig.29]	1`. $Re_t = 2279.8453$ $f = 0{,}0004$ ft^2/in^2 [fig.26]
2. Vc udara = $\Sigma X_i.Vc_i$ $= 85.882$ cm^3/mol $BM_{camp} = \Sigma X_i.BMi$ $= 28{,}84$ gr/gmol specific volume = $\frac{85.882}{28.82}$ $= 2.9779$ cm^3/gr $= 0.0477$ ft^3/lb $s = \frac{1}{0.0477\ 62.4} = 0.3358$ $N+1 = 12.\frac{L}{B} = 12.\frac{8}{5} = 19.2$ $D_s = \frac{12}{12} = 1\,ft$	2`. $\Delta P_t = \frac{f.G_t^2.L.n}{5{,}22.10^{10}.D.s.\varphi_t}$ $= \frac{0.0004.(48311{,}9592)^2.12.1}{5{,}22.10^{10}.0{,}1142.1.1}$ $= 0.0188$ psia $G_t = 48311.9592$ $\frac{V^2}{2.g'} = 0{,}02$ [fig.27] $\Delta P_r = \frac{4.n}{s}.\frac{V^2}{2.g'}$ $= \frac{4.1}{1}.0{,}02$ $= 0.08$ psia $\Delta P_T = \Delta P_t + \Delta P_r$ $= 0{,}0188 + 0{,}08$ $= 0{,}0988$ psia < 10 psia
3. $\Delta P_s = \frac{1}{2}.\frac{f.G_s^2.D_s.(N+1)}{5{,}22.10^{10}.D_e.s.\varphi_s}$ $= \frac{1}{2}.\frac{0{,}0009.(379793{,}1003)^2.1.19{,}2}{5{,}22.10^{10}.0{,}1233.0{,}3358.1}$ $= 0{,}5766$ psia < 2 psia	

Summary

95,0084	h outside	411
Uc	= 77,1696	
U_D	= 30	
R_d calcutated	= 0,0204	
R_d required	= 0,003	
0,5766	Calculated ΔP	0,0988
2	Allowable ΔP	10

4. Spesifikasi Cooler (E-113)

Fungsi : Untuk menurunkan suhu udara sebelum masuk kompresor

Type : Shell and Tube Heat Exchanger (STHE)

Dasar Pemilihan : Kapasitas besar, cocok untuk tekanan oprasi besar, luas perpindahan panas besar

Dimensi

~ Shell ID : 12"

Baffle space : 5"

~ Tube ID : 1,37"

OD : 1,5"

Jumlah : 18

Passes : 1

Pitch : 1 7/8"

Susunan : triangular

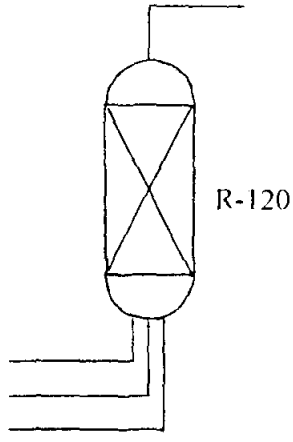
~ Panjang : 8 ft

~ Luas perpindahan panas : 56.5 ft^2

Bahan konstruksi : Carbon stell

Jumlah : 2 buah

5. REAKTOR I (R-120)



Fungsi : Untuk mereaksikan metana dengan oksigen

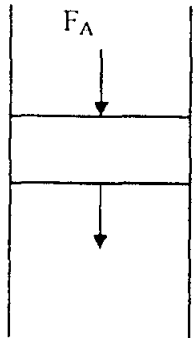
Type : Multi Turbular Fixed Bed Reactor

Dari perhitungan sebelumnya didapat:

- metana	= 15267,4517	kg/hari	= 1402,4427	lb/jam
- etana	= 34575,0672	kg/hari	= 3176,008	lb/jam
- propana	= 30650,6886	kg/hari	= 2815,5212	lb/jam
- i-butana	= 8586,9713	kg/hari	= 788,7849	lb/jam
- n-butana	= 10674,4936	kg/hari	= 980,5412	lb/jam
- i-pentana	= 7425,0244	kg/hari	= 682,0504	lb/jam
- n-pentana	= 7094,2065	kg/hari	= 651,6620	lb/jam
- heksana	= 14620,3141	kg/hari	= 1342,9977	lb/jam
- oksigen	= 15267,4517	kg/hari	= 1402,4427	lb/jam
- nitrogen	= 329297,5982	kg/hari	= 30248,6736	lb/jam
Total			= 43491,1792	lb/jam

neraca massa

Input – output – generation = 0



$$F_A(1-X_A)\,|_Z - F_A(1-X_A)\,|_{Z+\Delta Z} - W.\,r_A = 0$$

$$F_A(1-X_A)\,|_Z - F_A(1-X_A)\,|_{Z+\Delta Z} - \left(\frac{\pi}{4}D^2\,\Delta Z\,\rho\right).10^{-3}.(1-\varepsilon).r_A = 0$$

$$\frac{F_A(1-X_A)|_Z - F_A(1-X_A)|_{Z+\Delta Z}}{\Delta Z} = \frac{\pi}{4}D^2\rho.10^{-3}.(1-\varepsilon).r_A$$

untuk lim $\Delta Z \rightarrow 0$

$$F_A\frac{dx}{dz} = \frac{\pi}{4}D^2\rho.10^{-3}.(1-\varepsilon)r_A$$

$$dx = \frac{\frac{\pi}{4}D^2\rho.10^{-3}.(1-\varepsilon)r_A dz}{F_A} \qquad \ldots\ldots(1)$$

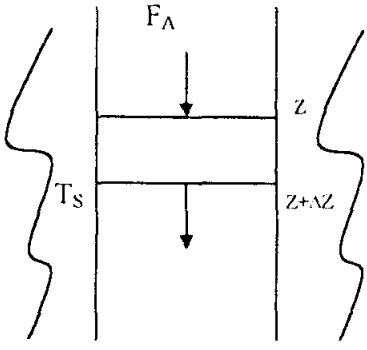
dimana z = panjang reactor, cm; x = konversi

F_A = laju molar CH_4, kmol/hari; D = diameter tube, cm

ρ = densitas katalis, gr/cm^3; ε = fraksi kosong

r_A = kecepatan reaksi, kmol methanol/kg katalis jam

neraca panas



Q masuk – Q keluar – Qserap – Qhilang = 0

$$\Sigma m_i.Hf_i\,|_Z - \Sigma m_i.Hf_i\,|_{Z+\Delta Z} - Qserap - 5\%.Qserap = 0$$

$$\Sigma m_i.Hf_i\,|_Z - \Sigma m_i.Hf_i\,|_{Z+\Delta Z} - 1.05\,U_D\,\pi D\,\Delta Z\,(T-T_S) = 0$$

$$\frac{\Sigma m_i Hf_i|_Z - \Sigma m_i Hf_i|_{Z+\Delta Z}}{\Delta z} = 1.05\,U_D\,\pi\,D\,(T-Ts)$$

untuk lim $\Delta Z \rightarrow 0$

$$\frac{d(\Sigma m_i Hf_i)}{dz} = 1.05\,U_D\pi\,D(T-T_S) \qquad \ldots\ldots(2)$$

dimana $\dfrac{d(\Sigma m_i Hf_i)}{dz} = \Sigma m_i\dfrac{dHf_i}{dz} + \Sigma Hf_i\dfrac{dm_i}{dz}$

$\rightarrow$ $\Sigma m_i\dfrac{dHf_i}{dz} = \Sigma m_i\,Cp\dfrac{dT}{dz}$

dengan komponen yang masuk reaktor terdiri atas

- ~ CH_4 = $F_A (1 - X_A)$
- ~ O_2 = $F_B - 0.5\ F_A\ X_A$
- ~ Methanol = $F_C + F_A\ X_A$
- ~ N_2 = 11760.6285 kmol
- ~ etana = 1152.5022 kmol
- ~ propana = 696.6066 kmol
- ~ i-butana = 148.0512 kmol
- ~ n-butana = 184.0430 kmol
- ~ i-pentana = 103.1253 kmol
- ~ n-pentana = 98.5306 kmol
- ~ heksana = 170.0037 kmol

maka

$$\Sigma m_i \frac{dHf_i}{dz} = \Sigma m_i\, Cp \frac{dT}{dz}$$

$$= [\{F_A(1-X_A)(1.702+9.0810^{-3}T-2.16410^{-6}T^2)\}+\{(F_B-0.5F_AX_A)(3.639+0.50610^{-3}T-\frac{0.22710^5}{T^2})\}+$$

$$\{(F_C+F_AX_A)(2.211+12.21610^{-3}T-3.4510^{-6}T^2)\}+\{11760.6285(3.28+0.59310^{-3}T-\frac{0.0410^5}{T^2})\}+$$

$$\{1152.5022(1.131+19.22510^{-3}T-5.56110^{-6}T^2)\}+\{696.6066(1.213+28.78510^{-3}T-8.82410^{-6}T^2)\}+$$

$$\{148.0512(1.677+37.85310^{-3}T-11.94510^{-6}T^2)\}+\{184.043(1.935+36.91510^{-3}T-11.40210^{-6}T^2)\}+$$

$$\{103.1253(2.381+46.47310^{-3}T-14.75710^{-6}T^2)\}+\{98.5306(2.464+45.35110^{-3}T-14.11110^{-6}T^2)\}+$$

$$\{170.0037(3.025+53.72210^{-3}T-16.79110^{-6}T^2)\}]x8.314\frac{dT}{dz}$$

$$=[\{F_A(1-X_A)(1.702+9.0810^{-3}T-2.16410^{-6}T^2)\}+\{(F_B-0.5F_AX_A)(3.639+0.50610^{-3}T-\frac{0.22710^5}{T^2})\}+$$

$$\{(F_C+F_AX_A)(2.211+12.21610^{-3}T-3.4510^{-6}T^2)\}+\{42330.3123+79.9744T-0.0222T^2-\frac{470.42510^5}{T^2})\}]$$

$$x\,8.314\frac{dT}{dz} \quad \text{.....(3)}$$

$$\rightarrow \Sigma Hf_i \frac{dm_i}{dz} = F_A\, \Delta H_R \frac{dx}{dz} \quad \text{.....(4)}$$

dimana

$$\Delta H_R = \Delta H_{298} + \int_{298}^{T} Cp\,dt$$

$$= (-201250 - (-74840)) + 8.314\{2.\left\{2.211(T-298) + \frac{12.21610^{-3}}{2}(T^2-298^2) - \frac{3.4510^{-6}}{3}(T^3-298^3)\right\} -$$

$$2.\left\{1.702(T-298) + \frac{9.08110^{-3}}{2}(T^2-298^2) - \frac{2.16410^{-6}}{3}(T^3-298^3)\right\} - \{3.639(T-298) + \frac{0.50610^{-3}}{2}(T^2-298^2)$$

$$- 0.22710^{5}(\frac{1}{T} - \frac{1}{298})\}\}$$

$$= -126410 + \left[-21.791(T-298) + 0.02396(T^2-298^2) - 7.127910^{-6}(T^3-298^3) - 1.887310^{5}(\frac{1}{T} - \frac{1}{298})\right] \quad \text{.....(5)}$$

~ persamaan (5) disubstitusikan ke persamaan (4)

~ persamaan (3) dan (4) disubstitusikan ke persamaan (2)

neraca panas pendingin

panas masuk = panas untuk menaikan suhu pendingin

$$\pi \text{ Do } U_D (T-T_S) = W \text{ Cp } \frac{dTs}{dz} \quad \text{.....(6)}$$

Menentukan kecepatan aliran pendingin

panas reaksi total = panas yang dibawa pendingin

F_A Nt ΔH_R x = W Cp ΔTs ; diharapkan $\Delta Ts \approx 15^0$

$$W = \frac{F_A.Nt.\Delta H_R.x}{15.Cp} \quad \text{.....(7)}$$

persamaan (7) disubstitusi ke persamaan (6), menjadi

$$\pi \text{ Do } U_D (T-T_S) = \frac{F_A.Nt.\Delta H_R.x}{15.} \frac{dTs}{dz}$$

$$dTs = \frac{\pi.Do.U_D(T-Ts).15.dz}{F_A.Nt.\Delta H_R.x} \quad \text{.....(8)}$$

Menentukan jumlah tube

~ digunakan pipa 2½"IPS, sech 40

ID = 2.469" = 6.2713 cm

OD = 2.88" = 7.3152 cm

~ $\mu_{campuran} = \Sigma x_i . \mu_l = 0{,}0307$ cp

~ agar transfer panas baik digunakan aliran turbulen

$$Re = \frac{D\,G}{\mu}$$

$$12100 = \frac{6.2713\,G}{0.0307\;3600\;10^{-5}}$$

$$G = 2.1324 \text{ kg/cm}^2 \text{ jam}$$

Area per tube = $\pi/4\ D^2 = 0.25 \times 3.14 \times 6.2713^2 = 30.8734 \text{ cm}^2$

Laju alir dalam tube = 2.1324 x 30.8734 = 65.8344 kg/jam

jumlah komponen masuk reactor = 479459.2674 kg/hari

= 19727.4695 kg/jam

$$\text{jumlah tube yang dibutuhkan} = \frac{19727.4695}{65.8344}$$

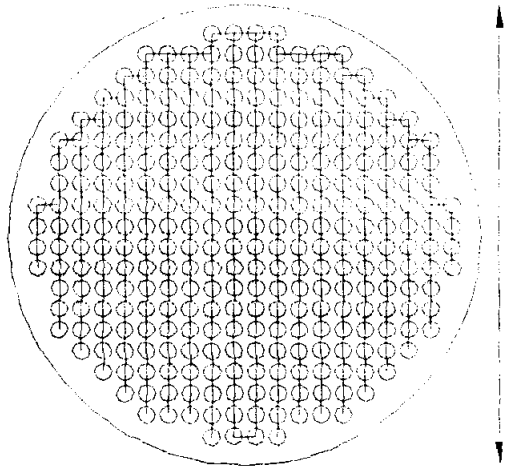
$$= 299.6527 \approx 300 \text{ tube}$$

Menentukan ID shell

~ susunan tube = square pitch

~ P_T = 1.25 OD = 9.144 cm

sehingga tube dapat disusun seperti :



ID shell = 198.14 cm

= 2 m

contoh perhitungan

Diketahui data:

~ $r_A = 58.3 - 0.1\ T$

~ $\Delta H_f\ CH_4 = -74.84$ kJ / mol
$\Delta H_f\ O_2 = 0$
$\Delta H_f\ CH_3OH = -201.25$ kJ / mol

$$\Delta H_{R\ 298} = \Delta H_f\ CH_3OH - \Delta H_f\ CH_4$$
$$= ((-201.25) - (-74.84)) \times 1000$$
$$= -126410\ J/mol$$

~ katalis yang digunakan terdiri dari:

$CuO = 62\ \% \rightarrow \rho_{CuO} = 8{,}92\ gr/cm^3$

$ZnO = 21\ \% \rightarrow \rho_{ZnO} = 5{,}42\ gr/cm^3$

$Al_2O_3 = 17\ \% \rightarrow \rho_{Al2O3} = 3{,}99\ gr/cm^3$

Maka $\rho = 0.62\ 8.92 + 0.21\ 5.42 + 0.17\ 3.99$
$= 7.3486\ gr/cm^3$

~ dimensi reaktor

untuk bagian tube digunakan pipa 2½"IPS, sech 40

ID = 2.469" = 6.2713 cm

OD = 2.88" = 7.3152 cm

untuk bagian shell, ID = 198.14 cm

~ asumsi $\varepsilon \approx 0.5$

~ pada Z = 0

$F_A = 954.2031$ kmol

$F_B = 477.1079$ kmol

$F_C = 0$

$T = 200^0C$

$Ts = 30^0C$

~ asumsi $U_D = 27$ btu/hr $ft^2\ ^0F = 3.679\ 10^{-3}$ kJ/hr cm^2 K

Penyelesaian

~ untuk Z = 10 cm ⟶ ΔZ = dz = 10 cm

mencari dx dari persamaan neraca massa (1)

$$dx = \frac{\frac{\pi}{4} 6.2713^2\ 7.348610^{-3}(58.3 - 0.17)(1-\varepsilon)10}{954.2301}$$

$$= \frac{\frac{\pi}{4} 6.2713^2\ 7.348610^{-3}(58.3 - 0.1473)(1-0.5)10}{954.2301}$$

$$= 0.01308$$

$$x = x + dx = 0.01308$$

~ mencari dT

dari persamaan (3)

$$\Sigma m_i \frac{dHf_i}{dz} = \Sigma m_i\, Cp \frac{dT}{dz}$$

$$= [\{954.2031(1-X_A)(1.702 + 9.0810^{-3}T - 2.16410^{-6}T^2)\} + \left\{(F_B - 0.5(954.2031)X_A)(3.639 + 0.50610^{-3}T - \frac{0.227\,10^5}{T^2})\right\} +$$

$$\{(F_C + F_A X_A)(2.211 + 12.21610^{-3}T - 3.4510^{-6}T^2)\} + \left\{42330.3123 + 79.9744T - 0.0222T^2 - \frac{470.425\,10^5}{T^2})\right\}]$$

$$x\ 8.314 \frac{dT}{dz}$$

$$= 509026{,}4836\ \frac{dT}{dz}$$

dari persamaan (5)

$$\Delta H_R = \Delta H_{298} + \int_{298}^{T} Cp\, dt$$

$$= -126410 + \left[-21.791(T - 298) + 0.02396(T^2 - 298^2) - 7.127910^{-6}(T^3 - 298^3) - 1.887310^5(\frac{1}{T} - \frac{1}{298})\right]$$

$$= -127321{,}9779$$

dari persamaan (4)

$$\Sigma Hf_i \frac{dm_i}{dz} = F_{A1}\, \Delta H_R \frac{dx}{dz}$$

$$= 954{,}2031 . -127321{,}9779\ \frac{0{,}02315}{10} = -281251{,}7252$$

mencari dT dari persamaan (2)

$$\frac{d(\Sigma m_i Hf_i)}{dz} = 1{,}05\, U_D \pi D(T - T_S)$$

$$\Sigma m_i \frac{dHf_i}{dz} + \Sigma Hf_i \frac{dm_i}{dz} = 1{,}05\ U_D \pi\ D\ (\ T - Ts\ )$$

$$\Sigma m_i Cp_i \frac{dT}{dz} + \Sigma Hf_i \frac{dm_i}{dz} = 1{,}05\ U_D \pi\ D\ (\ T - Ts\ )$$

$$509026{,}4836\ \frac{dT}{dz} + -281251{,}7252 = 1{,}05.3{,}6793.10^{-3}\ .\pi\ .6{,}2713\ (\ 473 - 303\ )$$

dT = 3,0884

T = T + dT = 476,0884 K

mencari dTs dari persamaan (8)

$$dTs = \frac{\pi.Do.U_D(T - Ts).\Delta Ts.dz}{F_A.Nt.\Delta H_R.x}$$

$$= \frac{\pi.7.3152.3.679310^{-3}(473 - 303).15.10}{954.2031.300.127321.9779.0.02315}$$

= 0.0929

Ts = Ts + dTs = 303.0929 K

Dengan cara yang sama didapat

Z, cm	X, %	T, K	Ts, K
0	0	473	303
10	1.3077	476.0884	303.0929
20	2.5173	479.0681	303.1839
30	3.7270	481.9446	303.2790
40	4.9366	484.7232	303.3784
50	6.1462	487.4085	303.4821
60	7.3559	490.0050	303.5902
70	8.5655	492.5167	303.7028
80	9.7751	494.9476	303.8200
90	10.9848	497.3012	303.9418
100	12.1944	499.5807	304.0685
110	13.4040	501.7893	304.2000
120	14.6137	503.9299	304.3365
130	15.8233	506.0054	304.4780
140	17.0329	508.0181	304.6248

150	18.2425	509.9707	304.7769
160	19.4522	511.8654	304.9344
170	20.6618	513.7044	305.0974
180	21.8714	515.4898	305.2661
190	23.0811	517.2235	305.4405
200	24.2907	518.9073	305.6208
210	25.5003	520.5432	305.8071
220	26.7100	522.1327	305.9996
230	27.9196	523.6774	306.1984
240	29.1292	525.1789	306.4035
250	30.3389	526.6387	306.6153
260	31.5485	528.0581	306.8337
270	32.7581	529.4384	307.0589
280	33.9678	530.7810	307.2911
290	35.1774	532.0871	307.5304
300	36.3870	533.3578	307.7769
310	37.5966	534.5942	308.0310
320	38.8063	535.7975	308.2925
330	40.0159	536.9686	308.5619
340	41.2255	538.1086	308.8391
350	42.4352	539.2184	309.1244
360	43.6448	540.2989	309.4179
370	44.8544	541.3511	309.7199
380	46.0641	542.3756	310.0304
390	47.2737	543.3735	310.3497
400	48.4833	544.3454	310.6780
410	49.6930	545.2921	311.0154
420	50.9026	546.2144	311.3621
430	52.1122	547.1129	311.7183
440	53.3219	547.9883	312.0843
450	54.5315	548.8414	312.4601
460	55.7411	549.6727	312.8461
470	56.9507	550.4828	313.2424
480	58.1604	551.2723	313.6493
490	59.3700	552.0419	314.0668
500	60.5796	552.7920	314.4954
510	61.7893	553.5232	314.9351
520	62.9989	554.2361	315.3862
530	64.2085	554.9310	315.8490
540	65.4182	555.6086	316.3237
550	66.6278	556.2693	316.8104
560	67.8374	556.9134	317.3095
570	69.0471	557.5416	317.8211
580	70.2567	558.1542	318.3456

Maka untuk x = 70% → z = 578 cm

T = 558,0256 K

Ts = 318,2355 K

Mengecek U_D

Bagian shell: air pendingin	**Bagian tube: gas**
*. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ = 0.72" B = 5" $= \frac{78,0079.5.0,72}{144\ \ 3,6}$ = 0,5417 ft^2 *.Massa air (w) = 29328,50585 kg/hari = 2694,0677 lb/jam $G_s = \frac{w}{a_s} = \frac{2694,0677}{0,5417}$ = 4973.3574 lb/(hr).(ft^2) *. Pada t_c = 67,5°F μ = 1 cp = 2,42 lb/ (ft).(hr) $De = \frac{4\left(P_T^2 - \frac{\pi}{4}do^2\right)}{\pi\, do}$ $= \frac{4\left(3.6^2 - \frac{\pi}{4}2.88^2\right)}{\pi\ 2.88} = 2.8525$ $Re_s = \frac{Gs\ De}{\mu} = \frac{4973.3574\ 2.8525}{2.42}$ = 5862.1909	*'. Re_t = 12100 *' j_H = 60 [fig.24] Pada T_c = 469.3312°F k_{metana} = 0,0420 k_{etana} = 0,0321 $k_{propana}$ = 0,0320 $k_{i\text{-}butana}$ = 0,0195 $k_{n\text{-}butana}$ = 0,0189 $k_{i\text{-}pentana}$ = 0,0265 $k_{n\text{-}pentana}$ = 0,0137 $k_{heksana}$ = 0,0207 $k_{oksigen}$ = 0,0311 $k_{nitrogen}$ = 0,0213 [table 5] $k_{campuran} = \Sigma\ x_i.\ k_i$ = 0,0289 Btu/(hr).(ft^2).(°F/ft) c_{metana} = 0,72 c_{etana} = 0,67 $c_{propana}$ = 0,95 $c_{i\text{-}butana}$ = 0,86 $c_{n\text{-}butana}$ = 0,84 $c_{i\text{-}pentana}$ = 0,79 $c_{n\text{-}pentana}$ = 0,76 $c_{heksana}$ = 0,74 $c_{oksigen}$ = 0,29

*. j_H = 40 [fig.28] Pada t_c = 67,5°F k_{air} = 0,347 Btu/(hr).(ft²).(°F/ft) [table 4] c_{air} = 1 Btu/(lb).(°F) [fig.2] $h_o = j_H \cdot \frac{k}{D_e} \cdot \left(\frac{c.\mu}{k}\right)^{1/3}$ $= 40 \frac{0.347}{2.8525} \left(\frac{1\,2.42}{0.347}\right)^{1/3}$ = 51.8480 Btu/(hr).(ft²).(°F)	$c_{nitrogen}$ = 0,34 [fig 3 & 4] $c_{campuran} = \Sigma x_i . c_i$ = 0,4201 Btu/(lb).(°F) *'. $h_i = j_H \cdot \frac{k}{D} \cdot \left(\frac{c.\mu}{k}\right)^{1/3}$ $= 60 \frac{0.0289}{2.88/12} \left(\frac{0.4201\,0.0307\,2.42}{0.0289}\right)^{1/3}$ = 74.1265 Btu/(hr).(ft²).(°F) *' $h_{io} = h_i \cdot \frac{ID}{OD} = 74.1265 \frac{2.469}{2.88}$ = 63.5481 Btu/(hr).(ft²).(°F)

$$U_c = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{63.5481\,51.8480}{63.5481+51.8480}$$

= 28.5524 Btu/(hr).(ft²).(°F)

Rd ≈ 0.003 (hr).(ft²).(°F)/Btu > 0.0015

$$U_D = \frac{1}{R_D + \frac{1}{Uc}} = \frac{1}{0.003 + \frac{1}{28.5524}}$$

= 26.3158 ≈ 27 asumsi U_D cocok 26.

Luas perpindahan panas = A = Nt.a".L

$$= 300.0{,}7533. \frac{577.8778}{2.54\,12} = 4285 \text{ ft}^2$$

Menghitung Pressure drop

$$\frac{\Delta P}{G'^2} \frac{\rho}{L} \frac{D}{1-\varepsilon} \frac{\varepsilon^3}{} = \frac{150}{N_{Re}} + 1.75$$

dimana G' = 2.1324 kg/cm² jam = 0.7677 kg m² sec

L = 420.4331 cm = 4.2043 m

D = 2.469" = 0.0627 m

N_{Re} = 12100

ε = 0.5

$BM_{camp} = \Sigma X_i.BMi = 27{,}8677$ lb/lbmol

Asumsi $\Delta P = 0.25$ atm $\rightarrow$ $P_2 = 40 - 0.25 = 39.75$ atm

$P_{avg} = (P_1+P_2)/2 = 39.875$ atm

$T_{avg} = (T_1+T_2)/2 = 515.96175$ K

$$\rho_{camp} = \frac{BM_{camp}}{V_o} \cdot \frac{P_{avg}}{P_o} \cdot \frac{T_o}{T_{avg}} = \frac{27.8677}{359} \cdot \frac{39.875}{1} \cdot \frac{273}{515.96175}$$

$= 1.6428$ lb/ft^3 $= 26.317$ kg/m^3

maka $$\frac{\Delta P}{G'^2} \frac{\rho}{L} \frac{D}{1-\varepsilon} \frac{\varepsilon^3}{} = \frac{150}{N_{Re}} + 1.75$$

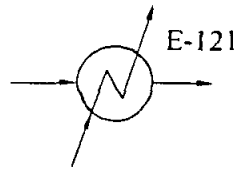
$$\frac{\Delta P}{0.7677^2} \frac{26.317}{4.2043} \frac{0.0627}{1-0.5} \frac{0.5^3}{} = \frac{150}{12100} + 1.75$$

$\Delta P = 0.2486$ atm ≈ 0.25 atm

5. Spesifikasi Reaktor (R-120)

Fungsi		: Untuk mereaksikan metana dengan oksigen
Type		: Multi turbular fixed bed reaktor
Dasar pemilihan		: Luas area perpindahan panas besar sehingga suhu reaksi dapat dipertahankan
Suhu operasi		: 200°-285°C
Tekanan operasi		: 40 atm
Dimensi		
~ Shell	ID	: 2 m
	Baffle space	: 5"
~ Tube	ID	: 2.469"
	OD	: 2.88"
	Jumlah	: 300
	Passes	: 1
	Susunan	: square
~ Panjang		: 578 cm
~ Luas perpindahan panas		: 4285 ft^2
Bahan konstruksi		: Carbon stell
Jumlah		: 1 buah

6. HEATER (E-121)



Fungsi : memanaskan gas alam sebelum masuk reaktor

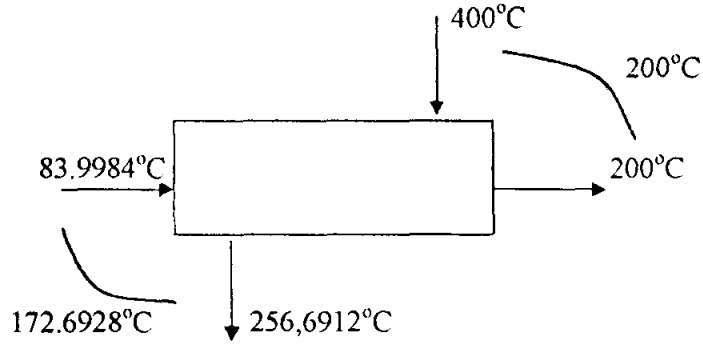
Type : Shell and Tube Heat Exchanger (STHE)

Dari perhitungan sebelumnya didapat:

- metana	=	11200	kg/hari	= 1028,8133	lb/jam
- etana	=	3871,1449	kg/hari	= 355,5969	lb/jam
- propana	=	3430,8971	kg/hari	= 315,1565	lb/jam
- i-butana	=	960,5408	kg/hari	= 88,2337	lb/jam
- n-butana	=	1194,9585	kg/hari	= 109,7669	lb/jam
- i-pentana	=	830,4183	kg/hari	= 76,2808	lb/jam
- n-pentana	=	794,9303	kg/hari	= 73,0209	lb/jam
- heksana	=	1636,1921	kg/hari	= 150,2979	lb/jam
		Total		= 2197,1669	lb/jam

Q = 7029956.1449 kJ/hari = 27762808.2 Btu/jam

Massa steam = 3808.5659 kg/hari = 349.7850 lb/jam



1. $\Delta T_{LMTD} = \dfrac{200-172.6928}{\ln\left(\dfrac{200}{172.6928}\right)} = 186.0125\ ^{o}C = 366.8224\ ^{o}F$

2. $T_c = \dfrac{400+256{,}6912}{2} = 328{,}3456^{o}C = 623{,}0021^{o}F$

$t_c = \dfrac{83.9984+200}{2} = 141.9992^{o}C = 287.5986\ ^{o}F$

3. Asumsi :

U_D = 35 Btu/(hr).(ft^2).(^{o}F)

$Q = U_D.A.\Delta T$

$$A = \frac{Q}{U_D.(T_c - t_c)}$$

$$= \frac{27762808.2}{35.(623{,}0021-287.5986)} = 236.4982\ ft^2$$

Dipilih ukuran pipa:

¾" OD, 16 BWG, 1" triangular pitch, L = 10 ft

$$N_t = \frac{A}{a".L} = \frac{236.4982}{0{,}1963.10} = 120.4779$$

Dari table 9, Kern diperoleh:

ID = 15 ¼"

N_t = 122

Passes = 4

U_D koreksi

$A = Nt.a".L$

$= 122.0{,}1963.10 = 240\ ft^2$

$Q = U_D.A.\Delta T$

$$U_D = \frac{27762808.2}{240.(623{,}0021-287.5986)}$$

$= 34.5633 \approx 35$ Btu/(hr).(ft^2).(^{o}F)

Bagian shell: steam	**Bagian tube: gas alam**
4. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ $= 1 - \frac{3}{4} = 0,25$ $B = 5"$ $= 15\frac{1}{4} . \frac{0,25.5}{144.1}$ $= 0,1324\ ft^2$ 5. $G_s = \frac{w}{a_s} = \frac{349.785}{0,1324}$ $= 2642,3103\ lb/(hr).(ft^2)$ 6. Pada $T_c = 623,0021^oF$ $\mu = 0,021\ cp = 0,0508\ lb/(ft).(hr)$ $De = \frac{0,73}{12} = 0,0608\ ft$ [fig. 28] $Re_s = \frac{D_e.G_s}{\mu} = \frac{0,0608.2642,3103}{0,0508}$ $= 3164.1839$ 7. $h_o = 1500\ Btu/(hr).(ft^2).(^oF)$ (condensate steam)	4'. $a'_t = 0,302\ ft^2$ [table 10] $a_t = \frac{N_t.a'_t}{144.n} = \frac{122.0,302}{144.4} = 0,064\ ft^2$ 5'. $G_t = \frac{w}{a_t} = \frac{2197,1669}{0,064}$ $= 34330.7328\ lb/(hr).(ft^2)$ 6'. Pada $t_c = 287.5986\ ^oF$ $\mu_{metana} = 0,0135$ $\mu_{etana} = 0,0117$ $\mu_{propana} = 0,0105$ $\mu_{butana} = 0,0107$ $\mu_{pentana} = 0,0085$ $\mu_{heksana} = 0,008$ [fig.15] $\mu_{campuran} = \Sigma x_i . \mu_i = 0,0127\ cp \times 2,42$ $= 0,0307\ lb/(ft).(hr)$ $D = \frac{0,620}{12} = 0,0517\ ft$ [table 10] $Re_t = \frac{G_t.D}{\mu_{camp}} = \frac{0,0517.34330.7328}{0,0307}$ $= 57814.296$ 7'. $j_H = 150$ [fig.24] Pada $t_c = 287.5986\ ^oF$ $k_{metana} = 0,0215$ $k_{etana} = 0,0175$ $k_{propana} = 0,0151$ $k_{i\text{-}butana} = 0,0139$ $k_{n\text{-}butana} = 0,0135$ $k_{i\text{-}pentana} = 0,0127$ $k_{n\text{-}pentana} = 0,0083$

	$k_{heksana}$ = 0,0080 [table 5] $k_{campuran} = \Sigma x_i . k_i$ = 0,0197 Btu/(hr).(ft^2).(°F/ft) c_{metana} = 0,6 c_{etana} = 0,52 $c_{propana}$ = 0,8 $c_{i\text{-}butana}$ = 0,73 $c_{n\text{-}butana}$ = 0,71 $c_{i\text{-}pentana}$ = 0,66 $c_{n\text{-}pentana}$ = 0,65 $c_{heksana}$ = 0,62 [fig 3 & 4] $c_{campuran} = \Sigma x_i . c_i$ = 0,6115 Btu/(lb).(°F) 8'. $h_i = j_H . \frac{k}{D} . \left(\frac{c.\mu}{k}\right)^{1/3} =$ $150 . \frac{0,0197}{0,0517} . \left(\frac{0,6115.0,0307}{0,0197}\right)^{1/3}$ = 56.2458 Btu/(hr).(ft^2).(°F) 9'. $h_{io} = h_i . \frac{ID}{OD} = 56,2458 . \frac{0,62}{0,75}$ = 46,4965 Btu/(hr).(ft^2).(°F)

10. $U_c = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{46,4965.1500}{46,4965+1500}$

= 45,0985 Btu/(hr).(ft^2).(°F)

$R_D = \frac{U_C - U_D}{U_C . U_D} = \frac{45,0985 - 35}{45,0985.35}$

= 0,0064 (hr).(ft^2).(°F)/Btu > 0,0015

Pressure Drop

Bagian Shell: steam	**Bagian Tube: gas alam**
1. Re_s = 3164.1839 f = 0,0027 ft^2/in^2 [fig.29] 2. specific volume = 1,8438 ft^3/lb [table 7] $s = \frac{1}{1,8438.62,4} = 8,6916.10^{-3}$ $N+1 = 12.\frac{L}{B} = 12.\frac{10}{5} = 24$ $D_s = \frac{15.25}{12} = 1,2708 ft$ 3. $\Delta P_s = \frac{1}{2}.\frac{f.G_s^2.D_s.(N+1)}{5,22.10^{10}.D_e.s.\varphi_s}$ $= \frac{1}{2}.\frac{0,0027(2642,3103)^2.1,2708.24}{5,22.10^{10}.0,0608.8,6916.10^{-3}.1}$ = 0,0104 psia < 1 psia	1'. Re_t = 57814.296 f = 0,00023 ft^2/in^2 [fig.26] 2'. Vc gas alam = $\Sigma X_i.Vc_i$ =128.8233 cm^3/mol $BM_{camp} = \Sigma X_i.BMi$ = 24,2642 gr/gmol specific volume = $\frac{128.8233}{54.2642}$ = 5.3092 cm^3/gr = 0.085 ft^3/lb $s = \frac{1}{0.085\ 62.4} = 0.1884$ $\Delta P_t = \frac{f.G_t^2.L.n}{5,22.10^{10}.D.s.\varphi_t}$ $= \frac{0,00023.(34330,7328)^2.10.4}{5,22.10^{10}.0,0517.0,1884.1}$ = 0,0213 psia < 2 psia

Summary

1500	H outside	46,4965
Uc = 45,0985		
U_D = 35		
R_d calcutated = 0,0064		
R_d required = 0,0015		
0,0104	Calculated ΔP	0,0213
1	Allowable ΔP	2

6. Spesifikasi Heater (E-121)

Fungsi : Untuk memanaskan gas alam sebelum masuk reaktor

Type : Shell and Tube Heat Exchanger (STHE)

Dasar Pemilihan : Kapasitas besar, cocok untuk tekanan oprasi besar, luas perpindahan panas besar

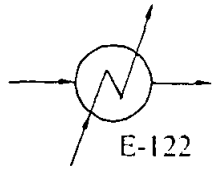
Dimensi

~ Shell	ID	: 15 ¼"
	Baffle space	: 5"
~ Tube	ID	: 0,62"
	OD	: ¾"
	Jumlah	: 122
	Passes	: 4
	Pitch	: 1"
	Susunan	: triangular
~ Panjang		: 10 ft
~ Luas perpindahan panas		: 240 ft^2

Bahan konstruksi : Carbon stell

Jumlah : 1 buah

7. HEATER (E-122)



Fungsi : memanaskan udara sebelum masuk reaktor

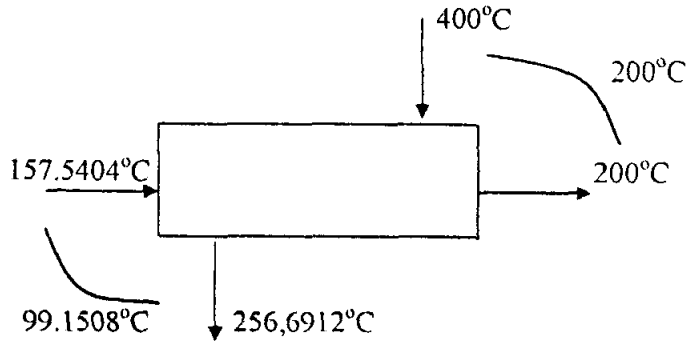
Type : Shell and Tube Heat Exchanger (STHE)

Dari perhitungan sebelumnya didapat:

- oksigen	= 15267,4517	kg/hari	= 1402,4427	lb/jam
- nitrogen	= 329297,5982	kg/hari	= 30248,7285	lb/jam
	Total		= 31651,1712	lb/jam

Q = 8809539.606 kJ/hari = 344467,108 Btu/jam

Massa steam = 4772.6774 kg/hari = 438.3306 lb/jam



1. $\Delta T_{LMTD} = \dfrac{200-99.1508}{\ln\left(\dfrac{200}{99.1508}\right)} = 143,7263°C = 290.7073°F$

2. $T_c = \dfrac{400+256,6912}{2} = 328,3456°C = 623,0021°F$

$t_c = \dfrac{157.5404+200}{2} = 178.7702°C = 353.7864°F$

3. Asumsi :

U_D = 30 Btu/(hr).(ft^2).(°F)

$Q = U_D.A.\Delta T$

$A = \dfrac{Q}{U_D.(T_c-t_c)}$

$= \dfrac{344467.108}{30.(623,0021-353.7864)}$

= 42.6507 ft^2

Dipilih ukuran pipa:

¾" OD, 16 BWG, 1 15/16" triangular pitch, L = 7 ft

$N_t = \dfrac{A}{a''.L}$

$= \dfrac{42.6507}{0,1963.7} = 31.039$

Dari table 9, Kern diperoleh:

ID = 8"

N_t = 32

Passes = 2

U_D koreksi

$A = Nt.a".L$

$= 32.0,1963.7$

$= 44\ ft^2$

$Q = U_D.A.\Delta T$

$$U_D = \frac{344467.108}{44.(623,0021 - 353.7864)}$$

$= 29.0991 \approx 30\ Btu/(hr).(ft^2).(^oF)$

Bagian shell: steam	**Bagian tube: udara**
4. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ $= 1\frac{1}{16} - \frac{3}{4} = 0,1875$ B = 5" $= 8.\frac{0,1875.5}{144.\frac{15}{16}}$ $= 0,0555\ ft^2$	4'. a'_t = 0,302 ft^2 [table 10] $a_t = \frac{N_t.a'_t}{144.n} = \frac{32.0,302}{144.2} = 0,0336\ ft^2$ 5'. $G_t = \frac{w'}{a_t} = \frac{31651,1712}{0,0336}$ $= 941999.1429\ lb/(hr).(ft^2)$
5. $G_s = \frac{w'}{a_s} = \frac{438.3306}{0,0555}$ $= 7897.8486\ lb/(hr).(ft^2)$	6'. Pada $t_c = 353.7864^oF$ μ_{udara} = 0,023 [fig.15] = 0,023 cp x 2,42 = 0,0557 lb/(ft).(hr)
6. Pada $T_c = 623,0021^oF$ μ = 0,021 cp = 0,0508 lb/ (ft).(hr) $De = \frac{0,55}{12} = 0,0458\ ft$ [fig 28]	$D = \frac{0,620}{12} = 0,0517$ ft [table 10] $Re_t = \frac{G_t.D}{\mu_{camp}} = \frac{941999.1429.0,0517}{0,0557}$ $= 874351.0895$ 7'. j_H = 150 [fig.24] Pada $t_c = 353.7864^oF$

$Re_s = \frac{D_e.G_s}{\mu} = \frac{0,0458.7897,8486}{0,0508}$	k_{udara} = 0,01895 Btu/(hr).(ft²).(°F/ft) [table 5]
= 7125.6836	c_{udara} = 0,25 Btu/(lb).(°F) [fig 3]
7. h_o = 1500 Btu/(hr).(ft²).(°F) (*condensate steam*)	8'. $h_i = j_H.\frac{k}{D}.\left(\frac{c.\mu}{k}\right)^{1/3}$ $=150.\frac{0,01895}{0,0517}.\left(\frac{0,25.0,0557}{0,01895}\right)^{1/3}$ = 49.6141 Btu/(hr).(ft²).(°F)
	9'. $h_{io} = h_i.\frac{ID}{OD}$ = 49.6141.$\frac{0,62}{0,75}$ = 41.0143 Btu/(hr).(ft²).(°F)

10. $U_c = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{41,0143.1500}{41,0143+1500}$

= 39.9227 Btu/(hr).(ft²).(°F)

$R_D = \frac{U_C-U_D}{U_C.U_D} = \frac{39.9227-30}{39.9227\ 30}$

= 0,0083 (hr).(ft²).(°F)/Btu > 0,003

Pressure Drop

Bagian Shell: steam	Bagian Tube: udara
1. Re_s = 7125.6836	1'. Re_t = 874351.0895
f = 0,0027 ft²/in² [fig.29]	f = 0,00016 ft²/in² [fig.26]
2. specific volume = 1,8438 ft³/lb [table 7]	2'. Vc udara = $\Sigma X_i.Vc_i$ = 85.882 cm³/mol
$s = \frac{1}{1,8438.62,4} = 8,6916.10^{-3}$	$BM_{camp} = \Sigma X_i.BMi$ = 28,84 gr/gmol
$N+1 = 12.\frac{L}{B} = 12.\frac{7}{5} = 16.8$	specific volume = $\frac{85.882}{28.82}$ = 2.9779 cm³/gr

$$D_s = \frac{8}{12} = 0{,}6667\,ft$$

3. $$\Delta P_s = \frac{1}{2}.\frac{f.G_s^2.D_s.(N+1)}{5{,}22.10^{10}.D_e.s.\varphi_s}$$

$$= \frac{1}{2}.\frac{0{,}0027.(7897{,}8486)^2.0{,}6667.16{,}8}{5{,}22.10^{10}.0{,}0792.8{,}6916.10^{-3}.1}$$

= 0,0262 psia < 1 psia

= 0.0477 ft³/lb

$$s = \frac{1}{0{,}0477.62{,}4} = 0.3358$$

$$\Delta P_t = \frac{f.G_t^2.L.n}{5{,}22.10^{10}.D.s.\varphi_t}$$

$$= \frac{0{,}00016.(941999.1429)^2.7.2}{5{,}22.10^{10}.0{,}0517.0.3358.1}$$

= 1,0967 psia < 2 psia

Summary

1500	h outside	41,0143
Uc	= 39,9277	
U_D	= 30	
R_d calcutated	= 0,0083	
R_d required	= 0,003	
0,0262	Calculated ΔP	1,0967
1	Allowable ΔP	2

7. Spesifikasi Heater (E-122)

Fungsi : Untuk memanaskan udara sebelum masuk reaktor

Type : Shell and Tube Heat Exchanger (STHE)

Dasar Pemilihan : Kapasitas besar, cocok untuk tekanan oprasi besar, luas perpindahan panas besar

Dimensi

~ Shell ID : 8"

Baffle space : 5"

~ Tube ID : 0,62"

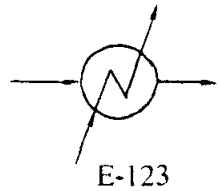
OD : ¼"

Jumlah : 32

Passes : 2

Pitch	: 15/16"
Susunan	: triangular
~ Panjang	: 7 ft
~ Luas perpindahan panas	: 44 ft^2
Bahan konstruksi	: Carbon stell
Jumlah	: 1 buah

8. HEATER (E-123)



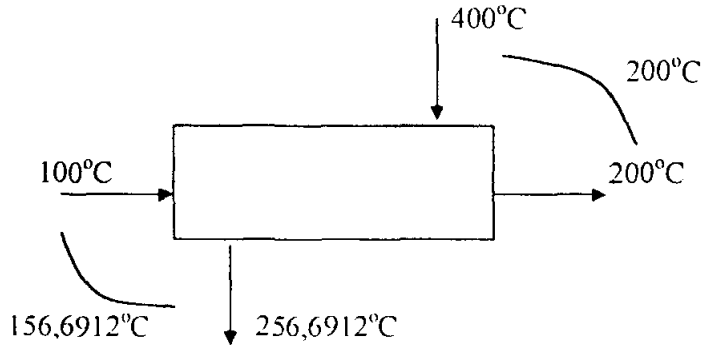
E-123

Fungsi : memanaskan recycle sebelum masuk reaktor

Type : Shell and Tube Heat Exchanger (STHE)

Dari perhitungan sebelumnya didapat:

- metana	=	4067,2491	kg/hari	= 373,6107	lb/jam
- etana	=	30702,6597	kg/hari	= 2820,2951	lb/jam
- propana	=	27217,8115	kg/hari	= 2500,1828	lb/jam
- i-butana	=	7625,2305	kg/hari	= 700,4198	lb/jam
- n-butana	=	9478,9503	kg/hari	= 870,7206	lb/jam
- i-pentana	=	6593,4217	kg/hari	= 605,6607	lb/jam
- n-pentana	=	6299,6554	kg/hari	= 578,6758	lb/jam
- heksana	=	12982,8390	kg/hari	= 1192,5819	lb/jam
- oksigen	=	4067,2491	kg/hari	= 373,6107	lb/jam
- nitrogen	=	292416,2672	kg/hari	= 26860,8709	lb/jam
		Total		= 36878,6883	lb/jam
Q	=	57737365,9683	kJ/hari	= 2280177,034	Btu/jam
Massa steam	=	31279,9343	kg/hari	= 2873,3226	lb/jam



1. $\Delta T_{LMTD} = \dfrac{200-156,6912}{\ln\left(\dfrac{200}{156,6912}\right)} = 177,4657^{\circ}C = 351,4383^{\circ}F$

2. $T_c = \dfrac{400+256,6912}{2} = 328,3456^{\circ}C = 623,0021^{\circ}F$

$t_c = \dfrac{100+200}{2} = 150^{\circ}C = 302^{\circ}F$

3. Asumsi :

$U_D = 38$ Btu/(hr).(ft^2).($^{\circ}$F)

$Q = U_D.A.\Delta T$

$A = \dfrac{Q}{U_D.(T_c-t_c)}$

$= \dfrac{2280177,034}{38.(623,0021-302)} = 186.9292\ ft^2$

Dipilih ukuran pipa:

1½" OD, 16 BWG, 1⅞" triangular pitch, L = 10 ft

$N_t = \dfrac{A}{a''.L}$

$= \dfrac{186.9292}{0,3925.10} = 47.6252$

Dari table 9, Kern diperoleh:

ID = 19¼"

N_t = 48

Passes = 8

U_D koreksi

$A = Nt.a".L$

$= 48.0,3925.10$

$= 189\ ft^2$

$Q = U_D.A.\Delta T$

$$U_D = \frac{2280177,034}{189.(623,0021-302)}$$

$= 37.7033 \approx 38\ Btu/(hr).(ft^2).(^oF)$

Bagian shell: steam	**Bagian tube: gas**
4. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ $= 1\frac{7}{8} - 1\frac{1}{2} = 0,375$ $B = 5"$ $= 19.25.\frac{0,375.5}{144.1\frac{7}{8}}$ $= 0.1337\ ft^2$	4'. $a'_t = 1,47\ ft^2$ [table 10] $a_t = \frac{N_t.a'_t}{144.n} = \frac{48.1,47}{144.8}$ $= 0,06125\ ft^2$
5. $G_s = \frac{w}{a_s} = \frac{2873,3226}{0,1337}$ $= 21490.8198\ lb/(hr).(ft^2)$	5'. $G_t = \frac{w}{a_t} = \frac{36878,6883}{0.06125}$ $= 602101.0335\ lb/(hr).(ft^2)$
6. Pada $T_c = 623,0021^oF$ $\mu = 0,021\ cp = 0,0508\ lb/(ft).(hr)$ $De = \frac{1,08}{12} = 0,09\ ft$ [fig 28] $Re_s = \frac{D_e.G_s}{\mu} = \frac{0,09.21490,8198}{0,0508}$ $= 38074.2871$	6'. Pada $t_c = 302^oF$ $\mu_{metana} = 0,014$ $\mu_{etana} = 0,013$ $\mu_{propana} = 0,0105$ $\mu_{butana} = 0,01$ $\mu_{pentana} = 0,009$ $\mu_{heksana} = 0,0085$ $\mu_{oksigen} = 0,025$ $\mu_{nitrogen} = 0,023$ [fig.15] $\mu_{campuran} = \Sigma x_i.\mu_i$ $= 0,0208\ cp \times 2,42$ $= 0,0503\ lb/(ft).(hr)$
7. $h_o = 1500\ Btu/(hr).(ft^2).(^oF)$ (*condensate steam*)	

$D = \frac{1,37}{12} = 0,1142$ ft [table 10]

$Re_t = \frac{G_t.D}{\mu_{camp}} = \frac{602102,0335.0,1142}{0,0503}$

$= 136699.678$

7'. $j_H = 400$ [fig.24]

Pada $t_c = 302^oF$

$k_{metana} = 0,0315$

$k_{etana} = 0,0227$

$k_{propana} = 0,0233$

$k_{i\text{-}butana} = 0,0149$

$k_{n\text{-}butana} = 0,0145$

$k_{i\text{-}pentana} = 0,0225$

$k_{n\text{-}pentana} = 0,0103$

$k_{heksana} = 0,0110$

$k_{oksigen} = 0,0213$

$k_{nitrogen} = 0,0192$ [table 5]

$k_{campuran} = \Sigma x_i . k_i$

$= 0,0197 Btu/(hr).(ft^2).(^oF/ft)$

$c_{metana} = 0,65$

$c_{etana} = 0,55$

$c_{propana} = 0,85$

$c_{i\text{-}butana} = 0,79$

$c_{n\text{-}butana} = 0,76$

$c_{i\text{-}pentana} = 0,7$

$c_{n\text{-}pentana} = 0,69$

$c_{heksana} = 0,65$

$c_{okgigen} = 0,23$

$c_{nitrogen} = 0,25$ [fig 3 & 4]

$c_{campuran} = \Sigma x_i . c_i$

$= 0,3317$ Btu/(lb).(^oF)

	8'. $h_i = j_H.\frac{k}{D}\left(\frac{c.\mu}{k}\right)^{1/3}$ $= 400.\frac{0,0197}{0,1142}\left(\frac{0,3317.0,0503}{0,0197}\right)^{1/3}$ $= 65.2843$ Btu/(hr).(ft^2).(^{o}F) 9' $h_{io} = h_i.\frac{ID}{OD} = 65,2843.\frac{1,37}{1,5}$ $= 59,6264$ Btu/(hr).(ft^2).(^{o}F)

10. $U_c = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{59,6264.1500}{59,6264+1500}$

$= 57,3468$ Btu/(hr).(ft^2).(^{o}F)

$R_D = \frac{U_C-U_D}{U_C.U_D} = \frac{57,3468-38}{57,3468.38}$

$= 0,00888$ (hr).(ft^2).(^{o}F)/Btu > 0,0015

Pressure Drop

Bagian Shell: steam	Bagian Tube: gas
1. $Re_s = 38074.2871$ f = 0,0016 ft^2/in^2 [fig.29]	1'. $Re_t = 136699.678$ f = 0,00015 ft^2/in^2 [fig.26]
2. specific volume = 1,8438 ft^3/lb [table 7]	2'. Vc gas = $\Sigma X_i.Vc_i$ = 105.3872 cm^3/mol
$s = \frac{1}{1,8438.62,4} = 8,6916.10^{-3}$	$BM_{camp} = \Sigma X_i.BMi$ = 42.049 gr/gmol
$N+1 = 12.\frac{L}{B} = 12.\frac{10}{5} = 24$	specific volume = $\frac{105.3872}{42.049}$ = 2.5063 cm^3/gr = 0.0402 ft^3/lb
$D_s = \frac{19.25}{12} = 1.6042 ft$	$s = \frac{1}{0.0402\,62.4} = 0.399$

3. $\Delta P_s = \frac{1}{2} \cdot \frac{f.G_s^2.D_s.(N+1)}{5,22.10^{10}.D_e.s.\varphi_s}$ $= \frac{1}{2} \cdot \frac{0,0016.(21490,8198)^2.1,6042.24}{5,22.10^{10}.0,09.8,6916.10^{-3}.1}$ = 0,3513 psia < 1 psia	$\Delta P_t = \frac{f.G_t^2.L.n}{5,22.10^{10}.D.s.\varphi_t}$ $= \frac{0,00015.(1602101,0335)^2.10.8}{5,22.10^{10}.0,1142.0,399.1}$ = 1,829 psia < 2 psia

Summary

1500	h outside	59,6264
Uc	= 57,3468	
U_D	= 38	
R_d calcutated	= 0,0088	
R_d required	= 0,0015	
0,3513	Calculated ΔP	1,829
1	Allowable ΔP	2

8. Spesifikasi Heater (E-123)

Fungsi : Untuk memanaskan recycle sebelum masuk reaktor

Type : Shell and Tube Heat Exchanger (STHE)

Dasar Pemilihan : Kapasitas besar, cocok untuk tekanan oprasi besar, luas perpindahan panas besar

Dimensi

~ Shell ID : 19¼ "

Baffle space : 5"

~ Tube ID : 1,37"

OD : 1,5"

Jumlah : 48

Passes : 8

Pitch : 1⅞"

Susunan : triangular

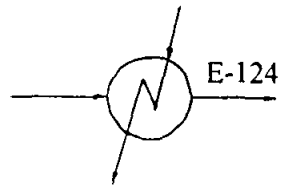
~ Panjang : 10 ft

~ Luas perpindahan panas : 189 ft^2

Bahan konstruksi : Carbon stell

Jumlah : 1 buah

9. COOLER (E-124)

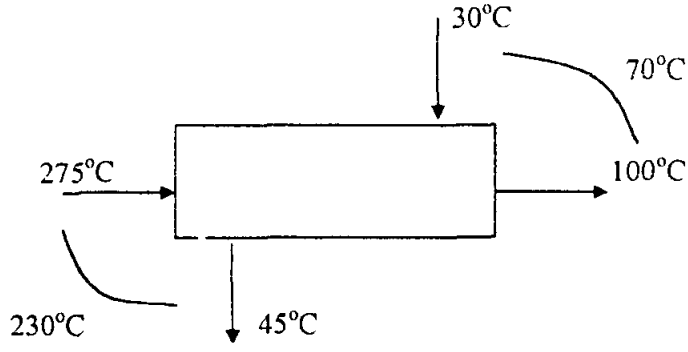


Fungsi : untuk menurunkan gas hasil reactor R-120

Type : Shell and Tube Heat Exchanger (STHE)

Dari perhitungan sebelumnya didapat:

- metana	= 4580,2355	kg/hari	= 420,7328	lb/jam
- etana	= 34575,0672	kg/hari	= 3176,0081	lb/jam
- propana	= 30650,6886	kg/hari	= 2815,5212	lb/jam
- i-butana	= 8586,9713	kg/hari	= 788,7849	lb/jam
- n-butana	= 10674,4936	kg/hari	= 980,5412	lb/jam
- i-pentana	= 7425,0244	kg/hari	= 682,0504	lb/jam
- n-pentana	= 7094,2065	kg/hari	= 651,6620	lb/jam
- heksana	= 14620,3141	kg/hari	= 1342,9977	lb/jam
- methanol	= 21374,4324	kg/hari	= 1963,4197	lb/jam
- oksigen	= 4580,2355	kg/hari	= 420,7328	lb/jam
- nitrogen	= 329297,5982	kg/hari	= 30248,7285	lb/jam
	Total		= 43491,1792	lb/jam
Q	= 125219682,5835	kJ/hari	= 4945203,847	Btu/jam
Massa air	= 1996407,701	kg/hari	= 183386,6841	lb/jam



1. $\Delta T_{LMTD} = \dfrac{230-70}{\ln\left(\dfrac{230}{70}\right)} = 134{,}5008^{\circ}C = 274{,}1014^{\circ}F$

2. $T_c = \dfrac{275+100}{2} = 187{,}5^{\circ}C = 369{,}5^{\circ}F$

$t_c = \dfrac{30+45}{2} = 37{,}5^{\circ}C = 67{,}5^{\circ}F$

3. Asumsi :

$U_D = 30$ Btu/(hr).(ft^2).($^{\circ}F$)

$Q = U_D.A.\Delta T$

$$A = \frac{Q}{U_D.(T_c - t_c)}$$

$$= \frac{4945203{,}847}{30.(369{,}5-67{,}5)}$$

$= 545{,}8282\ ft^2$

Dipilih ukuran pipa:

1½" OD, 16 BWG, 1⅞" triangular pitch, L = 10 ft

$$N_t = \frac{A}{a''.L}$$

$$= \frac{545.8282}{0{,}3925.10} = 139.0645$$

Dari table 9, Kern diperoleh:

ID = 29"

N_t = 141

Passes = 6

U_D koreksi

A = Nt.a".L

= 141.0,3925.10 = 554 ft^2

Q = U_D.A.ΔT

$$U_D = \frac{4945203,847}{554.(369,5-67,5)}$$

= 29,5882 ≈ 30 Btu/(hr).(ft^2).(°F)

Bagian shell: gas	**Bagian tube: air pendingin**
4. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ $= 1\frac{7}{8} - 1\frac{1}{2} = 0,375$ B = 5" $= 29.\frac{0,375.5}{144.1\frac{7}{8}}$ = 0,2014 ft^2	4'. a'_t = 1,47 ft^2 [table 10] $a_t = \frac{N_t.a'_t}{144.n} = \frac{141.1,47}{144.6}$ = 0,2399 ft^2
5. $G_s = \frac{w}{a_s} = \frac{43491,1792}{0,2014}$ = 215956.2002 lb/(hr).(ft^2)	5'. $G_t = \frac{w}{a_t} = \frac{183386,6841}{0,2399}$ = 764429.6961 lb/(hr).(ft^2) $v = \frac{G_t}{3600.\rho} = \frac{764429.6961}{3600.62,4}$ = 3,4029 fps
6. Pada T_c = 369,5°F μ_{metana} = 0,015 μ_{etana} = 0,014 $\mu_{propana}$ = 0,011 μ_{butana} = 0,0107 $\mu_{pentana}$ = 0,0095 $\mu_{heksana}$ = 0,009 $\mu_{metanol}$ = 0,014	6'. Pada t_c = 67,5°F μ_{air} = 1 cp x 2,42 = 2,42 lb/(ft).(hr) D = $\frac{1,37}{12}$ = 0,1142 ft [table 10] $Re_t = \frac{D.G_t}{\mu} = \frac{764429,6961.0,1142}{2,42}$ = 36073,5005 8'. h_i = 750 Btu/(hr).(ft^2).(°F) [fig.25]

$\mu_{oksigen}$ = 0,027

$\mu_{nitrogen}$ = 0,026 [fig.15]

$\mu_{campuran} = \Sigma x_i . \mu_i$

= 0,02297 cp x 2,42

= 0,0556 lb/(ft).(hr)

$De = \frac{1,08}{12} = 0,09\ ft$ [fig 28]

$Re_s = \frac{D_e . G_s}{\mu} = \frac{0,09.215956,2002}{0,0556}$

= 349569.3888

7. j_H = 350 [fig.28]

Pada T_c = 369,5°F

k_{metana} = 0,0345

k_{etana} = 0,0241

$k_{propana}$ = 0,0241

$k_{i\text{-}butana}$ = 0,0156

$k_{n\text{-}butana}$ = 0,0151

$k_{i\text{-}pentana}$ = 0,0234

$k_{n\text{-}pentana}$ = 0,0107

$k_{heksana}$ = 0,0117

$k_{metanol}$ = 0,0451

$k_{oksigen}$ = 0,0223

$k_{nitrogen}$ = 0,0198 [table 5]

$k_{campuran} = \Sigma x_i . k_i$

= 0,0215 Btu/(hr).(ft²).(°F/ft)

c_{metana} = 0,68

c_{etana} = 0,6

$c_{propana}$ = 0,92

$c_{i\text{-}butana}$ = 0,83

$c_{n\text{-}butana}$ = 0,80

9'. $h_{io} = h_i . \frac{ID}{OD}$

$= 750 . \frac{1,37}{1,5}$

= 685 Btu/(hr).(ft²).(°F)

$c_{i\text{-pentana}} = 0,75$

$c_{n\text{-pentana}} = 0,74$

$c_{heksana} = 0,70$

$c_{metanol} = 0,78$

$c_{oksigen} = 0,22$

$c_{nitrogen} = 0,26$ [fig 3 & 4]

$c_{campuran} = \Sigma x_i . c_i$

$= 0,3669$ Btu/(lb).(°F)

$$8'.\ h_o = j_H . \frac{k}{D} . \left(\frac{c.\mu}{k} \right)^{1/3}$$

$$= 350 . \frac{0,0215}{0,09} . \left(\frac{0,3669.0,0556}{0,0215} \right)^{1/3}$$

$= 89.1597$ Btu/(hr).(ft^2).(°F)

$$10.\ U_c = \frac{h_{io} . h_o}{h_{io} + h_o} = \frac{685.89,1597}{685 + 89,1597}$$

$= 78.8912$ Btu/(hr).(ft^2).(°F)

$$R_D = \frac{U_C - U_D}{U_C . U_D} = \frac{78,8912 - 30}{78,8912.30}$$

$= 0,0207$ (hr).(ft^2).(°F)/Btu > 0,0015

Pressure Drop

Bagian Shell: gas	**Bagian Tube: air pendingin**
1. $Re_s = 349569.3888$	1'. $Re_t = 36073,5005$
$f = 0,0016$ ft^2/in^2 [fig.29]	$f = 0,00024$ ft^2/in^2 [fig.26]
2. $Vc = \Sigma X_i . Vc_i$	2'. $\Delta P_t = \frac{f.G_t^2.L.n}{5,22.10^{10}.D.s.\varphi_t}$
$= 111.7252$ cm^3/mol	$= \frac{0,00024.(764429,6961)^2.10.6}{5,22.10^{10}.0,1142.1.1}$
$BM_{camp} = \Sigma X_i . BMi = 46.0125$ gr/gmol	$= 1,4116$ psia

specific volume $= \frac{111.7252}{46.0125}$

$= 2.4281\ cm^3/gr$

$= 0.0389\ ft^3/lb$

$s = \frac{1}{0.0389\ 62.4} = 0.4118$

$N+1 = 12.\frac{L}{B} = 12.\frac{10}{5} = 24$

$D_s = \frac{29}{12} = 2.4167 ft$

3. $\Delta P_s = \frac{1}{2}.\frac{f.G_s^2.D_s.(N+1)}{5{,}22.10^{10}.D_e.s.\varphi_s}$

$= \frac{1}{2}.\frac{0{,}0016.(215956{,}2002)^2.2{,}4167.24}{5{,}22.10^{10}.0{,}1233.0{,}4118.1}$

$= 0.8165$ psia < 2 psia

$G_t = 764429.6961$

$\frac{V^2}{2.g'} = 0{,}05$ [fig.27]

$\Delta P_r = \frac{4.n}{s}.\frac{V^2}{2.g'}$

$= \frac{4.6}{1}.0{,}05 = 1.2$ psia

$\Delta P_T = \Delta P_t + \Delta P_r$

$= 1.4116 + 1.2$

$= 2.6116$ psia < 10 psia

Summary

89,1597	h outside	685
Uc	= 78,8912	
U_D	= 30	
R_d calcutated	= 0,0207	
R_d required	= 0,0015	
0,8165	Calculated ΔP	2,6116
2	Allowable ΔP	10

9. Spesifikasi Cooler (E-124)

Fungsi : untuk menurunkan suhu gas hasil reactor R-120

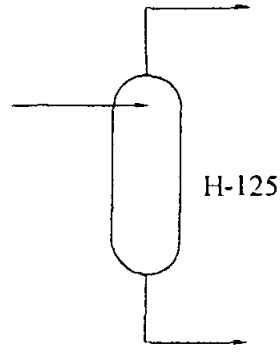
Type : Shell and Tube Heat Exchanger (STHE)

Dasar Pemilihan : Kapasitas besar, cocok untuk tekanan oprasi besar, luas perpindahan panas besar

Dimensi

~ Shell	ID	: 29"
	Baffle space	: 5"
~ Tube	ID	: 1,37"
	OD	: 1,5"
	Jumlah	: 141
	Passes	: 6
	Pitch	: 1 ⅞"
	Susunan	: triangular
~ Panjang		: 10 ft
~ Luas perpindahan panas		: 554 ft^2
Bahan konstruksi		: Carbon stell
Jumlah		: 1 buah

10. DRUM SEPARATOR (H-125)



Fungsi : memisahkan methanol dari gas

Type : tangki vertical dengan tutup atas dan bawah ellipsoidal

Rate yang masuk = 21374,4324 kg/hari

$\rho_{methanol}$ = 786,64 kg/m^3

$$\text{Rate volumetric} = \frac{21374,4324.10^3}{0,78664} = 27171809,72 \text{ cm}^3\text{/hari}$$

$$= 39,9799 \text{ ft}^3\text{/jam} \approx 40 \text{ ft}^3\text{/jam}$$

Keterangan : H = 1,5 D

Liquid mengisi ¾ bagian shell

Volume liquid = ¾ volume shell + volume elipsoidal

$$40 = \frac{3}{4}\left(\frac{\pi}{4}D^2.H\right) + 0.131328\ D^3$$

$$40 = \frac{3}{4}\left(\frac{\pi}{4}D^2.1{,}5D\right) + 0.131328\ D^3$$

$$40 = 0{,}8831\ D^3 + 0{,}131328\ D^3$$

$$40 = 1.0144\ D^3$$

$$D^3 = 39.4113$$

D_{shell} = 3.5 ft

H_{shell} = 1,5 D = 5.2019 ft

$$H_{elipsoidal} = \frac{D}{4} = \frac{3.4679}{4} = 0.8669\ \text{ft}$$

H_{tangki} = H_{shell} + 2 x $H_{elipsoidal}$

= 5.2019 + 2 x 0.8669

= 7 ft

Tebal Shell

$$t_{shell} = \frac{P.D}{2.f\,E} + c$$

dimana:

* $f_{allow} = f_u.f_m.f_s.f_a.f_r$

  f_u = 75000 psia (untuk SA-240 grade S tipe 304)

  f_m = 0,92 (untuk bahan kualitas C → *structure steel*)

  f_a = 1,0 (tidak dikenakan *radiograph*)

  f_r = 1,0 (tidak dikenakan *stress relief*)

  $f_{allow} = f_u.f_m.f_s.f_a.f_r$ = 17250 psi

* E = 0,8 dengan type pengelasan Double Welded Butt Joint

* $P = \frac{\rho.(H-1)}{144}$

  ρ = 0,78664 g/cm^3 = 49,1099 lb/ft^3

$H = \frac{3}{4} H_{shell} + H_{elipsoidal}$

$= \frac{3}{4}\ 5.2019 + 0.8669 = 4.7683$ ft

$$P = \frac{49,1099.(4.7683-1)}{144} = 1.3309 \text{psia}$$

$P_{operasi} = (40 \times 14.7) + P = 588 + 1.3309 = 589.3309$ psia

untuk safety $P_{operasi} = 1,2\ .\ 589,3309 = 707.1971$ psia

Maka,

$$t_{shell} = \frac{707.1971.3,5.12}{2.17250.0,8} + 0,1$$

$= 1.2895$ " $\approx$1.29"

Tebal Elipsoidal

$$v = \frac{1}{6}.\left(2 + k^2\right)$$

$$= \frac{1}{6}.\left(2 + 2^2\right) = 1$$

$$t_{elipsoidal} = \frac{P.D.v}{2.f\,E - 0,2.P} + c$$

$$= \frac{40.14,7.3,5.12}{2.17250.0,8 - 0,2.19,2371} + 0,1 = 1.2879" \approx 1.29"$$

10. Spesifikasi DRUM SEPARATOR (H-125)

Fungsi : memisahkan methanol dari gas sisa reaksi

Type : Tangki vertical dengan tutup atas dan bawah ellipsoidal

Dasar pemilihan : Untuk memisahkan fasa cair dan gas yang tidak saling larut secara cepat.

Kapasitas : 40 ft^3

Suhu operasi : 100°C

Tekanan operasi : 40 atm

Dimensi

~ diameter shell : 3.5 ft

~ tebal shell : 1.29"

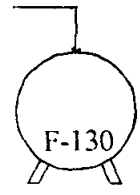
~ tebal ellipsoidal : 1.29"

~ tinggi : 7 ft

Bahan konstruksi : Carbon stell

Jumlah : 1 buah

11. STORAGE TANK (F-130)



Fungsi : menyimpan gas sisa reaksi yang di purge

Type : bola

Direncanakan: T penyimpanan = 30°C = 303 K

P penyimpanan = 20 atm

$BM_{camp} = \Sigma X_i.BMi$

= (0,0194.16)+(0,0782.30)+(0,0473.44)+(0,0225.58)+(0,0137.72)+(0,0115.86)
+(0,0097.32)+(0,7977.28)

= 42,049 lb/lbmol

$$\rho_{camp} = \frac{BM_{camp}}{V_o}.\frac{P}{P_o}.\frac{T_o}{T}$$

$$= \frac{42,049}{359}.\frac{20}{1}.\frac{273}{303}$$

$= 2,1287 \text{ lb/ft}^3$

rate = 50611,3161 kg/hari = 52415,8911 ft^3/hari

Waktu penyimpanan = 15 hari

Maka, volume gas = 786238.3665 ft^3 = 22263.9118 m^3

Jika digunakan 2 tangki, maka volume masing-masing tangki = 11132 m^3

$$11132 = \frac{4}{3}.\pi.\left(\frac{1}{2}.D\right)^3$$

$$D^3 = 21271.2533$$

$$D = 28 \text{ m}$$

$$r = 14 \text{ m}$$

Tebal dinding

$$t_{shell} = \frac{P.r}{1{,}8.f - 0{,}2.P} + c \qquad \text{(Ulrich, p.250)}$$

dimana:

$f_{allow} = f_u.f_m.f_s.f_a.f_r$

f_u = 75000 psia (untuk SA-240 grade S tipe 304)

f_m = 0,92 (untuk bahan kualitas C → *structure steel*)

f_a = 1,0 (tidak dikenakan *radiograph*)

f_r = 1,0 (tidak dikenakan *stress relief*)

$f_{allow} = f_u.f_m.f_s.f_a.f_r$ = 17250 psi

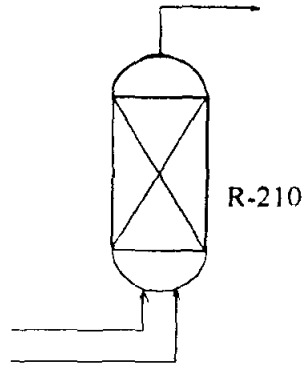
Maka,

$$t_{shell} = \frac{(20.14{,}696).(14.39{,}37)}{1{,}8.17250 - 0{,}2.(20.14{,}696)} + 0{,}1 = 2{,}78 \text{ “} \approx 3\text{”}$$

11. Spesifikasi Storage Tank (F-130)

Fungsi	: menyimpan gas sisa reaksi yang dipurge
Type	: Bola
Dasar pemilihan	: tekanan penyimpanan tinggi
Kapasitas	: 11132 m^3
Suhu penyimpanan	: 30°C
Tekanan penyimpanan	: 20 atm
Tebal dinding	: 3”
Bahan konstruksi	: Carbon stell
Jumlah	: 2 buah

12. REAKTOR II (R-210)



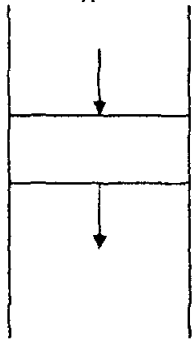
Fungsi : Untuk mendehidrasikan methanol

Type : Multi turbular fixed bed reaktor

Dari perhitungan sebelumnya didapat:

- methanol	=	26583,7749 kg/hari	=	2441,9413 lb/jam
- H_2O	=	29,5986 kg/hari	=	2,7189 lb/jam
		Total	=	2444,6602 lb/jam

neraca massa



Input – output – generation = 0

$$F_A(1-X_A)\,|_z - F_A(1-X_A)\,|_{z+\Delta Z} - W.\,r_A = 0$$

$$F_A(1-X_A)\,|_z - F_A(1-X_A)\,|_{z+\Delta Z} - \left(\frac{\pi}{4} D^2\,\Delta Z\,\rho\right).10^{-3}.(1-\varepsilon).r_A = 0$$

$$\frac{F_A(1-X_A)|_z - F_A(1-X_A)|_{z+\Delta Z}}{\Delta Z} = \frac{\pi}{4} D^2 \rho .10^{-3}.(1-\varepsilon) r_A$$

untuk lim $\Delta Z \rightarrow 0$

$$F_A \frac{dx}{dz} = \frac{\pi}{4} D^2 \rho.10^{-3}.(1-\varepsilon) r_A$$

$$dx = \frac{\frac{\pi}{4} D^2 \rho.10^{-3}.(1-\varepsilon) r_A\, dz}{F_A} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

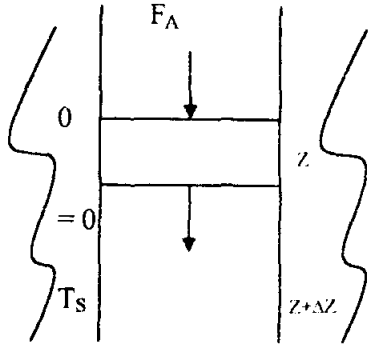
dimana z = panjang reactor, cm; x = konversi

F_A = laju molar CH_4, kmol/hari; D = diameter tube, cm

ρ = densitas katalis, gr/cm^3; ε = fraksi kosong

r_A = kecepatan reaksi, kmol DME/kg katalis jam

neraca panas



Q masuk – Q keluar – Qserap – Qhilang = 0

$\Sigma m_i.Hf_i \mid_Z - \Sigma m_i.Hf_i \mid_{Z+\Delta Z}$ – Qserap – 5%.Qserap =

$\Sigma m_i.Hf_i \mid_Z - \Sigma m_i.Hf_i \mid_{Z+\Delta Z} - 1.05\ U_D\ \pi D\ \Delta Z\ (T-T_S)$

$$\frac{\Sigma m_i Hf_i\big|_Z - \Sigma m_i Hf_i\big|_{Z+\Delta Z}}{\Delta z} = 1.05 U_D\ \pi\ D\ (T - Ts)$$

untuk lim ΔZ → 0

$$\frac{d(\Sigma m_i Hf_i)}{dz} = 1.05\ U_D \pi\ D(T - T_S) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

dimana $$\frac{d(\Sigma m_i Hf_i)}{dz} = \Sigma m_i \frac{dHf_i}{dz} + \Sigma Hf_i \frac{dm_i}{dz}$$

$$\rightarrow\ \Sigma m_i \frac{dHf_i}{dz} = \Sigma m_i\ Cp \frac{dT}{dz}$$

dengan komponen yang masuk reactor terdiri atas

~ Methanol = F_A (1 – X_A)

~ DME = F_B + 0.5 F_A X_A

~ H_2O = F_C + F_A X_A

maka

$$\Sigma m_i \frac{dHf_i}{dz} = \Sigma m_i\ Cp \frac{dT}{dz}$$

$$= [\{F_A(1-X_A)(2.211+12.216\ 10^{-3}T-3.45\ 10^{-6}T^2)\}+\{(F_B+0.5F_AX_A)(3.518+20.001\ 10^{-3}T-6.00210^{-6}T^2)\}+$$

$$\left\{(F_C+0.5F_AX_A).(3.4710+1.45\,10^{-3}T+\frac{0.12110^5}{T^2})\right\}]x\,8.314\frac{dT}{dz} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\rightarrow \Sigma Hf_i \frac{dm_i}{dz} = F_A \Delta H_R \frac{dx}{dz} \quad \text{.....(4)}$$

dimana

$$\Delta H_R = \Delta H_{298} + \int_{298}^{T} Cp\,dt$$

$$= [(-183000 - 241826) - -201250] + 8.314 \left\{ 3.518\,(T-298) + \frac{20.001\,10^{-3}}{2}(T^2 - 298^2) - \frac{6.002\,10^{-6}}{3}(T^3 - 298^3) \right\} +$$

$$\left\{ 3.470\,(T-298) + \frac{1.45\,10^{-3}}{2}(T^2 - 298^2) - 1.121\,10^5 \left(\frac{1}{T} - \frac{1}{298}\right) \right\} - 2.\{2.211\,(T-298) + \frac{12.216\,10^{-3}}{2}(T^2 - 298^2)$$

$$- \frac{3.45\,10^{-6}}{3}(T^3 - 298^3)\}]$$

$$= -223576 + \left[-21.3337\,(T-298) - 0.0124\,(T^2 - 298^2) + 2.4887\,10^{-6}(T^3 - 298^3) + 1.006\,10^5 \left(\frac{1}{T} - \frac{1}{298}\right) \right] \quad \text{.....(5)}$$

~ persamaan (5) disubstitusikan ke persamaan (4)

~ persamaan (3) dan (4) disubstitusikan ke persamaan (2)

neraca panas pendingin

panas masuk = panas untuk menaikan suhu pendingin

$$\pi \text{ Do } U_D \text{ (T-Ts)} = \text{W Cp } \frac{dTs}{dz} \quad \text{.....(6)}$$

menentukan kecepatan aliran pendingin

panas reaksi total = panas yang dibawa pendingin

$$F_A \text{ Nt } \Delta H_R \text{ x} \quad = \quad \text{W Cp } \Delta \text{Ts}$$

$$W = \frac{F_A.Nt.\Delta H_R.x}{\Delta Ts.Cp} \quad \text{.....(7)}$$

persamaan (7) disubstitusi ke persamaan (6), menjadi

$$\pi \text{ Do } U_D \text{ (T-Ts)} = \frac{F_A.Nt.\Delta H_R.x}{\Delta Ts.} \frac{dTs}{dz}$$

$$dTs = \frac{\pi.Do.U_D(T - Ts).\Delta Ts.dz}{F_A.Nt.\Delta H_R.x}$$

$diharapkan\ \Delta Ts = 15^0$

$$dTs = \frac{\pi.Do.U_D(T - Ts).\Delta Ts.dz}{F_A.Nt.\Delta H_R.x} \quad \text{.....(8)}$$

menentukan jumlah tube

~ digunakan pipa 2½"IPS, sech 40

ID = 2.469" = 6.2713 cm

OD = 2.88" = 7.3152 cm

~ $\mu_{campuran} = \Sigma x_i . \mu_l$ = 0,0349 cp

~ agar transfer panas baik digunakan aliran turbulen

$$Re = \frac{D\,G}{\mu}$$

$$2400 = \frac{6.2713\,G}{0.0349\ 3600\ 10^{-5}}$$

$$G = 0.4841 \text{ kg/cm}^2 \text{ jam}$$

Area per tube = $\pi/4\ D^2 = 0.25 \times 3.14 \times 6.2713^2 = 30.8734 \text{ cm}^2$

Laju alir dalam tube = 0.4841 x 30.8734 = 14.9471 kg/jam

jumlah komponen masuk reactor = 26613.3735 kg/hari

= 1108.8906 kg/jam

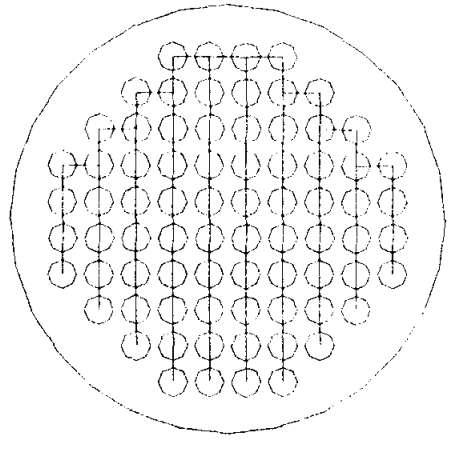
$$\text{jumlah tube yang dibutuhkan} = \frac{1108.8906}{14.9471} = 74.1879 \approx 76 \text{ tube}$$

menentukan ID shell

~ susunan tube = square pitch

~ P_T = 1,25 OD = 9,144 cm = 3,6"

sehingga tube dapat disusun seperti :



ID shell = 108.38 cm

= 1.1 m

contoh perhitungan

Diketahui data:

~ $r_A = 0.4\ T - 192.2$

~ ΔH_f DME = -183.0000 kJ / mol
ΔH_f H_2O = -241.8260 kJ/mol
ΔH_f CH_3OH = -201.25 kJ / mol

$$\Delta H_{R\ 298} = (\Delta H_f DME + \Delta H_f H_2O) - \Delta H_f\ CH_3OH$$
$$= ((-183 + -241.826) - -201.25) \times 1000$$
$$= -223576\ J/mol$$

~ katalis yang digunakan terdiri dari:

SiO_2 = 10,2 % → ρ_{SiO2} = 2,32 gr/cm^3

Al_2O_3 = 89,8 % → ρ_{Al2O3} = 3,99 gr/cm^3

Maka ρ = 0.102 2.32 + 0.898 3.88
= 3.7209 gr/cm^3

~ asumsi $\varepsilon = 0.5$

~ dimensi reaktor

untuk bagian tube digunakan pipa 2½"IPS, sech 40

ID = 2.469" = 6.2713 cm

OD = 2.88" = 7.3152 cm

untuk bagian shell, ID = 108.38 cm

~ pada Z = 0

F_A = 830.743 kmol

F_B = 1.6444 kmol

F_C = 0

T = 250^{0}C

Ts = 30^{0}C

~ asumsi U_D = 27 btu/hr ft^2 ^{0}F
= 3.6793 10^{-3} kJ/hr cm^2 K

Penyelesaian

~ untuk Z = 10 cm → ΔZ = dz = 10 cm

mencari dx dari persamaan neraca massa (1)

$$dx = \frac{\frac{\pi}{4} D^2 \rho .10^{-3} r_A (1-\varepsilon) dz}{F_A}$$

$$= \frac{\frac{\pi}{4} 6.2713^2\, 3.7209\ 10^{-3} (0.4T - 192.2) 0,5}{830.743}$$

$$= \frac{\frac{\pi}{4} 6.2713^2\, 3.7209\ 10^{-3} (0.4\ 523 - 192.2) 0,5}{830.743}$$

$$= 0.01442$$

$$x = x + dx = 0.01442$$

~ mencari dT

dari persamaan (3)

$$\Sigma m_i \frac{dHf_i}{dz} = \Sigma m_i\, Cp \frac{dT}{dz}$$

$$= 1\left\{F_A(1-X_A)(2.211+12.216\ 10^{-3}T - 3.45\ 10^{-6}T^2)\right\} + \left\{(F_B + 0.5F_A X_A)(3.518 + 20.001\ 10^{-3}T - 6.00210^{-2}T^2)\right\} +$$

$$\left\{(F_C + 0.5F_A X_A).(3.4710 + 1.45\,10^{-3}T + \frac{0.12110^5}{T^2})\right\} x\, 8.314 \frac{dT}{dz}$$

$$= 52914.3229 \frac{dT}{dz}$$

dari persamaan (5)

$$\Delta H_R = \Delta H_{298} + \int_{298}^{T} Cp\, dt$$

$$= -223576 + \left[-21.3337\,(T - 298) - 0.0124\,(T^2 - 298^2) + 2.4887\ 10^{-6}(T^3 - 298^3) + 1.006\ 10^5 (\frac{1}{T} - \frac{1}{298})\right]$$

$$= -220246.4091$$

dari persamaan (4)

$$\Sigma Hf_i \frac{dm_i}{dz} = F_A\, \Delta H_R \frac{dx}{dz}$$

$$= 830,743. -220246,4091\ \frac{0,01442}{10}$$

$$= -263840,0905$$

~ mencari dT dari persamaan (2)

$$\frac{d(\Sigma m_i Hf_i)}{dz} = 1{,}05\, U_D \pi\, D(T - T_S)$$

$$\Sigma m_i \frac{dHf_i}{dz} + \Sigma Hf_i \frac{dm_i}{dz} = 1{,}05\ U_D \pi\ D\ (\ T - Ts\ )$$

$$\Sigma m_i Cp_i \frac{dT}{dz} + \Sigma Hf_i \frac{dm_i}{dz} = 1{,}05\ U_D \pi\ D\ (\ T - Ts\ )$$

$$52914{,}3229 \frac{dT}{dz} + -263840{,}0905 = 1{,}05.3{,}6793.10^{-3}\ .\pi.6{,}2713\ (\ 523 - 303\ )$$

dT = 3,3314

T = T + dT = 526,3314 K

~ mencari dTs dari persamaan (8)

$$dTs = \frac{\pi.Do.U_D(T - Ts).\Delta Ts.dz}{F_A.Nt.\Delta H_R.x}$$

$$= \frac{\pi.7.3152.3.679310^{-3}(523-303).15.10}{830.743.76.220246.40910.01442}$$

= 1.2408

Ts = Ts + dTs = 304.2408 K

Dengan cara yang sama didapat

Z, cm	X, %	T, K	Ts, K
0	0	523	303
10	1.4417	526.3314	304.2408
20	3.1105	530.1028	305.3416
30	5.0422	534.3581	306.3231
40	6.9883	538.5351	307.3313
50	8.9490	542.6354	308.3664
60	10.9245	546.6604	309.4286
70	12.9147	550.6117	310.5180
80	15.2184	555.0532	311.4932
90	17.8850	560.0239	312.3715
100	20.9715	565.5590	313.1678
110	24.5441	571.6874	313.8950
120	28.6795	578.4281	314.5646

130	33.4661	585.7866	315.1866
140	39.0067	593.7505	315.7702
150	45.4199	602.2846	316.3238
160	52.9111	611.4020	316.8510
170	61.6617	621.0050	317.3607
180	70.9154	630.1114	317.9084
190	80.7012	638.7037	318.4989

Maka untuk x = 80% → z = 190 cm

T = 638.0894 K

Ts = 318.4567 K

Mengecek U_D

Bagian shell: air pendingin	**Bagian tube: gas**
*. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ = 0.72" B = 5" $= \frac{78,0079.5.0,72}{144.3,6}$ = 0.5417 ft^2	*'. Re_t = 2400 *' j_H = 50 [fig.24] $k_{methanol}$ = 0,037Btu/(hr).(ft^2).(°F/ft) [table 5] $c_{methanol}$ = 0,77 Btu/(lb).(°F) [fig 3]
*. Massa air (w) = 49101.7372 kg/hari = 13696,5961 lb/jam $G_s = \frac{w}{a_s} = \frac{13696.5961}{0.5417}$ = 25284.4676 lb/(hr).(ft^2)	*'. $h_i = j_H.\frac{k}{D}.\left(\frac{c.\mu}{k}\right)^{1/3}$ $= 50\frac{0.037}{2.88/12}\left(\frac{0.77 \quad 0.0349 \quad 2.42}{0.037}\right)^{1/3}$ = 39.3026 Btu/(hr).(ft^2).(°F)
*. Pada t_c = 67,5°F μ = 1 cp = 2,42 lb/ (ft).(hr) $De = \frac{4\left(P_T^2 - \frac{\pi}{4}do^2\right)}{\pi\, do}$ $= \frac{4\left(3.6^2 - \frac{\pi}{4}2.88^2\right)}{\pi\, 2.88} = 2.8525$	*' $h_{io} = h_i.\frac{ID}{OD} = 39.3026\frac{2.469}{2.88}$ = 33.6938 Btu/(hr).(ft^2).(°F)

$$Re_s = \frac{Gs\ De}{\mu} = \frac{25284.4676\ 2.8525}{2.42}$$

$$= 29803.2826$$

*. $j_H = 90$ [fig.28]

Pada $t_c = 67{,}5^oF$

$k_{air} = 0{,}347$ Btu/(hr).(ft^2).(^oF/ft) [table 4]

$c_{air} = 1$ Btu/(lb).(^oF) [fig.2]

$$h_o = j_H \cdot \frac{k}{D_e} \cdot \left(\frac{c.\mu}{k}\right)^{1/3}$$

$$= 90 \frac{0.347}{2.8525} \left(\frac{1\ 2.42}{0.347}\right)^{1/3}$$

$$= 124.4055 \text{ Btu/(hr).(ft}^2\text{).(}^o\text{F)}$$

$$U_c = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{33.6938\,124.4055}{33.6938+124.4055}$$

$$= 29.5379 \text{ Btu/(hr).(ft}^2\text{).(}^o\text{F)}$$

$Rd \approx 0{,}003$ (hr).(ft^2).(^{o}F)/Btu > 0,0015

$$U_D = \frac{1}{R_D + \frac{1}{Uc}} = \frac{1}{0.003 + \frac{1}{29.5379}} = 27.1335 \approx 27$$ asumsi U_D cocok

Luas perpindahan panas = A = Nt.a".L $= 76.0{,}7533. \frac{108.38}{2.54\ 12}$

$= 204\ ft^2$

Menghitung Pressure Drop

$$\frac{\Delta P}{G'^2} \frac{\rho}{L} \frac{D}{1-\varepsilon} \frac{\varepsilon^3}{} = \frac{150}{N_{Re}} + 1.75$$

dimana G' $= 0.4841$ kg/cm^2 jam $= 0.1743$ kg m^2 sec

L $= 189.285$ cm $= 1.8929$ m

D $= 2.469" = 0.0627$ m

$N_{Re} = 2400$

BM = 60 lb/lbmol

Asumsi $\Delta P = 0.3$ atm

$P_2 = 20 - 0.3 = 19.7$ atm

$P_{avg} = (P_1+P_2)/2 = 19.85$ atm

$T_{avg} = (T_1+T_2)/2 = 580.5447$ K

$$\rho_{camp} = \frac{BM}{V_o}\cdot\frac{P_{avg}}{P_o}\cdot\frac{T_o}{T_{avg}} = \frac{60}{359}\cdot\frac{19.85}{1}\cdot\frac{273}{580.5447}$$

$= 1.5717$ lb/ft^3 $= 25.1783$ kg/m^3

$$\text{maka } \frac{\Delta P}{G'^2}\frac{\rho}{L}\frac{D}{1-\varepsilon}\frac{\varepsilon^3}{} = \frac{150}{N_{Re}} + 1.75$$

$$\frac{\Delta P}{0.1743^2}\frac{25.1783}{1.8929}\frac{0.0627}{1-0.5}\frac{0.5^3}{} = \frac{150}{2400} + 1.75$$

$\Delta P = 0.2633$ atm ≈ 0.3 atm

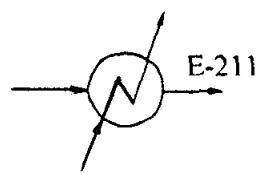
12. Spesifikasi Reaktor (R-210)

Fungsi		: Untuk mendehidrasikan methanol
Type		: Multi turbular fixed bed reaktor
Dasar pemilihan		: Luas area perpindahan panas besar sehingga suhu reaksi dapat dipertahankan
Suhu operasi		: 250°-365°C
Tekanan operasi		: 15 atm
Dimensi		
~ Shell	ID	: 110 cm
	Baffle space	: 5"
~ Tube	ID	: 2.469"
	OD	: 2.88"
	Jumlah	: 76
	Passes	: 1
	Susunan	: square
~ Panjang		: 190 cm
~ Luas perpindahan panas		: 204 ft^2

Bahan konstruksi : Carbon stell

Jumlah : 1 buah

13. HEATER (E-211)

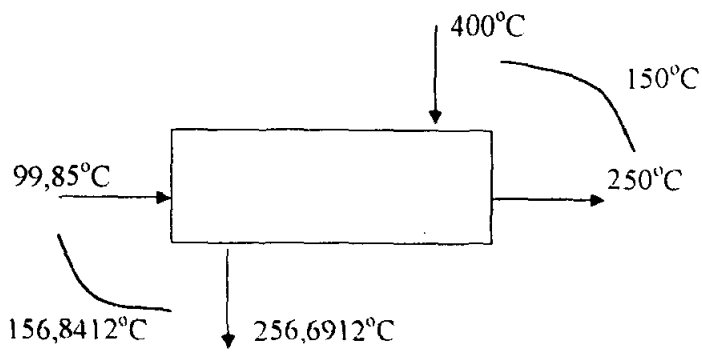


Fungsi : memanaskan metanol sebelum masuk reaktor

Type : Shell and Tube Heat Exchanger (STHE)

Dari perhitungan sebelumnya didapat:

- metanol masuk = 21374,4324 kg/hari = 1963,4197 lb/jam
- Q = 24220066,0188 kJ/hari = 956504,2908 Btu/jam
- Massa steam = 13121,5212 kg/hari = 1205,3211 lb/jam



1. $\Delta T_{LMTD} = \dfrac{156,8412 - 150}{\ln\left(\dfrac{156,8412}{150}\right)} = 154,795^{\circ}C = 310,6311^{\circ}F$

2. $T_c = \dfrac{400 + 256,6912}{2} = 328,3456^{\circ}C = 623,0021^{\circ}F$

$t_c = \dfrac{99,85 + 250}{2} = 174,925^{\circ}C = 347^{\circ}F$

3. Asumsi :

U_D = 30 Btu/(hr).(ft^2).(^oF)

$Q = U_D.A.\Delta T$

$$A = \frac{Q}{U_D.(T_c - t_c)} = \frac{956504,2908}{30.(623,0021-347)} = 115.519 \text{ ft}^2$$

Dipilih ukuran pipa:

¾" OD, 16 BWG, 15/16" triangular pitch, L = 7 ft

$$N_t = \frac{A}{a".L} = \frac{115.519}{0,1963.7} = 84.0688$$

Dari table 9, Kern diperoleh:

ID = 13¼"

N_t = 86

Passes = 8

U_D koreksi

$A = Nt.a".L$

$= 86.0,1963.7 = 118 \text{ ft}^2$

$Q = U_D.A.\Delta T$

$$U_D = \frac{956504,2908}{118.(623,0021-347)}$$

$= 29.3263 \approx 30$ Btu/(hr).(ft^2).(^oF)

Bagian shell: steam	**Bagian tube: methanol**
4. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ $= 15/16 - 3/4 = 0,1875$ B = 5" $= 13,25.\frac{0,1875.5}{144.15/16}$ $= 0,092 \text{ ft}^2$	4'. $a'_t = 0,302 \text{ ft}^2$ [table 10] $a_t = \frac{N_t.a'_t}{144.n} = \frac{86.0,302}{144.8}$ $= 0,0225 \text{ ft}^2$ 5'. $G_t = \frac{w}{a_t} = \frac{21374,4324}{0,0225}$ $= 948072.7755$ lb/(hr).(ft^2)

5. $G_s = \frac{w}{a_s} = \frac{13121,5272}{0,092}$

$= 142625.2957$ lb/(hr).(ft^2)

6. Pada $T_c = 623,0021^oF$

$\mu = 0,021$ cp $= 0,0508$ lb/ (ft).(hr)

$De = \frac{0,55}{12} = 0,0458\ ft$ [fig 28]

$Re_s = \frac{D_e.G_s}{\mu} = \frac{0,0458.142625,2957}{0,0508}$

$= 128680.959$

7. $h_o = 1500$ Btu/(hr).(ft^2).(^{o}F)

(*condensate steam*)

6'. Pada $t_c = 347^oF$

$\mu_{metanol} = 0,11$Cp [fig.15]

$= 0,11$ cp x 2,42

$= 0,2662$ lb/(ft).(hr)

$D = \frac{0,620}{12} = 0.0517$ ft [table 10]

$Re_t = \frac{G_t.D}{\mu} = \frac{0,0517.948072,7755}{0,2662}$

$= 184129.8366$

7'. $j_H = 60$ [fig.24]

Pada $t_c = 347^oF$

$k_{methanol} = 0,111$ Btu/(hr).(ft^2).(^{o}F/ft) [table 5]

$c_{methanol} = 0,75$ Btu/(lb).(^{o}F) [fig 3]

8'. $h_i = j_H.\frac{k}{D}.\left(\frac{c.\mu}{k}\right)^{1/3}$

$= 60.\frac{0,111}{0,0517}.\left(\frac{0,75.0,2662}{0,111}\right)^{1/3}$

$= 156,6628$ Btu/(hr).(ft^2).(^{o}F)

9'. $h_{io} = h_i.\frac{ID}{OD} = 156,6628.\frac{0,62}{0,75}$

$= 129,5079$ Btu/(hr).(ft^2).(^{o}F)

10. $U_c = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{129,5079.1500}{129,5079+1500}$

$= 119,215$ Btu/(hr).(ft^2).(^{o}F)

$R_D = \frac{U_C-U_D}{U_C.U_D} = \frac{119,215-30}{119,215.30}$

$= 0,0249$ (hr).(ft^2).(^{o}F)/Btu > 0,0015

Pressure Drop

Bagian Shell: steam	Bagian Tube: methanol
1. Re_s = 128680.959 f = 0,0014 ft^2/in^2 [fig.29] 2. specific volume = 1,8438 ft^3/lb [table 7] $s = \frac{1}{1,8438.62,4} = 8,6916.10^{-3}$ $N+1 = 12.\frac{L}{B} = 12.\frac{7}{5} = 16.8$ $D_s = \frac{13.25}{12} = 1.1042 ft$ 3. $\Delta P_s = \frac{1}{2}.\frac{f.G_s^2.D_s.(N+1)}{5,22.10^{10}.D_e.s.\varphi_s}$ $= \frac{1}{2}.\frac{0,0014.(142625,2957)^2.1,1042.16,8}{5,22.10^{10}.0,0458.8,6916.10^{-3}.1}$ = 0,6356 psia < 1 psia	1'. Re_t = 184129.8366 f = 0,00013 ft^2/in^2 [fig.26] Vc = 118 cm^3/mol specific volume = $\frac{118}{32}$ = 3.6875 cm^3/gr = 0.0591 ft^3/lb $s = \frac{1}{0.0591\,62.4} = 0.2712$ 2'. $\Delta P_t = \frac{f.G_t^2.L.n}{5,22.10^{10}.D.s.\varphi_t}$ $= \frac{0,00013.(948072.7755)^2.7.8}{5,22.10^{10}.0,0517.0,2712.1}$ = 8.9405 psia < 10 psia

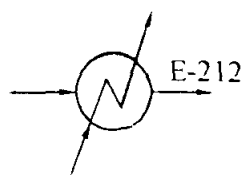
Summary

1500	h outside	129,5079
Uc	= 119,215	
U_D	= 30	
R_d calcutated	= 0,0249	
R_d required	= 0,0015	
0,6356	Calculated ΔP	8,9465
1	Allowable ΔP	10

13. Spesifikasi Heater (E-211)

Fungsi		: Untuk memanaskan methanol sebelum masuk reactor
Type		: Shell and Tube Heat Exchanger (STHE)
Dasar Pemilihan		: Kapasitas besar, cocok untuk tekanan oprasi besar, luas perpindahan panas besar
Dimensi		
~ Shell	ID	: 13¼ "
	Baffle space	: 5"
~ Tube	ID	: 1,37"
	OD	: 1,5"
	Jumlah	: 86
	Passes	: 8
	Pitch	: $^{15}/_{16}$ "
	Susunan	: triangular
~ Panjang		: 7 ft
~ Luas perpindahan panas		: 118 ft^2
Bahan konstruksi		: Carbon stell
Jumlah		: 1 buah

14. HEATER (E-212)



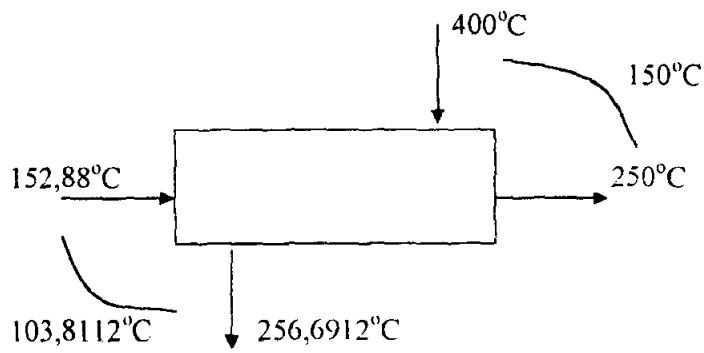
Fungsi : memanaskan destilat sebelum masuk reaktor

Type : Shell and Tube Heat Exchanger (STHE)

Dari perhitungan sebelumnya didapat:

- Destilat masuk:

methanol	= 5209,3425	kg/hari	=	478,5215	lb/jam
H_2O	= 29,5986	kg/hari	=	2,7189	lb/jam
	Total		=	481.2404	lb/jam
- Q	= 5429237,5012	kJ/hari	=	214412,6677	Btu/jam
- Massa steam	= 2941,3568	kg/hari	=	270,1881	lb/jam



1. $\Delta T_{LMTD} = \dfrac{150-103,8112}{\ln\left(\dfrac{150}{103,8112}\right)} = 125,4921^{\circ}C = 257,8858^{\circ}F$

2. $T_c = \dfrac{400+256,6912}{2} = 328,3456^{\circ}C = 623,0021^{\circ}F$

$t_c = \dfrac{152,88+250}{2} = 201,44^{\circ}C = 394,592^{\circ}F$

3. Asumsi :

U_D = 15 Btu/(hr).(ft^2).($^{\circ}$F)

$Q = U_D.A.\Delta T$

$$A = \frac{Q}{U_D.(T_c - t_c)}$$

$$= \frac{214412,6677}{15.(623,0021-394,592)} = 62,5812\ ft^2$$

Dipilih ukuran pipa:

¾" OD, 16 BWG, 15/16" triangular pitch, L = 7 ft

$$N_t = \frac{A}{a''.L}$$

$$= \frac{62.5812}{0,1963.7}$$

$$= 45,5434$$

Dari table 9, Kern diperoleh:

ID = 10"

N_t = 47

Passes = 4

U_D koreksi

$$A = Nt.a''.L$$

$$= 47.0,1963.7$$

$$= 65 \text{ ft}^2$$

$$Q = U_D.A.\Delta T$$

$$U_D = \frac{214412,6677}{65.(623,0021 - 394,592)}$$

$$= 14,5351 \approx 15 \text{ Btu/(hr).(ft}^2\text{).(°F)}$$

Bagian shell: steam	**Bagian tube: destilat**
4. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ $= 15/16 - 3/4 = 0,1875$ B = 5" $= 10.\frac{0,1875.5}{144.15/16} = 0,0694 \text{ ft}^2$	4'. a'_t = 0,302 ft² [table 10] $a_t = \frac{N_t.a'_t}{144.n} = \frac{47.0,302}{144.4}$ $= 0,0246 \text{ ft}^2$
5. $G_s = \frac{w}{a_s} = \frac{270,1881}{0,0694}$ $= 3890,7086 \text{ lb/(hr).(ft}^2\text{)}$	5'. $G_t = \frac{w'}{a_t} = \frac{481,2404}{0,0246}$ $= 19528.9890 \text{ lb/(hr).(ft}^2\text{)}$
	6'. Pada t_c = 394,592°F $\mu_{metanol}$ = 0,107 cp [fig.15] = 0,107 cp x 2,42 = 0,2589 lb/(ft).(hr)

6. Pada T_c = 623,0021°F

μ = 0,021 cp = 0,0508 lb/ (ft).(hr)

$De = \frac{0,55}{12} = 0,0458\ ft$ [fig 28]

$Re_s = \frac{D_e.G_s}{\mu} = \frac{0,0458.3890,7086}{0,0508}$

= 3510.3178

7. h_o = 1500 Btu/(hr).(ft^2).(°F)

(*condensate steam*)

$D = \frac{0,620}{12} = 0,0517$ ft [table 10]

$Re_t = \frac{G_t.D}{\mu} = \frac{0,0517.19528,9890}{0,2589}$

= 3899.7633

7'. j_H = 20 [fig.24]

Pada t_c = 394,592°F

$k_{methanol}$ = 0,105 Btu/(hr).(ft^2).(°F/ft) [table 5]

$c_{methanol}$ = 0,77 Btu/(lb).(°F) [fig 3]

8'. $h_i = j_H.\frac{k}{D}.\left(\frac{c.\mu}{k}\right)^{1/3}$

$= 20.\frac{0,105}{0,0517}.\left(\frac{0,77.0,2589}{0,105}\right)^{1/3}$

= 50.2967 Btu/(hr).(ft^2).(°F)

9'. $h_{io} = h_i.\frac{ID}{OD} = 50,2967.\frac{0,62}{0,75}$

= 41,5786 Btu/(hr).(ft^2).(°F)

10. $U_c = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{41,5786.1500}{41,5786+1500}$

= 40.4572 Btu/(hr).(ft^2).(°F)

$R_D = \frac{U_C-U_D}{U_C.U_D} = \frac{40,4572-15}{40,4572.15}$

= 0,0419 (hr).(ft^2).(°F)/Btu > 0,0015

Pressure Drop

Bagian Shell: steam	Bagian Tube: destilat
1. Re_s = 3510.3178 f = 0,0025 ft^2/in^2 [fig.29] 2. specific volume = 1,8438 ft^3/lb [table 7] $s = \frac{1}{1,8438.62,4} = 8,6916.10^{-3}$ $N+1 = 12.\frac{L}{B} = 12.\frac{7}{5} = 16.8$ $D_s = \frac{10}{12} = 0,833 ft$ 3. $\Delta P_s = \frac{1}{2}.\frac{f.G_s^2.D_s.(N+1)}{5,22.10^{10}.D_e.s.\varphi_s}$ $= \frac{1}{2}.\frac{0,0025.(3890,7086)^2.0,833.16,8}{5,22.10^{10}.0,0458.8,6916.10^{-3}.1}$ = 0,0127 psia < 1 psia	1'. Re_t = 3899.7633 f = 0,00035 ft^2/in^2 [fig.26] 2'. Vc = 118 cm^3/mol specific volume = $\frac{118}{32}$ = 3,6875 cm^3/gr = 0,0591 ft^3/lb $s = \frac{1}{0,0591.62,4} = 0,2712$ $\Delta P_t = \frac{f.G_t^2.L.n}{5,22.10^{10}.D.s.\varphi_t}$ $= \frac{0,00035.(19528,9890)^2.7.4}{5,22.10^{10}.0,0517.0,2712.1}$ = 5,1632 psia < 10 psia

Summary

1500	h outside	41,5786
Uc	= 40,4572	
U_D	= 15	
R_d calcutated	= 0,0419	
R_d required	= 0,0015	
0,0127	Calculated ΔP	5,1632
1	Allowable ΔP	10

14. Spesifikasi Heater (E-212)

Fungsi : Untuk memanaskan destilat sebelum masuk reaktor

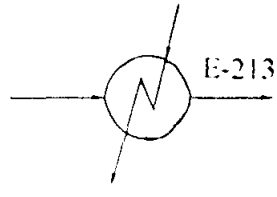
Type : Shell and Tube Heat Exchanger (STHE)

Dasar Pemilihan : Kapasitas besar, cocok untuk tekanan oprasi besar, luas perpindahan panas besar

Dimensi

~ Shell	ID	: 10"
	Baffle space	: 5"
~ Tube	ID	: 1,37"
	OD	: 1,5"
	Jumlah	: 47
	Passes	: 4
	Pitch	: $^{15}/_{16}$"
	Susunan	: triangular
~ Panjang		: 7 ft
~ Luas perpindahan panas		: 65 ft^2
Bahan konstruksi		: Carbon stell
Jumlah		: 1 buah

15. COOLER (E-213)

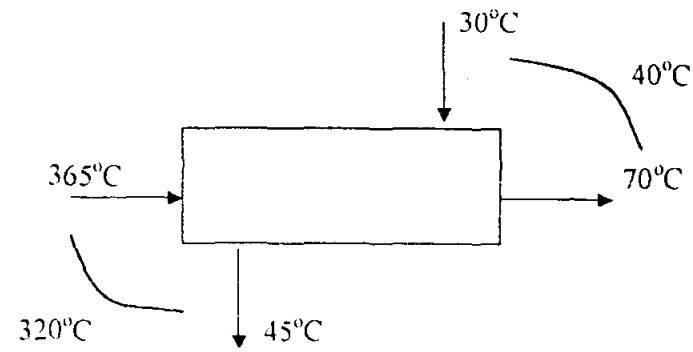


Fungsi : untuk menurunkan suhu gas hasil reactor R-210

Type : Shell and Tube Heat Exchanger (STHE)

Dari perhitungan sebelumnya didapat:

- metanol	=	5316,752	kg/hari	=	488,388 lb/jam
- H_2O	=	6010,9476	kg/hari	=	552,1556 lb/jam
- DME	=	15285,6739	kg/hari	=	1404,1165 lb/jam
		Total		=	2444,6601 lb/jam
Q	=	27152165,7990	kJ/hari	=	1072299,434 Btu/jam
Massa air	=	432893,5571	kg/hari	=	39764,8802 lb/jam



1. $\Delta T_{LMTD} = \dfrac{320-40}{\ln\left(\dfrac{320}{40}\right)} = 134,6515^{\circ}C = 274,3728^{\circ}F$

2. $T_c = \dfrac{365+70}{2} = 217,5^{\circ}C = 423,5^{\circ}F$

$t_c = \dfrac{30+45}{2} = 37,5^{\circ}C = 67,5^{\circ}F$

3. Asumsi :

$U_D = 30$ Btu/(hr).(ft^2).($^{\circ}$F)

$Q = U_D.A.\Delta T$

$A = \dfrac{Q}{U_D.(T_c - t_c)}$

$= \dfrac{1072299,434}{30.(423,5-67,5)}$

$= 100,4025$ ft^2

Dipilih ukuran pipa:

¼" OD, 16 BWG, 1" square pitch, L = 10 ft

$N_t = \dfrac{A}{a''.L}$

$= \dfrac{100,4025}{0,1963.10} = 43,8407$

Dari table 9, Kern diperoleh:

ID = 10"

N_t = 52

Passes = 2

U_D koreksi

$A = Nt.a".L$

$= 52.0,1963.10$

$= 102\ ft^2$

$Q = U_D.A.\Delta T$

$$U_D = \frac{1072299,434}{102.(423,5 - 67,5)}$$

$= 29,5082 \approx 30\ Btu/(hr).(ft^2).(^oF)$

Bagian shell: gas	**Bagian tube: air pendingin**
4. $a_s = ID.\frac{C".B}{144.P_T} \rightarrow C" = P_T - OD$ $= 1 - \frac{1}{4} = 0,25$ $B = 5"$ $= 10.\frac{0,25.5}{144.1} = 0,0868\ ft^2$	4'. $a'_t = 0,302\ ft^2$ [table 10] $a_t = \frac{N_t.a'_t}{144.n} = \frac{52.0,302}{144.2}$ $= 0,0545\ ft^2$
5. $G_s = \frac{w}{a_s} = \frac{2444,6601}{0,0868}$ $= 28164,2869\ lb/(hr).(ft^2)$	5'. $G_t = \frac{w}{a_t} = \frac{39764,8802}{0,0545}$ $= 729630,8294\ lb/(hr).(ft^2)$ $v = \frac{G_t}{3600.\rho} = \frac{729630,8294}{3600.62,4}$ $= 3,248\ fps$
6. Pada $T_c = 423,5^oF$ $\mu_{metanol} = 0,0155$ $\mu_{air} = 0,0165$ [fig.15] $\mu_{DME} = 0,014$ $\mu_{campuran} = \Sigma x_i.\mu_i$ $= 0,01486\ cp \times 2,42$ $= 0,03597\ lb/(ft).(hr)$	6'. Pada $t_c = 67,5^oF$ $\mu_{air} = 1\ cp \times 2,42$ $= 2,42\ lb/(ft).(hr)$ $D = \frac{0,62}{12}$ $= 0,0517\ ft$ [table 10]

$De = \frac{0,95}{12} = 0,0792\ ft$ [fig 28]

$Re_s = \frac{D_e.G_s}{\mu} = \frac{0,0792.28164,2869}{0,03597}$

$= 62031.1087$

7. $j_H = 180$ [fig.28]

Pada $T_c = 423,5^oF$

$k_{metanol} = 0,014$

$k_{air} = 0,0187$ [table 5]

$k_{DME} = 0,0209$

$k_{campuran} = \Sigma x_i . k_i$

$= 0,019$ Btu/(hr).(ft^2).(^{o}F/ft)

$c_{metanol} = 0.71$

$c_{air} = 0,48$ [fig 3]

$c_{DME} = 0,539$

$c_{campuran} = \Sigma x_i . c_i$

$= 0,6586$ Btu/(lb).(^{o}F)

$$8'.\ h_o = j_H.\frac{k}{D}.\left(\frac{c.\mu}{k}\right)^{1/3}$$

$$= 180.\frac{0,019}{0,0792}.\left(\frac{0,6586.0,03597}{0,019}\right)^{1/3}$$

$= 46,4769$ Btu/(hr).(ft^2).(^{o}F)

$Re_i = \frac{D.G_t}{\mu_{air}} = \frac{729630,8294.0,0517}{2,42}$

$= 15587.5677$

8'. $h_i = 680$ Btu/(hr).(ft^2).(^{o}F) [fig.25]

$$9'.\ h_{io} = h_i.\frac{ID}{OD}$$

$$= 680.\frac{0,62}{0,75}$$

$= 562.1333$ Btu/(hr).(ft^2).(^{o}F)

$$10.\ U_c = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{562,1333.46,4769}{562,1333+46,4769}$$

$= 42,9277$ Btu/(hr).(ft^2).(^{o}F)

$$R_D = \frac{U_C-U_D}{U_C.U_D} = \frac{42,9277-30}{42,9277.30}$$

$= 0,01$ (hr).(ft^2).(^{o}F)/Btu > 0,0015

Pressure Drop

Bagian Shell: gas	Bagian Tube: air pendingin
1. Re_s = 62031.1087 f = 0,0015 ft^2/in^2 [fig.29]	1'. Re_t = 15587.5677 f = 0,0002 ft^2/in^2 [fig.26]
2. $N+1 = 12.\frac{L}{B} = 12.\frac{10}{5} = 24$ $D_s = \frac{10}{12} = 0{,}8333\,ft$ Vc gas = $\Sigma X_i.Vc_i$ =132.1358 cm^3/mol $BM_{camp} = \Sigma X_i.BMi$ = 36.8832gr/gmol specific volume = $\frac{132{,}1358}{36{,}8832}$ = 3,5825 cm^3/gr = 0,0574 ft^3/lb $s = \frac{1}{0.0574\ 62.4} = 0{,}2791$	2'. $\Delta P_t = \frac{f.G_t^2.L.n}{5{,}22.10^{10}.D.s.\varphi_t}$ $= \frac{0{,}0002.(729630{,}8294)^2.10.2}{5{,}22.10^{10}.0{,}0517.1.1}$ = 0,7891 psia G_t = 729630.8294 $\frac{V^2}{2.g'} = 0{,}07$ [fig.27] $\Delta P_r = \frac{4.n}{s}.\frac{V^2}{2.g'}$ $= \frac{4.2}{1}.0{,}07$ = 0.56 psia $\Delta P_T = \Delta P_t + \Delta P_r$ = 0.7891 + 0.56 = 1.3491 psia < 10 psia
3. $\Delta P_s = \frac{1}{2}.\frac{f.G_s^2.D_s.(N+1)}{5{,}22.10^{10}.D_e.s.\varphi_s}$ $= \frac{1}{2}.\frac{0{,}0015.(28164{,}2869)^2.0{,}8333.24}{5{,}22.10^{10}.0{,}0792.0.2791.1}$ = 0,0103 psia < 2 psia	

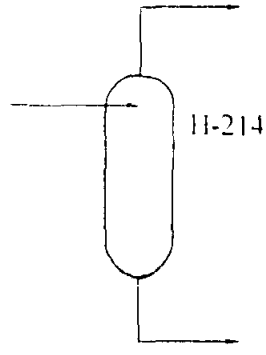
Summary

46,4769	h outside	562,1333
Uc	= 42,9277	
U_D	= 30	
R_d calculated	= 0,01	
R_d required	= 0,0015	
0,0103	Calculated ΔP	1,3491
2	Allowable ΔP	10

15. Spesifikasi Cooler (E-213)

Fungsi	: untuk menurunkan suhu gas hasil reactor R-210	
Type	: Shell and Tube Heat Exchanger (STHE)	
Dasar Pemilihan	: Kapasitas besar, cocok untuk tekanan oprasi besar, luas perpindahan panas besar	
Dimensi		
~ Shell	ID	: 10"
	Baffle space	: 5"
~ Tube	ID	: 1,37"
	OD	: 1,5"
	Jumlah	: 52
	Passes	: 2
	Pitch	: 1"
	Susunan	: square
~ Panjang		: 10 ft
~ Luas perpindahan panas		: 102 ft^2
Bahan konstruksi		: Carbon stell
Jumlah		: 1 buah

16. DRUM SEPARATOR (H-214)



Fungsi : memisahkan DME dari methanol dan air

Type : tangki vertical dengan tutup atas dan bawah ellipsoidal

Rate yang masuk

- methanol = 5316,752 kg/hari
- air = 6010,9476 kg/hari

$\rho_{methanol}$ = 0,78664 g/cm^3

ρ_{air} = 1 g/cm^3

$$\text{Rate volumetric} = \frac{5316,752.10^3}{0,78664} + \frac{6010,9476.10^3}{1} = 1276976035 \text{ cm}^3\text{/hari}$$

$$= 18,7891 \text{ ft}^3\text{/jam} \approx 19 \text{ ft}^3\text{/jam}$$

Keterangan : H = 1,5 D

Liquid mengisi ¾ bagian shell

Volume liquid = ¾ volume shell + volume konis

Volume liquid = ¾ volume shell + volume elipsoidal

$$19 = \frac{3}{4}\left(\frac{\pi}{4} D^2.H\right) + 0.131328\ D^3$$

$$19 = \frac{3}{4}\left(\frac{\pi}{4} D^2.1,5D\right) + 0.131328\ D^3$$

$$19 = 0,8831\ D^3 + 0,131328\ D^3$$

$$19 = 1.0144\ D^3$$

$$D^3 = 19,6006$$

$$D_{shell} = 2,6962 \text{ ft} \approx 3 \text{ ft}$$

$$H_{shell} = 1,5\ D = 4,0443 \text{ ft}$$

$$H_{elipsoidal} = \frac{D}{4} = \frac{2,6962}{4} = 0,6741 \text{ ft}$$

$$H_{tangki} = H_{shell} + 2 \times H_{elipsoidal}$$

$$= 4,0443 + 2 \times 0,674$$

$$= 5,3923 \text{ ft} \approx 5,5 \text{ ft}$$

Tebal Shell

$$t_{shell} = \frac{P.D}{2.f.E} + c$$

dimana:

* $f_{allow} = f_u.f_m.f_s.f_a.f_r$

  f_u = 75000 psia (untuk SA-240 grade S tipe 304)

  f_m = 0,92 (untuk bahan kualitas C → *structure steel*)

  f_a = 1,0 (tidak dikenakan *radiograph*)

  f_r = 1,0 (tidak dikenakan *stress relief*)

  $f_{allow} = f_u.f_m.f_s.f_a.f_r$ = 17250 psi

* E = 0,8 dengan type pengelasan Double Welded Butt Joint

* $P = \frac{\rho.(H-1)}{144}$

  $\rho = (0,4694.45,1099) + (0,5306.62,4)$ g/cm^3 = 56,1616 lb/ft^3

  $H = \frac{3}{4} H_{shell} + H_{elipsoidal}$

  $= \frac{3}{4}$ 4.0443 + 0.6741 = 3.7073 ft

  $P = \frac{56,1616.(3,7073-1)}{144} = 1,0965$ psia

  $P_{operasi}$ = (15 x 14,7) + P = 220 + 1,0965 = 221.0965 psia

  untuk safety $P_{operasi}$ = 1,2 . 221.0965 = 265.3158 psia

Maka,

$$t_{shell} = \frac{265,3158.3.12}{2.17250.0,8} + 0,1$$

$$= 1,226" \approx 1,3"$$

Tebal Elipsoidal

$$v = \frac{1}{6}\left(2 + k^2\right)$$

$$= \frac{1}{6}\left(2 + 2^2\right) = 1$$

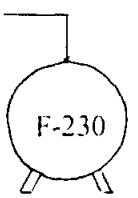
$$t_{elipsoidal} = \frac{P.D.v}{2.f.E - 0,2.P} + c$$

$$= \frac{265,3158.3.12.1}{2.17250.0,8 - 0,2.19,3423} + 0,1 = 1,226" \approx 1,3"$$

16. Spesifikasi Drum Separator (H-214)

Fungsi	: memisahkan DME dari methanol dan air
Type	: Tangki vertical dengan tutup atas dan bawah elipsoidal
Dasar pemilihan	: Untuk memisahkan fasa cair dan gas yang tidak saling larut secara cepat.
Kapasitas	: 19 ft^3
Suhu operasi	: 70°C
Tekanan operasi	: 15 atm
Dimensi	
~ diameter shell	: 3 ft
~ tebal shell	: 1.3"
~ tebal ellipsoidal	: 1.3"
~ tinggi	: 5,5 ft
Bahan konstruksi	: Carbon stell
Jumlah	: 1 buah

17. STORAGE TANK (F-230)



Fungsi : menyimpan produk DME

Type : bola

Direncanakan: T penyimpanan = 30°C = 303 K

P penyimpanan = 10 atm

Rate = 15285,6739 kg/hari

Densitas = 649 kg/m^3

Maka volume liquid = 19,8546 m^3/ hari

Jika disimpan dengan waktu tinggal 15 hari, maka kapasitas tangki ≈ 300 m^3

$$300 = \frac{4}{3}.\pi.\left(\frac{1}{2}.D\right)^3$$

$$D^3 = 573,2484$$

$$D = 9 \text{ m}$$

$$r = 4,5 \text{ m}$$

Tebal dinding

$$t_{shell} = \frac{P.r}{1,8.f - 0,2.P} + c \qquad \text{(Ulrich, p.250)}$$

dimana:

$f_{allow} = f_u.f_m.f_s.f_a.f_r$

f_u = 75000 psia (untuk SA-240 grade S tipe 304)

f_m = 0,92 (untuk bahan kualitas C → *structure steel*)

f_a = 1,0 (tidak dikenakan *radiograph*)

f_r = 1,0 (tidak dikenakan *stress relief*)

$f_{allow} = f_u.f_m.f_s.f_a.f_r$ = 17250 psi

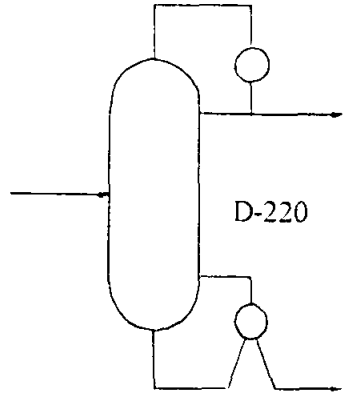
Maka,

$$t_{shell} \quad \frac{(10.14,696).(4,5.39,37)}{1,8.17250 - 0,2.(20.14,696)} + 0,1 = 2.63 \text{ " } \approx 3\text{"}$$

17. Spesifikasi Storage Tank (F-230)

Fungsi	: menyimpan produk DME
Type	: bola
Dasar pemilihan	: tekanan penyimpanan tinggi
Kapasitas	: 300 m^3
Suhu penyimpanan	: 30°C
Tekanan penyimpanan	: 10 atm
Diameter	: 9 m
Bahan konstruksi	: Carbon stell
Jumlah	: 1 buah

18. MENARA DESTILASI (D-220)



Fungsi : memisahkan methanol dan air

Type : Sieve Tray

Menghitung surface tension liquid (σ)

Feed merupakan larutan biner methanol-air

- ρ_{H2O} = 1 gr/cm^3 = 0,0555 gmol/cm^3
- $\rho_{metanol}$ = 0,78664 gr/cm^3 = 0,02458 gmol/cm^3

Dari Perry edisi 5 diperoleh:

- γ_{H2O} (2 x 11,3) + (1 x 20) = 42,6
- $\gamma_{metanol}$ = (1 x 4,8) + (4 x 11,3) + (1 x 20) = 87,8

Maka, σ_{H2O} = $(\gamma_{H2O} \times \rho_{H2O})^4$

= $(42,6 \times 0,0555)^4$

= 31,2741 dyne/cm

$\sigma_{metanol}$ = $(\gamma_{metanol} \times \rho_{metanol})^4$

= $(87,8 \times 0,0246)^4$

= 21,6315 dyne/cm

σ_{camp} = (0,3322 x 21,6315) + (0,6678 x 31,2741)

= 28,0965 dyne/cm

Menentukan jumlah plate minimum

$$\alpha_{LK,HK\ puncak} = \left(\frac{K_{LK}}{K_{HK}}\right)_{puncak}$$

$$= \frac{1,1236}{0,9987} = 1.1251$$

$$\alpha_{LK,HK\ bottom} = \left(\frac{K_{LK}}{K_{HK}}\right)_{bottom}$$

$$= \frac{2,5833}{0,9840} = 2,6253$$

$$\alpha_{rata\text{-}rata} = \sqrt{\alpha_{puncak}.\alpha_{bottom}}$$

$$= \sqrt{1,1251.2,6253}$$

$$= 1,7186$$

$$N_m = \frac{\log\left\{\left(\frac{x_{LK}}{x_{HK}}\right)_D.\left(\frac{x_{HK}}{x_{LK}}\right)_B\right\}}{\log \alpha}$$

$$= \frac{\log\left\{\left(\frac{0,99}{0,01}\right).\left(\frac{0,99}{0,01}\right)\right\}}{\log 1,7186}$$

$$= 8,7159 \text{ stage}$$

Menentukan jumlah plate ideal

$$\frac{R_{operasi} - R_{min}}{R_{operasi} + 1} = \frac{1,0388 - 0,8657}{1,0388 + 1}$$

$$= 0,0874$$

Dari grafik Gilliland didapatkan:

$$\frac{N - N_{min}}{N + 1} = 0,55$$

$$\frac{N - 8,7159}{N + 1} = 0,55$$

$$N - 0,55.N = 8,7159 + 0,55$$

$$N = 20,5909 \approx 21$$

Menentukan diameter kolom

Dipakai jarak antar tray 20"

Dari Ludwig fig.8.50 untuk σ_{camp} = 28,0965 dyne/cm dan jarak antara tray 20" didapat harga konstanta empiris = k = 560.

Rate massa maksimum (G)

$\rho_l \approx \rho_{H2O}$ = 62,4 lb/cuft

$$\rho v = \rho_{metanol} = \frac{BM}{V_o}.\frac{T_o}{T}.\frac{P}{P_o}$$

$$= \frac{32}{359}.\frac{273}{(273+70)}.\frac{14,5}{1}$$

= 1,0287 lb/cuft

$$G = k.\sqrt{\rho_v.(\rho_l - \rho_v)}$$

$$= 560.\sqrt{1,0287.(62,4 - 1,0287)}$$

= 4449,5394 lb/(hr).(ft^2)

Diameter kolom (D)

$$D = \left(\frac{4}{\pi}.\left[\frac{V'}{G}\right]\right)^{1/2}$$

$$= 1,13.\sqrt{\frac{V'}{G}}$$

$$= 1,13.\sqrt{\frac{11327,6996}{4449,5394}} = 1,803 \text{ ft}$$

Menentukan tinggi kolom

Tinggi kolom = jumlah plate x jarak antar plate

= 21 x 20/12 = 35 ft

Tinggi tutup atas dan tutup bawah yang berbentuk ellipsoidal = 2.(¼ .D)

= 0,08061 ft

Total tinggi = (35 + 0,08061) = 35,08061 ft

Dengan menggunakan tebal plate 0,25", maka Di = 1,803 ft

Do = 1,803 + (2 x 0,25/12)

= 1,8447 ft

Menentukan lokasi pemasukan feed

$(x_{IK})_B = 0,01$

$(x_{HK})_D = 0,01$

D = 164,4364 kmol

B = 335,6542 kmol

$(x_{IK})_F = 0,3322$

$(x_{HK})_F = 0,6678$

$$\frac{N_R}{N_S} = \left[\left(\frac{X_{HK,F}}{X_{LK,F}}\right)\left(\frac{X_{LK,B}}{X_{HK,D}}\right)^2\left(\frac{B}{D}\right)\right]^{0,206}$$

$$\frac{N_R}{N_S} = \left[\left(\frac{0,6678}{0,3322}\right)\left(\frac{0,01}{0,01}\right)^2\left(\frac{335,6542}{164,4364}\right)\right]^{0,206}$$

$\frac{N_R}{N_S} = 1,3375 \rightarrow N_R = 1,3375\ N_S$

$N_R + N_S = N$

$1,3375\ N_S + N_S = 20,5909$

$N_S = 8,8089 \approx 9$

$N_R = 11,7819 \approx 12$

Maka feed masuk pada stage ke 12 dari atas atau stage ke 9 dari bawah

Menentukan isolasi/heat losses

Diameter rata-rata = (1,803 + 1,8447)/2 = 1,8239 ft

Exposed area

- Head ellipsoidal = $2.(1,09.D^2)$ = $2.(1,09.1,8239^2)$ = 5,8134 ft^2
- Sisi silinder = $\pi.D.H$ = 3,14.1,8239.35,08061 = 179,9713 ft^2

Total area = 185,7847 ft^2

Digunakan isolator dari calcium silicate, k = 0,372 Btu/(hr).(ft^2).(^oF/ft) dengan tebal 2 in

$$U = 0,11.\left(\frac{0,372}{0,23}\right)$$ (dari Frank and Gary, table 8.7)

= 0,178 Btu/(hr).(ft^2).(^oF)

Panas yang hilang = Q = U.A.ΔT

= 0,178.185,7847.(343.94-86)

= 11915,0045 Btu/jam

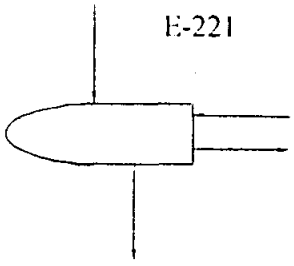
Diameter luar isolasi = $D_o + \left(\frac{2.\text{tebal plate}}{12}\right)$

= $1{,}8447 + \left(\frac{2.2}{12}\right)$ = 2,1572 ft

18. Spesifikasi Menara Destilasi (D-220)

Fungsi	: memisahkan methanol dan air
Type	: Sieve Tray
Dasar Pemilihan	: Bahan yang didestilasi tidak bersifat korosif, dan tidak viscous
Kapasitas	: 64450 kg / hari
Suhu operasi	: 173,2°C
Tekanan operasi	: 15 atm
Dimensi	
~ Diameter	: 2 ft
~ tinggi	: 40 ft
~ tebal isolasi	: 2"
Bahan isolasi	: Calcium silicate
Bahan konstruksi	: Carbon steel
Jumlah	: 1 buah

19. KONDENSER (E-221)

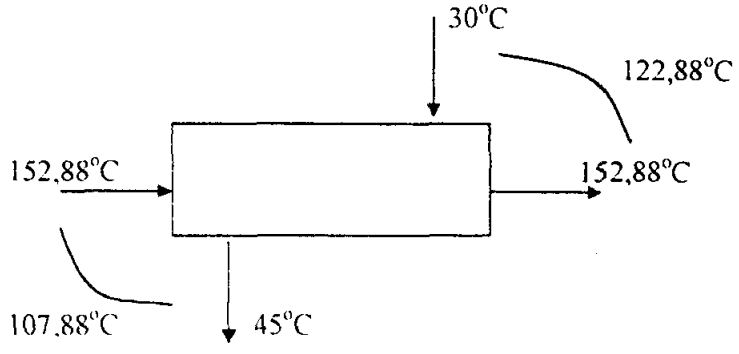


Fungsi : untuk mengkondensasikan produk atas menara destilasi

Type : Shell and Tube Heat Exchanger (STHE)

Dari perhitungan sebelumnya didapat:

- metanol	=	10953,6064	kg/hari	=	1006,1801 lb/jam
- H_2O	=	62,2368	kg/hari	=	5,7169 lb/jam
		Total		=	1011,8970 lb/jam
Qc	=	6188050,361	kJ/hari	=	244379,8757 Btu/jam
Massa air	=	98657,5848	kg/hari	=	9060,8771 lb/jam



1. $\Delta T_{LMTD} = \dfrac{122,88 - 107,88}{\ln\left(\dfrac{122,88}{107,88}\right)} = 115,251^{\circ}C = 239,4518^{\circ}F$

2. $T_c = \frac{152,88 + 152,88}{2} = 152,88^oC = 307,184^oF$

$t_c = \frac{30 + 45}{2} = 37,5^oC = 67,5^oF$

3. Asumsi :

U_D = 24 Btu/(hr).(ft^2).(^oF)

$Q = U_D.A.\Delta T$

$$A = \frac{Q}{U_D.(T_c - t_c)} = \frac{244379,8757}{24.(307,184 - 67,5)} = 42.4830\ ft^2$$

Dipilih ukuran pipa:

¾" OD, 16 BWG, 1" square pitch, L = 9 ft

$$N_t = \frac{A}{a''.L}$$

$$= \frac{42,4830}{0,1963.9} = 24.0465$$

Dari table 9, Kern diperoleh:

ID = 8"

N_t = 26

Passes = 2

U_D koreksi

$A = Nt.a''.L$

$= 26.0,1963.9$

$= 46\ ft^2$

$Q = U_D.A.\Delta T$

$$U_D = \frac{244379,8757}{46.(307,184 - 67,5)}$$

$= 23.1968 \approx 24$ Btu/(hr).(ft^2).(^oF)

Bagian shell: gas	Bagian tube: air pendingin
4. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ $= 1 - \frac{3}{4} = 0,25$ $B = 5"$ $= 8.\frac{0,25.5}{144.1}$ $= 0,0694\ ft^2$	4'. $a'_t = 0,302\ ft^2$ [table 10] $a_t = \frac{N_t.a'_t}{144.n} = \frac{26.0,302}{144.2}$ $= 0,0273\ ft^2$
5. $G_s = \frac{w}{a_s} = \frac{1011,8970}{0,0694}$ $= 14572.2494\ lb/(hr).(ft^2)$	5'. $G_t = \frac{w}{a_t} = \frac{9060,8771}{0,0273}$ $= 332509,2514\ lb/(hr).(ft^2)$ $v = \frac{G_t}{3600.\rho} = \frac{332509,2514}{3600.62,4}$ $= 1.4802\ fps$
6. Pada $T_c = 307.184°F$ $\mu_{metanol} = 0,014\ cp$ [fig.14] $= 0,014\ cp \times 2,42$ $= 0,0339\ lb/(ft).(hr)$ $De = \frac{0,95}{12} = 0,0792\ ft$ [fig 28] $Re_s = \frac{D_e.G_s}{\mu} = \frac{0,0792.14572,2494}{0,0339}$ $= 34044.9013$	6'. Pada $t_c = 67,5°F$ $\mu_{air} = 1\ cp \times 2,42$ $= 2,42\ lb/(ft).(hr)$ $D = \frac{0,62}{12} = 0,0517\ ft$ [table 10] $Re_t = \frac{D.G_t}{\mu_{air}} = \frac{0,0517.332509,2514}{2,42}$ $= 7103.6067$
7. $j_H = 90$ [fig.28] Pada $T_c = 307.184°F$ $k_{metanol} = 0,124\ Btu/(hr).(ft^2).(°F/ft)$ [table 4] $c_{metanol} = 0,71\ Btu/(lb).(°F)$ [fig 3]	8'. $h_t = 450\ Btu/(hr).(ft^2).(°F)$ [fig.25]
8'. $h_o = j_H.\frac{k}{D}\left(\frac{c.\mu}{k}\right)^{1/3}$ $= 90.\frac{0,124}{0,0792}\left(\frac{0,71.0,0339}{0,124}\right)^{1/3}$ $= 81,5864\ Btu/(hr).(ft^2).(°F)$	9'. $h_{io} = h_i.\frac{ID}{OD}$ $= 450.\frac{0,62}{0,75}$ $= 372\ Btu/(hr).(ft^2).(°F)$

10. $U_c = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{372.81,5864}{372+81,5864}$

$= 66.9115$ Btu/(hr).(ft^2).(^{o}F)

$R_D = \frac{U_C-U_D}{U_C.U_D} = \frac{66,9115-24}{66,9115.24}$

$= 0,0267$ (hr).(ft^2).(^{o}F)/Btu > 0,0015

Pressure Drop

Bagian Shell: gas	Bagian Tube: air pendingin
1. $Re_s = 34044.9013$ f = 0,0022 ft^2/in^2 [fig.29]	1'. $Re_t = 7103.6067$ f = 0,00026 ft^2/in^2 [fig.26]
2. $N+1 = 12.\frac{L}{B} = 12.\frac{9}{5} = 21.6$ $D_s = \frac{8}{12} = 0.6667 ft$ Vc = 118 cm^3/mol specific volume = $\frac{118}{32}$ = 3.6875 cm^3/gr = 0.0591 ft^3/lb $s = \frac{1}{0.0591\,62.4} = 0.2712$	2'. $\Delta P_t = \frac{f.G_t^2.L.n}{5,22.10^{10}.D.s.\varphi_t}$ $= \frac{0,00026.(4332509,2514)^2.9.2}{5,22.10^{10}.0,0517.1.1}$ = 0.1917 psia $G_t = 332509.2514$; $\frac{V^2}{2.g'} = 0,02$ [fig.27] $\Delta P_r = \frac{4.n}{s}.\frac{V^2}{2.g'} = \frac{4.2}{1}.0,02$ = 0,16 psia $\Delta P_T = \Delta P_t + \Delta P_r$ = 0.1917 + 0.16 = 0,3517 psia < 10 psia
3. $\Delta P_s = \frac{1}{2}.\frac{f.G_s^2.D_s.(N+1)}{5,22.10^{10}.D_e.s.\varphi_s}$ $= \frac{1}{2}.\frac{0,0022.(14572,2494)^2.0,6667.21,6}{5,22.10^{10}.0,0792.0,2712.1}$ = 0,3 psia < 2 psia	

Summary

81,5864	H outside	372
Uc	= 66,9115	
U_D	= 24	
R_d calcutated	= 0,0267	
R_d required	= 0,0015	
0,3	Calculated ΔP	0,3517
2	Allowable ΔP	10

19. Spesifikasi Condenser (E-221)

Fungsi :Untuk mengkondensasikan produk atas menara destilasi

Type : Shell and Tube Heat Exchanger (STHE)

Dasar Pemilihan : Kapasitas besar, cocok untuk tekanan oprasi besar, luas perpindahan panas besar

Dimensi

~ Shell ID : 8"

Baffle space : 5"

~ Tube ID : 0,62"

OD : ¾ "

Jumlah : 26

Passes : 2

Pitch : 1"

Susunan : square

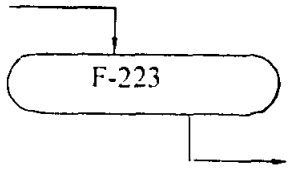
~ Panjang : 9 ft

~ Luas perpindahan panas : 46 ft^2

Bahan konstruksi : Carbon steel

Jumlah : 1 buah

20. AKUMULATOR (F-223)



Fungsi : menampung destilat dari kondensor

Type : tangki horisontal dengan tutup samping ellipsoidal

Rate yang masuk = 10681,1578 kg/hari

ρ = 0,78664 g/cm^3

$$\text{Rate volumetric} = \frac{10681,1578.10^3}{0,78664} = 14003665,21 \text{ cm}^3\text{/hari}$$

= 14,0037 m^3/hari = 494,5321 ft^3/hari

= 20,6055 ft^3/jam ≈ 21 ft^3/jam

Keterangan : L = 2.D

Liquid mengisi ¾ bagian tangki

Volume liquid = ¾ volume shell + volume elipsoidal

$$21 = \frac{3}{4}\left(\left[\frac{\pi}{4}D^2.L\right] + 2.\left[0,131328.D^3\right]\right)$$

$$21 = \frac{3}{4}\left(\left[\frac{\pi}{4}D^2.2.D\right] + 2.\left[0,131328.D^3\right]\right)$$

$$21 = \frac{3}{4}.(1,8335\ D^3)$$

$$21 = 1,375.D^3$$

$$D^3 = 14,9858$$

$$D_{shell} = 2,5 \text{ ft}$$

$$L_{shell} = 2.D = 4,9308 \text{ ft}$$

$$L_{elipsoidal} = 2.\frac{D}{4} = 2.\frac{2,4624}{4} = 1,2327 \text{ ft}$$

$$L_{tangki} = L_{shell} + L_{elipsoidal}$$

= 4,9308 + 1,2327 = 6,1635 ft ≈ 6,5 ft

Tebal Shell

$$t_{shell} = \frac{P.D}{2.f.E} + c$$

dimana:

* $f_{allow} = f_u.f_m.f_s.f_a.f_r$

  f_u = 75000 psia (untuk SA-240 grade S tipe 304)

  f_m = 0,92 (untuk bahan kualitas C → *structure steel*)

  f_a = 1,0 (tidak dikenakan *radiograph*)

  f_r = 1,0 (tidak dikenakan *stress relief*)

  $f_{allow} = f_u.f_m.f_s.f_a.f_r$ = 17250 psi

* E = 0,8 dengan type pengelasan Double Welded Butt Joint

* $P = \frac{\rho.(H-1)}{144}$

  ρ = 0,78664 g/cm^3 = 49,1099 lb/ft^3

  H = ¾ D

  = ¾ 2,4654 = 1,8491 ft

  $$P = \frac{49,1099.(1.8491-1)}{144} = 0,2984 \text{ psia}$$

  $P_{operasi}$ = (15x14,7) + P = 220,5 + 0,2984 = 220,7984 psia

  untuk safety $P_{operasi}$ = 1,2 . 220,7984 = 264,9581 psia

Maka,

$$t_{shell} = \frac{264,9581.2,5.12}{2.17250.0,8} + 0,1$$

$$= 0,384'' \approx 0,41''$$

Tebal Elipsoidal

$$v = \frac{1}{6}.\left(2 + k^2\right)$$

$$= \frac{1}{6}.\left(2 + 2^2\right) = 1$$

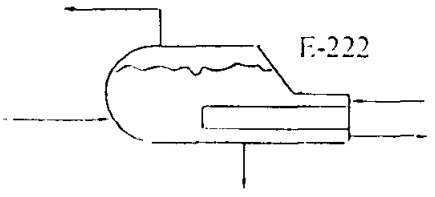
$$t_{ellipsoidal} = \frac{P.D.v}{2.f.E - 0,2.P} + c$$

$$= \frac{264,9581.2,5.12}{2.17250.0,8 - 0,2.17,9981} + 0,1 = 0,384" \approx 0,41"$$

20. Spesifikasi Acumulator (F-223)

Fungsi	: menampung destilat dari kondensor
Type	: Tangki horisontal dengan tutup samping ellipsoidal
Dasar pemilihan	: Tekanan tidak terlalu besar
Kapasitas	: 21 ft^3
Suhu operasi	: 152,88°C
Tekanan operasi	: 15 atm
Dimensi	
~ diameter shell	: 2,5 ft
~ tebal shell	: 0,41"
~ tebal ellipsoidal	: 0,41"
~ panjang	: 6,5 ft
Bahan konstruksi	: Carbon steel
Jumlah	: 1 buah

21. REBOILER (E-222)

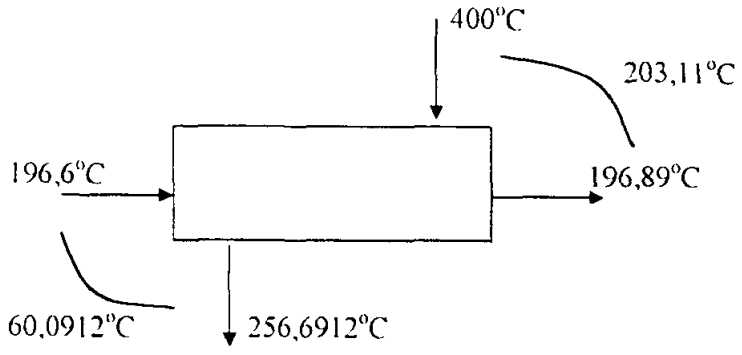


Fungsi : menguapkan kembali produk bawah dari menara destilasi

Type : Kettle Reboiler

Dari perhitungan sebelumnya didapat:

- Q_r	=	10729715.6226 kJ/hari	=	423740.341	Btu/jam
- Massa steam	=	5812.9565 kg/hari	=	533.8716	lb/jam



1. $\Delta T_{LMTD} = \dfrac{203,11 - 60,0912}{\ln\left(\dfrac{203,11}{60,0912}\right)} = 117,4332^{\circ}C = 243,3780^{\circ}F$

2. $T_c = \dfrac{400 + 256,6912}{2} = 328,3456^{\circ}C = 623,0021^{\circ}F$

$t_c = \dfrac{196,6 + 196,89}{2} = 196,745^{\circ}C = 386,141^{\circ}F$

3. Asumsi :

U_D = 25 Btu/(hr).(ft^2).($^{\circ}$F)

$Q = U_D.A.\Delta T$

$$A = \frac{Q}{U_D.(T_c - t_c)}$$

$$= \frac{423740,341}{25.(623,0021 - 386,141)}$$

$$= 71,5592 \ ft^2$$

Dipilih ukuran pipa:

¼" OD, 16 BWG, 1¼" triangular pitch, L = 8 ft

$$N_t = \frac{A}{a'.L}$$

$$= \frac{71,5592}{0,1963.8}$$

$$= 45,5675$$

Dari table 9, Kern diperoleh:

ID = 10"

N_t = 47

Passes = 4

U_D koreksi

$A = Nt.a".L$

$= 47.0,1963.8$

$= 74\ ft^2$

$Q = U_D.A.\Delta T$

$$U_D = \frac{423740.341}{74.(623,0021 - 386,141)}$$

$= 24.2381 \approx 25\ Btu/(hr).(ft^2).(^oF)$

Bagian shell: liquid	**Bagian tube: steam**
4. $a_s = ID.\frac{C'.B}{144.P_T} \rightarrow C' = P_T - OD$ $= 15/16 - 3/4 = 0,1875$ $B = 5"$ $= 10.\frac{0,1875.5}{144.^{15}/_{16}} = 0,0694\ ft^2$	4'. $a'_t = 0,302\ ft^2$ [table 10] $a_t = \frac{N_t.a'_t}{144.n} = \frac{47.0,302}{144.4}$ $= 0,0246\ ft^2$
5. $G_s = \frac{w}{a_s} = \frac{11370,4256}{0,0694}$ $= 163838,9856\ lb/(hr).(ft^2)$	5'. $G_t = \frac{w}{a_t} = \frac{533,8716}{0,0246}$ $= 21664,7909\ lb/(hr).(ft^2)$
6. Pada $t_c = 386,141^oF$ $\mu = 0,2\ cp \times 2,42$ $= 0,484\ lb/(ft).(hr)$ $De = \frac{0,55}{12} = 0,0458 ft$ [table 10] $Re_s = \frac{D_e.G_s}{\mu} = \frac{0,0458.163838,9856}{0,484}$ $= 15503,772$	6'. Pada $T_c = 623,0021^oF$ $\mu = 0,021\ cp \times 2,42$ $= 0,0508\ lb/(ft).(hr)$ $D = \frac{0,62}{12} = 0,0517\ ft$ [table 10] $Re_t = \frac{D.G_t}{\mu} = \frac{0,0517.21664,7909}{0,0508}$ $= 22048,6159$

7. j_H = 90 [fig.28] Pada t_c = 386,141°F k = 0,124 Btu/(hr).(ft²).(°F/ft) [table 4] c = 0,71 Btu/(lb).(°F) [fig 3] 8'. $h_o = j_H \cdot \frac{k}{D_e} \cdot \left(\frac{c.\mu}{k}\right)^{1/3}$ $= 90.\frac{0,124}{0,0458}\left(\frac{0,71.0,484}{0,124}\right)^{1/3}$ = 342,2626 Btu/(hr).(ft²).(°F)	7'. h_{io} = 1500 Btu/(hr).(ft²).(°F) (*condensate steam*)

10. $U_c = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{342,2626.1500}{342,2626+1500}$

= 278,6757 Btu/(hr).(ft²).(°F)

$R_D = \frac{U_c - U_D}{U_c.U_D} = \frac{278,6757 - 25}{278,6757.25}$

= 0,036 (hr).(ft²).(°F)/Btu > 0,0015

Cek maksimum heat fluk

$= \frac{Q}{A} = \frac{423740.341}{73.8088} = 5741.0545$ Btu/(hr).(ft²) < 12000 Btu/(hr).(ft²)

Cek Pressure Drop

1. Re_t = 22048,6159

f = 0,0003 ft²/in² [fig.26]

2. specific volume = 1,8438 ft³/lb [table 7]

$s = \frac{1}{1,8438.62,4} = 8,6916.10^{-3}$

3. $\Delta P_t = \frac{f.G_t^2.L.n}{5,22.10^{10}.D.s.\varphi_t}$

$= \frac{0,0003.(21664,7909)^2.8.4}{5,22.10^{10}.0,0517.8,6916.10^{-3}.1}$

= 0,1921 psia < 1 psia

Summary

342,2626	h outside	1500
Uc	= 278,6757	
U_D	= 25	
R_d calcutated	= 0,036	
R_d required	= 0,0015	
Neg	Calculated ΔP	0,1921
Neg	Allowable ΔP	1

21. Spesifikasi Reboiler (E-222)

Fungsi :Untuk menguapkan kembali produk bawah menara destilasi

Type : Kettle reboiler

Dasar pemilihan : pressure drop kecil dan luas perpindahan panas besar

Dimensi

~ Shell ID : 10"

Baffle space : 5"

~ Tube ID : 0,62"

OD : ¾ "

Jumlah : 47

Passes : 4

Pitch : 15/16 "

Susunan : triangular

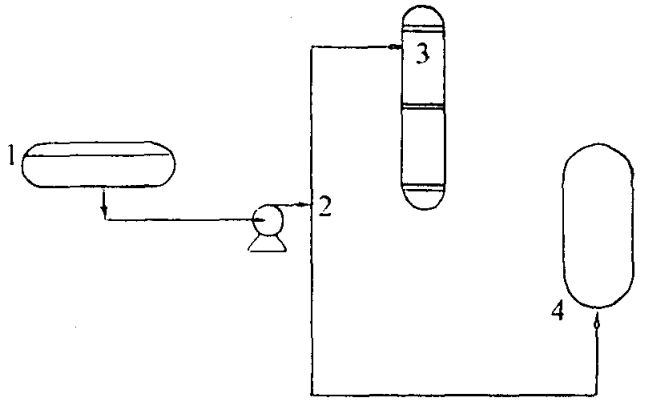
~ Panjang : 8 ft

~ Luas perpindahan panas : 74 ft^2

Bahan konstruksi : Carbon steel

Jumlah : 1 buah

22. Recycle Pump (L-224)



Fungsi : Memompa liquida dari akumulator (F-223) untuk direcycle ke Destilator (D-210) dan memompa destilat ke R-210

Menghitung Friksi yang dialami oleh aliran dari titik 1 ke titik 2

m_1 = (331,9004 x 32) + (3,3525 x 18) = 10681.1578 kg/hari = 0.2725 lb/sec

$m_1 = m_3 + m_4$

m_3 = (169,1084 x 32) + (1,7081 x 18) = 5442.2146 kg/hari = 0.1388 lb/sec

m_4 = 5238.9411 kg/hari = 0.1336 lb/sec

$\rho \approx \rho_{methanol}$ = 0,78664 g/cm^3 = 49.1099 lb/ft^3

$$Q_1 = \frac{10681,1578.10^3}{0,78664} = 14003665,21 \text{ cm}^3\text{/hari}$$

= 14,0037 m^3/hari = 0,00572 ft^3/sec = 2,5675 gpm ≈ 3 gpm

$Q_1 = Q_3 + Q_4$

Q_3 = 0.00283 ft^3/sec

Q_4 = 0.00289 ft^3/sec

ID Optimum = 3,9. $Q^{0,45}.\rho^{0,13}$

ID Optimum = 3,9. $0,00572^{0,45}$. $49.1099^{0,13}$

ID Optimum = 0,6339 inch

Maka dipilih pipa ¾ inch sch 80

ID = 0.742 in = 0.0618 ft

OD = 1.050 in

Luas penampang = 0,003 ft^2

Kecepatan Aliran :

Kecepatan aliran mula-mula = $V_1 = 0$

$$V_2 = \frac{0{,}00572\ ft^3/detik}{0{,}003\ ft^2} = 1{,}9067\ ft/s$$

$$N_{Re} = \frac{D.V.\rho}{\mu} = \frac{0{,}0618.1{,}9067.49{,}1099}{0{,}15.6{,}72 \times 10^{-4}} = 57408.9177$$

Maka aliran turbulen

Dipilih pipa commercial steel (e = 0.00015) (Brown, 1961, hal.141)

Didapat e/D = 0.002

Dari fig 2.10.3 Geankoplis, 1997, hal. 88 didapat f = 0,008

Panjang pipa lurus = 20 ft

Le elbow 90° ; ID = 0.742" → Le = 2 buah x 1,5 ft = 3 ft

gate valve (¾ open) ; ID = 0.742" → Le = 2 buah x 2.5 ft = 5 ft

Panjang total = 20 + 3 + 5 = 28 ft

$Z_1 \approx 2$ ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{gc.D}$$

$$f = \frac{2.0{,}008.1{,}9067^2.28}{32{,}17.0{,}0618} = 0{,}8191\ ft$$

b. Friksi karena kontraksi dari tangki ke pipa

$$fc = \frac{Kc.v^2}{2.gc.\alpha}$$, Karena aliran turbulen maka $\alpha = 1$

$$fc = \frac{0{,}75.1{,}9067^2}{2.32{,}17} = 0{,}0448$$

$\Sigma F = 0{,}8639$ ft

Menghitung Friksi yang dialami oleh aliran dari titik 2 ke titik 3

$Q_3 = 0.00283\ ft^3/sec$

ID Optimum = $3,9.\ 0,00283^{0,45}.\ 49.1099^{0,13}$

ID Optimum = 0,4615 inch

Maka dipilih pipa 3/8 inch sech 40

ID = 0,493 in = 0,0411 ft

OD = 0,675 in

Luas penampang = $0,0013\ ft^2$

Kecepatan Aliran :

$V_2 = 1,9067$ ft/s

$$V_3 = \frac{0,00283\,ft^3/detik}{0.0013\,ft^2} = 2.2077 \text{ ft/s}$$

$$N_{Re} = \frac{D.V.\rho}{\mu} = \frac{0,0411.2,2077.49,1099}{0,15.6,72 \times 10^{-4}} = 9097.1376$$

Maka aliran turbulen

Dipilih pipa commercial steel (e = 0.00015) (Brown, 1961, hal.141)

Didapat e/D = 0.002

Dari fig 2.10.3 Geankoplis, 1997, hal. 88 didapat f = 0,01

Panjang pipa lurus = 40 ft

Le elbow 90° ; ID = 0.493" → Le = 2 buah x 0.8 ft = 1.6 ft

gate valve (¾ open) ; ID = 0.493" → Le = 1 buah x 2 ft = 2 ft

Panjang total = 40 + 1.6 + 2 = 43.6 ft

$Z_3 = 40$ ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{gc.D}$$

$$f = \frac{2.0,01.2,2077^2.43,6}{32,17.0,0411} = 3.2144 \text{ ft}$$

b. Friksi karena kontraksi

$$Kc = 0,75\left(1 - \frac{A_2}{A_1}\right)$$

$$Kc = 0{,}75\left(1 - \frac{0{,}0013}{0{,}003}\right) = 0{,}425$$

$$fc = \frac{Kc.v^2}{2.gc.\alpha}$$, Karena aliran turbulen maka $\alpha = 1$

$$fc = \frac{0{,}425.2{,}2077^2}{2.32{,}17} = 0{,}0322 \text{ ft}$$

c. Friksi karena perluasan (enlargement)

$$Fe = \frac{(v3 - v2)^2}{2.gc.\alpha} = \frac{(2{,}2077 - 1{,}9067)^2}{2.32{,}17.1} = 0{,}0014$$

$\Sigma F = 3.248$ ft

Menghitung Friksi yang dialami oleh aliran dari titik 2 ke titik 4

$Q_4 = 0.00289 \text{ ft}^3/\text{sec}$

ID Optimum = $3{,}9.\ 0{,}00289^{0{,}45}.\ 49{,}1099^{0{,}13}$

ID Optimum = 0,4659 inch

Maka dipilih pipa 3/8 inch sech 40

ID = 0,493 in = 0,0411 ft

OD = 0,675 in

Luas penampang = 0,0013 ft^2

Kecepatan Aliran :

$V_2 = 1{,}9067$ ft/s

$$V_4 = \frac{0{,}00289 \text{ ft}^3/\text{detik}}{0{,}0013 \text{ ft}^2} = 2.1923 \text{ ft/s}$$

$$N_{Re} = \frac{D.V.\rho}{\mu} = \frac{0{,}0411.2{,}1923.49{,}1099}{0{,}15.6{,}72 \times 10^{-4}} = 9033.6797$$

Maka aliran turbulen

Dipilih pipa commercial steel (e = 0.00015) (Brown, 1961, hal.141)

Didapat e/D = 0.002

Dari fig 2.10.3 Geankoplis, 1997, hal. 88 didapat f = 0,01

Panjang pipa lurus = 30 ft

Le elbow 90° ; ID = 0.493" → Le = 2 buah x 0.8 ft = 1.6 ft

gate valve (¾ open) ; ID = 0.493" → Le = 1 buah x 2 ft = 2 ft

Panjang total = 30 + 1.6 + 2 = 33.6 ft

Z_4 = 10 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{gc.D}$$

$$f = \frac{2.0{,}01.2{,}1923^2.33{,}6}{32{,}17.0{,}0411} = 2.4427 \text{ ft}$$

b. Friksi karena kontraksi

$$Kc = 0{,}75\left(1 - \frac{A_2}{A_1}\right)$$

$$Kc = 0{,}75\left(1 - \frac{0{,}0013}{0{,}003}\right) = 0{,}425$$

$$fc = \frac{Kc.v^2}{2.gc.\alpha}$$, Karena aliran turbulen maka α = 1

$$fc = \frac{0{,}425.2{,}1923^2}{2.32{,}17} = 0{,}0145 \text{ ft}$$

c. Friksi karena perluasan (enlargement)

$$Fe = \frac{(v3 - v2)^2}{2.gc.\alpha} = \frac{(2{,}1923 - 1{,}9067)^2}{2.32{,}17.1} = 0{,}0011$$

ΣF = 2.4583 ft

$$m_4\left(\frac{P_4}{\rho} + Z_4\frac{g}{gc} + \frac{(v_4)^2}{2.\alpha.gc}\right) + m_3\left(\frac{P_3}{\rho} + Z_3\frac{g}{gc} + \frac{(v_3)^2}{2.\alpha.gc}\right) - m_1\left(\frac{P_1}{\rho} + Z_1\frac{g}{gc} + \frac{(v_1)^2}{2.\alpha.gc}\right)$$

$$+ m_1.\Sigma F_1 + m_3.\Sigma F_3 + m_4.\Sigma F_4 = m_1.-Ws$$

$$0{,}1336\left(\frac{84672}{49.1099} + 6\frac{32{,}17}{32{,}17} + \frac{(2{,}1923)^2}{2.1.32{,}17}\right) + 0{,}1388\left(\frac{86112}{49.1099} + 40\frac{32{,}17}{32{,}17} + \frac{(2{,}2077)^2}{2.1.32{,}17}\right)$$

$$- 0{,}2725\left(\frac{84672}{49.1099} + 2\frac{32.17}{32.17} + 0\right) + 0{,}2725.0{,}8639 + 0{,}1388.3{,}248 + 0{,}1336.2{,}4583$$

$$= 0{,}2725.-Ws$$

$$-Ws = 24.3721 \ \frac{ft.lb_f}{lb}$$

Efisiensi pompa = 50 %

Maka Hp = $\frac{-Ws.m_1}{\eta.550} = \frac{24,3721.0,2725}{0,5.550}$ =0,24 Hp ≈ 0.3 Hp

22.Spesifikasi Recycle Pump (L-224) :

Fungsi : Memompa liquida dari akumulator (F-223) untuk direcycle ke Destilator (D-210) dan memompa destilat ke R-210

Jenis : Centrifugal

Dasar pemilihan : untuk memompa liq yang tidak viscous

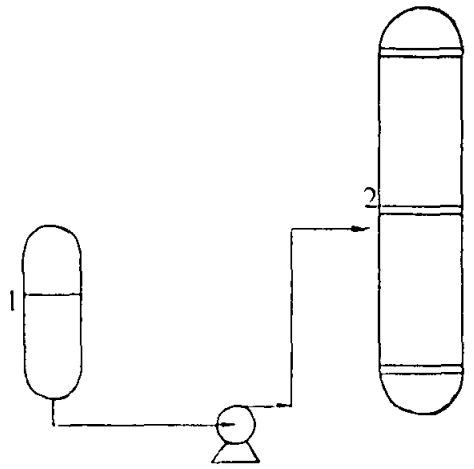
Rate : 3 gpm

Power : 0,3 Hp

Bahan : Cast Iron

Jumlah : 1 buah

23. Destilator Pump (L-225)



Fungsi : memompa methanol dan air dari H-214 menuju destilator D-220

Perkiraan panjang pipa lurus = 25 ft

Jumlah elbow = 3

Jumlah valve = 2 (Gate Valve)

Densitas campuran = (0,4694 x 0,78664) + (0,5306 x 1) = 0,8998 gr/cm^3

= 56,1776 lb/ft^3

Viskositas campuran = (0,4694 x 0,3) + (0,5306 x 1) = 0,6714 cps

Rate pemompaan (Q) = 12,7698 m^3/hari

= 2,3426 gpm = 0,0052 ft^3/dtk

ID Optimum = 3,9. $Q^{0,45}.\rho^{0,13}$

ID Optimum = 3,9. $0.0052^{0,45}$. $56.1776^{0,13}$

ID Optimum = 0.6176 inch

Maka dipilih pipa ½ " sech 40

ID = 0,622 in

OD = 0,84 in

Luas penampang = 0.3039 in^2 = 0,0021 ft^2

Kecepatan Aliran :

Kecepatan aliran mula-mula = $V_1 = 0$

$$V_2 = \frac{0,0052\,ft^3/detik}{0,0021\,ft^2} = 2,4639\ ft/s$$

$$N_{Re} = \frac{D.V.\rho}{\mu} = \frac{\left(\frac{0,622}{12}\right).2,4639.56,1776}{0,6714 . 6,72x10^{-4}} = 15901.7451$$

Maka aliran turbulen

Dipilih pipa commercial steel (e = 0.00015) (Brown, 1961, hal. 141)

Didapat e/D = 0.002

Dari fig 2.10.3 Geankoplis, 1997, hal. 88 didapat f = 0,009

Panjang pipa lurus = 25 ft

Le elbow 90° ; ID = 0,622" → Le = 3 buah x 2.1 ft = 6.3 ft

gate valve (¾ open) ; ID = 0,622" → Le = 2 buah x 3 ft = 6 ft

Panjang total = 25 + 6.3 + 6 = 37.3 ft

$\Delta Z \approx 15$ ft, $\Delta P = 0$

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{gc.D}$$

$$f = \frac{2.0{,}009.2{,}4639^2.37{,}3}{32{,}17\left(\frac{0{,}622}{12}\right)}$$

f = 2,4444 ft

b. Friksi karena kontraksi dari tangki ke pipa

$fc = \frac{Kc.v^2}{2.gc.\alpha}$, Karena aliran turbulen maka $\alpha = 1$

Kc = 0.75 (Peters and Timmerhaus, 1991, hal.484)

$fc = \frac{0{,}75.2{,}4639^2}{2.32{,}17} = 0{,}0708$ ft

c. Friksi karena perluasan (enlargement)

$fe = \frac{(v1 - v2)^2}{2.gc.\alpha} = \frac{(2{,}4639 - 0)^2}{2.32{,}17.1} = 0{,}0944$ ft

$\Sigma F = 2{,}6092$ ft

$$\Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2.gc} + \frac{\Delta P}{\rho} + \Sigma F = -Ws$$

$$15 + \frac{2{,}4639^2}{2.32{,}17} + 0 + 2{,}6092 = -Ws$$

$$-Ws = 17{,}7036 \frac{ft.lb_f}{lb}$$

Flowrate = 0.0052 ft^3/dtk x 62,4 lb/ft^3 = 0,3245 lb/detik

$$Hp = \frac{\text{Flowrate x Ws x 1 Hp}}{550\ \text{ft.lbf/s}} = \frac{0{,}3245 \times 17{,}7036 \times 1\ \text{Hp}}{550\ \text{ft.lbf/s}} = 0{,}01\ \text{Hp}$$

Efisiensi motor = 50 % (Peters and Timmerhaus, 1991, hal. 521)

$$\text{Hp aktual} = \frac{0{,}01}{0{,}5} = 0{,}02\ \text{Hp} = 0{,}1\ \text{Hp}$$

23.Spesifikasi Destilator Pump (L-225) :

Fungsi : memompa methanol dan air dari H-214 menuju destilator D-220

Jenis : Centrifugal

Dasar pemilihan : untuk memompa liquida yang tidak viscous

Diameter Pipa : ½ " sech 40
Rate : 2,5 gpm
Power : 0,1 Hp
Bahan : Cast Iron
Jumlah : 1 buah

APPENDIX D

PERHITUNGAN ANALISA EKONOMI

APPENDIX D
PERHITUNGAN ASPEK EKONOMI

Metode penasiran harga

Harga alat-alat produksi dapat berubah setiap saat, tergantung pada kondisi ekonomi pada saat itu. Untuk memperkirakan harga alat pada tahun tertentu digunakan metode index harga, dimana harga alat pada tahun sebelumnya dikonversi menjadi harga ekuivalen saat ini.

$$\text{Harga saat ini} = \frac{\text{indeks harga sekarang}}{\text{indeks harga tahun A}} \text{ x Harga pada tahun A}$$

1. Perhitugan peralatan pabrik

Dalam perhitungan ini digunakan indeks harga Marshall dan Swift Equipment Cost Index dan Chemical Engineering Plant Cost Index. Indeks harga tersebut adalah:

- Marshall dan Swift Equipment Cost Index
  - tahun 1990 = 904
  - tahun 2001 = 1073,5
- Chemical Engineering Plant Cost Index
  - tahun 1982 = 315
  - tahun 2001 = 394,3

Contoh perhitungan harga peralatan

Nama alat	:	kompresor (G-111)
Harga pada tahun 1990	:	$ 15000
Harga pada tahun 2001	:	$\frac{1073,5}{904}$ x $ 15000 = $ 17812,5000

Selanjutnya harga masing masing peralatan dapat dilihat pada table D -1

2. Perhitungan bahan baku

2.1. Harga bahan baku

~ Gas Alam

Harga beli	:	Rp.350,-/m^3
Kebutuhan	:	1226,1061 m^3/hari
Total	:	Rp.429150,-/hari
		= Rp 141619500,-/tahun

2.2 Harga katalis

1. CuO

Harga beli	:	Rp.17700,-/kg
Kebutuhan	:	9,5 kg / 3 tahun
Total	:	Rp.168150,- / 3 tahun
		≈ Rp.56050,- / tahun

2. ZnO

Harga beli	:	Rp.15900,-/kg
Kebutuhan	:	3,5 kg / 3 tahun
Total	:	Rp.55650,-/ 3 tahun
		≈ Rp.18550,- / tahun

3. Al_2O_3

Harga beli	:	Rp.22500,-/kg
Kebutuhan	:	12 kg / 3 tahun
Total	:	Rp.270000,- / 3 tahun
		≈ Rp.90000,- / tahun

4. SiO_2

Harga beli	:	Rp.2100,-/kg
Kebutuhan	:	1 kg / 3 tahun
Total	:	Rp.2100,- / 3 tahun
		≈ Rp.700,- / tahun

Total Harga Beli Bahan Baku dan Katalis = Rp.141784800,-/tahun

2.3. Harga jual produk

~ DME

Harga	:	Rp.9000,-/kg
Produksi	:	15286,6996 kg/hari
Total	:	Rp.137583000,-/hari

2.4. Hasil samping

~ Gas sisa reaksi

Harga	:	Rp.150,-/m^3
Produksi	:	14843,2282 m^3/hari
Total	:	Rp.2226500,-/hari

3. Perhitungan Gaji Karyawan

gaji karyawan perbulan	=	Rp 232000000,-
gaji karyawan pertahun	=	12 x Rp 232000000,-
	=	Rp 2784000000,-

4. Perhitungan Harga Utilitas

4.1 Alum

Harga beli	:	Rp 1350,- / kg
Kebutuhan	:	23 kg/hari
Total	:	Rp 31100,-/hari
		= 330 x Rp 31100,-
		= Rp 10263000,-/tahun.

4.2. Zeolit

Harga beli	:	Rp 2500,- / kg
Kebutuhan	:	80 kg / 3 bulan
Total	:	Rp 200000,- / 3 bulan
		= Rp 800000,-/tahun

4.3. Fuel Oil

Harga beli : Rp 1200,- / ltr

Kebutuhan : 4746.6998 ft^3/hari

Total : Rp 5612000,-/hari

= 330 x Rp 5612000,-

= Rp 1851960000,-/tahun

4.5 Listrik

Biaya beban : Rp 35000,-

Beban : 600 kW

Total biaya beban : = 600 x Rp 35000,-

= Rp 21000000,-/bulan

= Rp 252000000,-/tahun

Tarif : jam 18.00-22.00 = Rp 388,-

jam 22.00-18.00 = Rp 314,-

Listrik terpakai :

~ full operation selama 330 hari

Proses : 240 kW

Utilitas :135 kW

Penerangan : ½ 82 kW

416 kW

~ off operation selama 30 hari

Penerangan : ½ 82 kW

Biaya listrik := {[(4x388x416)+(20x314x416)]x330}+{[(4x388x41)+(20x314x41)]x30}

= Rp 1084810500.-/tahun

Total biaya listrik: = Rp 1336810500,-/tahun

Total Biaya Utilitas = Rp. 3199833500,-/tahun

5.Perhitungan harga tanah dan bangunan

Luas tanah : 18000 m^2

Luas bangunan : 10186 m^2

Harga tanah : Rp 30000,- x 18000 = Rp 540000000,-

Harga bangunan : Rp 750000,- x 10186 = Rp 7639500000,-

6. Biaya Pengemasan

Berat produk tiap tangki : 15 kg

Harga tiap tangki : Rp 300000,-

Jumlah tangki : $\frac{15285,6739}{15} \approx 1020$

Total biaya : Rp 306000000,-

Tabel D – 1. Harga Peralatan Proses Pabrik DME

No	Nama Alat	Kode	Jumlah	Peters and Timerhaus, 2001	Ulrich, 2001	Total
1	storage tank	F-110	2	178500.0000		357000.0000
2	kompresor	G-111	1	17812.5000		17812.5000
3	kompresor	G-112	3	29687.5000		89062.5000
4	cooler	E-113	2		3369.0190	6738.0380
5	reaktor 1	R-120	1		19964.5570	19964.5570
6	heater	E-121	1		5615.0316	5615.0316
7	heater	E-122	1		2745.1266	2745.1266
8	heater	E-123	1		4367.2468	4367.2468
9	cooler	E-124	1		6862.8165	6862.8165
10	drum separator	H-125	1	4156.2500		4156.2500
11	storage tank	F-130	15	32062.5000		480937.5000
12	reaktor 2	R-210	1		12477.8481	12477.8481
13	heater	E-211	1		4367.2468	4367.2468
14	heater	E-212	1		3743.3544	3743.3544
15	cooler	E-213	1		3992.9114	3992.9114
16	drum separator	H-214	1	3087.5000		3087.5000

17	storage tank	F-230	15	26125.0000		391875.0000
18	menara destilasi	D-220	1	10093.7500		10093.7500
19	kondensor	E-221	1		1871.6772	1871.6772
20	akumulator	F-223	1	1781.2500		1781.2500
21	reboiler	E-222	1		3743.3544	3743.3544
22	recycle pump	L-224	1		1247.7848	1247.7848
23	destilator pump	L-225	1		712.5000	712.5000
Total						1189606.0546

Tabel D – 2. Harga Peralatan Utilitas Pabrik DME

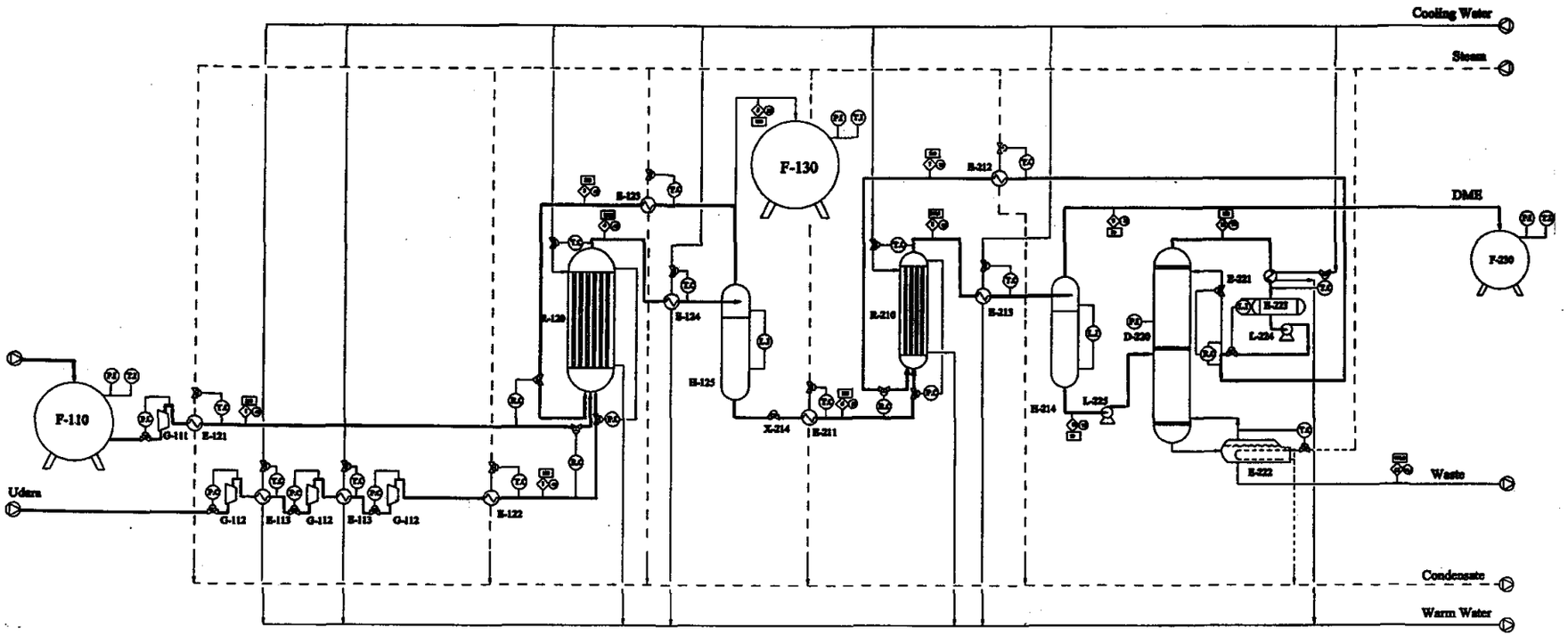
No	Nama Alat	Kode	Jumlah	Peters and Timerhaus, 2001	Ulrich, 2001	Total
1	boiler	P-360	1	23750.0000		23750.0000
2	cooling tower	P-340	1	29687.5000		29687.5000
3	Settling bin	H-310	1	712.5000		712.5000
4	pompa	L-311	1		1871.6772	1871.6772
5	clarifier	H-320	1		14973.4177	14973.4177
6	water storage	F-321	1	712.5000		712.5000
7	sand filter	H-330	2		1247.7848	2495.5696
8	pompa	L-331	1		1247.7848	1247.7848
9	filtered water storage	F-332	1	653.1250		653.1250
10	pompa	L-333	1		712.5000	712.5000
11	pompa	L-341	1		1497.3418	1497.3418
12	cold water storage	F-342	1	712.5000		712.5000
13	pompa	L-343	1		2183.6234	2183.6234
14	demineral tank	R-350	2	890.6250		1781.2500
15	Pompa	L-351	1		712.5000	712.5000
16	fuel oil storage	F-361	1	17812.5000		17812.5000
17	Pompa	L-362	1		712.5000	712.5000
Total						88001.5743

Tabel D – 3. Gaji karyawan Pabrik DME

No	jabatan	jumlah	Gaji, Rp	Total, Rp
1	direktur utama	1	10000000	10000000
2	wakil direktur utama	1	8500000	8500000
3	sekretaris	1	3000000	3000000

4	Staff ahli	5	6000000	30000000
5	manager produksi dan tehnik	1	7000000	7000000
6	kabag prod	1	4000000	4000000
7	kabid proses	1	2500000	2500000
8	karyawan proses	48	750000	36000000
9	kabid lab	1	2500000	2500000
10	Karyawan lab	8	750000	6000000
11	kabid utilitas	1	2500000	2500000
12	karyawan utilitas	22	750000	16500000
13	kabag tehnik	1	4000000	4000000
14	kabid maintenance dan perbaikan	1	2500000	2500000
15	karyawan maintenance dan perbaikan	10	750000	7500000
16	kabid gudang	1	2500000	2500000
17	karyawan gudang	6	750000	4500000
18	kabid spare part	1	2500000	2500000
19	karyawan spare part	5	750000	3750000
20	manager administrasi dan umum	1	7000000	7000000
21	kabag administrasi	1	4000000	4000000
22	kabid keuangan	1	2500000	2500000
23	karyawan keuangan	3	750000	2250000
24	kabid pembukuan	1	2500000	2500000
25	karyawan pembukuan	3	750000	2250000
26	kabag pemasaran	1	4000000	4000000
27	kabid pembelian	1	2500000	2500000
28	karyawan pembelian	5	750000	3750000
29	kabid penjualan	1	2500000	2500000
30	karyawan penjualan	10	750000	7500000
31	kabag umum	1	4000000	4000000
32	kabid personalia	1	2500000	2500000
33	karyawan personalia	5	750000	3750000
34	kabid keamanan	1	2500000	2500000
35	karyawan keamanan	12	750000	9000000
36	kabid humas	1	2500000	2500000
37	karyawan humas	5	750000	3750000
38	pekerja harian	10	750000	7500000
	Total	180		232000000

PRA PERANCANG PABRIK DIMETHYL ether (DME)
DARI GAS ALAM KAPASITAS ISTON / HARI
Oleh :
Agus Fajar (5203099028)
Dina Kusumawati (5203099056)



24.	X-214	Expansion valve
23.	F-230	Tangki penyimpan produk (DME)
22.	L-225	Distillate Pump
21.	L-224	Reflux Pump
20.	D-223	Akumulator
19.	E-222	Reboiler
18.	E-221	Kondensor
17.	D-220	Menara Distilasi
16.	H-214	Drum Separator
15.	E-213	Cooler
14.	E-212	Heater
13.	E-211	Heater
12.	R-210	Reaktor II
11.	F-130	Tangki penyimpan gas alam sementara
10.	H-125	Drum Separator
09.	E-124	Cooler
08.	E-123	Heater
07.	E-122	Heater
06.	E-121	Heater
05.	R-120	Reaktor I
04.	E-113	Cooler
03.	G-112	Kompresor udara
02.	G-111	Kompresor gas alam
01.	F-110	Tangki penyimpan gas alam
NO	KODE	NAMA

Control Instrument
T.I = Temperature Indicator
P.I = Pressure Indicator
P.C = Pressure Controller
T.C = Temperature Controller
R.C = Ratio Controller
L.I = Level Indicator

Simbol
◇ = Nomor aliran
○ = Tekanan, atm
▭ = Suhu, °C

Neraca Massa, kg/hari

Senyawa	Nomor aliran											
	1	2	3	4	5	6	7	8	9	10	11	12
CH_4	11200		4067.2491	4580.2355	512.9864							
C_2H_6	3871.1449		30702.6597	34575.0672	3872.4075							
C_3H_8	3430.8971		27217.8115	30650.6888	3432.8771							
I C_4H_{10}	960.5408		7625.2302	8586.9713	961.7408							
n C_4H_{10}	1194.9585		9478.9503	10674.4936	1195.5433							
I C_5H_{12}	830.4183		6593.4217	7425.0244	831.6027							
n C_5H_{10}	794.9303		6299.6554	7094.2065	794.5511							
C_6H_{14}	1636.1921		12982.839	14620.3141	1637.4752							
O_2		11200	4067.2491	4580.2355	512.9864							
N_2		36866.6667	292416.2672	329297.5982	36881.331							
Methanol				21374.4324		21374.4324	5209.3425	5316.752		5316.752	8998.1472	107.4095
H_2O							29.5986	6010.9476		6010.9476	51.1254	5981.349
DME								15285.6739	15285.6739			
Total	23919.0818	48066.6667	401473.5189	473459.2673	50611.3161	21374.4324	5238.9411	26613.3735	15285.6739	11327.6996	9049.2726	6088.7585

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FAKULTAS TEKNIK
JURUSAN TEKNIK KIMIA

FLOW SHEET PABRIK DME DARI GAS ALAM

Digambar oleh:	Disetujui oleh: 11/2023
Agus Fajar / 5203099028 Dina Kusumawati / 5203099056	Ir. Soramo Lourentius, M.S. Dosen Pembimbing