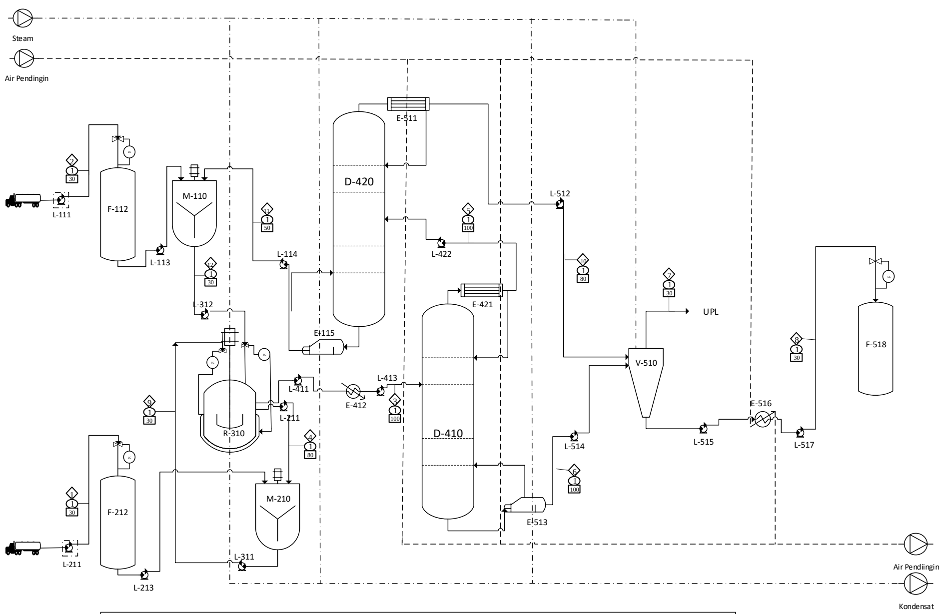
LAMPIRAN

PRARANCANGAN PABRIK ASAM FORMAT DARI METIL FORMAT DENGAN PROSES HIDROLISIS

KAPASITAS 12.000 TON/TAHUN



KODE	KETERANGAN
F-112	TANGKI H2O
F-212	TANGKI METIL FORMAT
M-110	MIXER II
M-210	MIXER I
R-310	REAKTOR
D-410	MENARA DESTILSI I
D-420	MENARA DESTILASI II
V-510	EVAPORATOR
E-515	REBOILER I
E-421	KONDENSOR I
E-115	REBOILER II
E-511	KONDENSOR II
E-412	HEATER
E-516	COOLER
F-518	TANGKI ASAM FORMAT
L-311	POMPA 1
L-312	POMPA 2
L-411	POMPA 3
L-413	POMPA 4
L-514	POMPA 5
L-422	POMPA 6
L-114	POMPA 7
L-512	POMPA 8
L-211	POMPA 9
L-515	POMPA 10
L-517	POMPA 11
L-113	POMPA 12
L-213	POMPA 13
LC	LEVEL CONTROL
TC	TEMPERATUR
LC	LEVEL CONTROL
◇	NOMOR ARUS
○	TEKANAN
□	TEMPERATUR
– – – –	AIR PENDINGIN
– · – · –	STEAM
———	AIR PROSES

Neraca Massa Total

Komponen (Kg/jam)	Arus 1	Arus 2	Arus 3	Arus 4	Arus 5	Arus 6	Arus 7	Arus 8	Arus 9	Arus 10	Arus 11	Arus 12
C2H4O2	1102,27			367,42					1469,70			
CH3OH				45,45					45,45			
H2O		1483,17	1184,56		1149,03	35,54	35,18	3,91		3,55	31,98	1515,15
CH2O2			844,85		42,24	802,61	152,50	1372,46				
Total	1102,27	1483,17	2029,41	412,88	1191,27	838,14	187,68	1376,37	1515,15	3,55		

PRARANCANGAN PABRIK ASAM FORMAT DARI METIL FORMAT DENGAN PROSES HIDROLISIS KAPASITAS 12.000 TON/TAHUN		
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1. Tangki Metil Format

kondisi operasi :	T	=	30	C
			303,15	K
	P	=	1	atm
			760	mmHg

KOMPONEN	INPUT (kg/jam)	ρ (kg/m3)	fraksi x	ρ.x	
C2H4O2	1469,6970	959,8767	0,9700	931,0804	
CH3OH	45,4545	970,1759	0,03	29,10528	
Total	1515,1515			960,1857	kg/m3
				0,960186	kg/L

m	=	3340,333	lb/jam
T =	30	◦C	303	K

Komponen	ρ(kg/m3)	μ (cP)
C2H4O2	931,0804	0,3150
CH3OH	29,10528	0,5060

Log μ = A + B/T + CT + D (Yaws, 1999 hal 503)

T	=	30	C
		303,15	K

$$\rho\ cam = \frac{1}{\frac{0,9700}{959,8767} + \frac{0,03}{970,1759}}$$

= 960,1825 kg/m^3

= 59,9433 lb/ft^3

= 0,960182 kg/L

$$\mu\ cam = \frac{1}{\frac{0,9700}{0,3150} + \frac{0,03}{0,5060}}$$

= 0,3186 cP

= 0,7711 lb/ft.S

= 0,000214 lb/ft.s

densitas	=	960,182	kg/m3
viskositas	=	0,3186	cP
	=	0,000214	lb/ft.s
	=	0,000319	Pa s

$$\text{Flowrate volumetrik (Fv)} = \frac{\text{massa}}{\text{densitas}}$$

$$= \frac{1515,152\ \text{kg/jam}}{0,9602\ \text{kg/L}}$$

= 1577,983 L/jam

= 1,5780 m^3/jam

Volume tangki		=	$\frac{\pi}{4} \times D^2 \times H = \frac{\pi}{4} \times D^3$		
$D = \sqrt[3]{\frac{4 \times V_{tangki}}{\pi}}$		=	1,3411	m	
(D:H=1:1)		=	52,8003	in	
H		=	52,8003	in	
		=	4,4000	ft	
V head		=	2 x (Vdish + Vsf)		
	$V_{sf} = \frac{\pi}{4} \times D^2 \times \frac{sf}{144}$				
dimana:					
Ds	=	diameter shell, in			
Vdish	=	$0{,}000049.D^3$ (volume, ft^3)			
sf	=	2 (straight flange)			
Sehingga :					
V head		=	2 x (Vdish + Vsf)		
		=	0,0435	ft^3	
		=	0,0012	m^3	
V tangki		=	Vshell + Vhead		
		=	1,89	+	0,0012 m^3
		=	1,89	m^3	

Dengan spesifikasi mixer sebagai berikut :				
Diameter shell	**=**	**1,3411**	**m**	
Tinggi shell	**=**	**1,3411**	**m**	
Volume shell	**=**	**1,8936**	**m^3**	
Volume head	**=**	**0,0012**	**m^3**	
Volume tangki	**=**	**1,8948**	**m^3**	
Volume bottom	=	0,5 x Volume head		
	=	0,000616	m^3	

Volume cairan dalam shell	=	volume shell - volume bottom		
	=	1,894	-	0,000616
	=	1,893	m^3	
Tinggi cairan dalam shell	=	$h = \frac{4.V}{\pi.D^2} =$		
	=	1,3407	m	
	=	4,3986	ft	

3) Menentukan tebal shell (ts)

Dirancang menggunakan Stainless steel SA-240 (tipe 405)

$$ts = \frac{P.r}{(f.E - 0{,}6.P)} + C$$

(Pers. 13.1, Brownell & young, 1959; hal 254)

Dalam hubungan ini :							
	ts	=	tebal shell, in				
	r	=	Jari-jari				
		=	½ .Diameter tangki				
		=	0,5 x	52,8003 in	=	26,4002	in
	E	=	effisiensi penggelasan		=	0,8500	
	C	=	faktor korosi		=	0,1250	
	f	=	tegangan yang diizinkan		=	18750	psi
						(Brownell, hal 342)	
			Poperasi = atmosferis		=	14,7000	psi
			Pdesain = 1.1* P operasi		=	16,1700	psi
			P = tekanan dalam mixer		=	16,1700	psi

Sehingga :

$$ts = \frac{P.r}{(f.E - 0{,}6.P)} + C$$

ts	=	0,1518			
digunakan tebal standar	**=**		3/16	in	(Brownell, Halaman 350)
		=	0,0048	m	

4) Menentukan tebal head (th) dan tebal bottom

Jenis head yang dipilih adalah = Torispherical, dengan alasan :

1. Tekanan operasi antara 15 psig - 200 psig.
2. Cocok untuk tangki silinder vertikal/horisontal.

(Brownell, Halaman 88)

4) Menentukan tebal head (th) dan tebal bottom

Jenis head yang dipilih adalah = Torispherical, dengan alasan :

1. Tekanan operasi antara 15 psig - 200 psig.
2. Cocok untuk tangki silinder vertikal/horisontal.

(Brownell, Halaman 88)

P	=	Pdesain - Pudara luar	=	1,4700	psi
OD	=	ID + 2ts	=	53,17534	in
Dipakai OD			=	78	in

Dari tabel 5-7 Brownell, hal 90

untuk : OD	=	78	in	icr	=	4 3/4	in
ts	=	1/4	in	r	=	78	in

$$w = \frac{1}{4}\left(3 + \sqrt{\frac{r}{icr}}\right)$$

(Pers. 7.76, Brownell & young; hal 138)

= 0,8117 in

$$th = \frac{P.r.w}{(2.f.E - 0{,}2.P)} + C$$

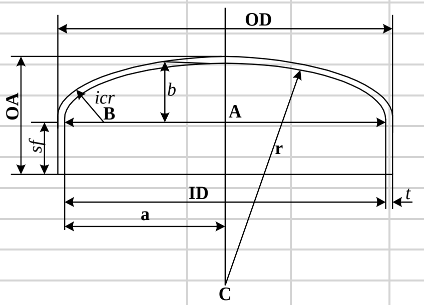
(Pers. 7.77, Brownell & young, 1959; hal 138)

= 0,1279 in 0,12792

OD	78		84		90		96		102		108		114	
t	icr	r	icr	r	icr	r	icr	r	icr	r	icr	r	icr	r
3/16														
1/4														
5/16	4 3/4	78	5 1/8	84	5 1/2	90	5 7/8	96	6 1/8	96				
3/8		78				90		96			6 1/2	102	6 7/8	108
7/16		78				84		90						
1/2		72												
5/8														
3/4														
7/8														
1				84						96		102		
1 1/8				78						90		96		
1 1/4								90						
1 3/8								84						
1 1/2	4 3/4													108
1 5/8	4 7/8		5 1/8											102
1 3/4	5 1/4		5 1/4		5 1/2									
1 7/8	5 5/8				5 5/8		5 7/8							
2	6						6		6 1/8		6 1/2			
2 1/4	6 3/4								6 3/4		6 3/4		6 7/8	
2 1/2	7 1/4												7 1/4	

5) Menentukan tinggi tangki total

untuk th	=	3/16	in pada tabel 5.6 Brownell & Young, hal 88 diperoleh sf = 1 1/2 - 3 1/2						
Diambil sf		2							



keterangan :	
ID	diameter dalam head
OD	diameter luar head
th	tebal head
r	jari-jari dish
icr	jari-jari dlm sudut dish
b	tinggi head
sf	straight flange

(Brownell & young, 1959; hal 87)

ID = OD standart - (2*ts)				=	77,6250				
				=	38,7500	in	(jari-jari dalam shell)		
AB	=	a - icr		=	34,0000	in			
BC	=	r – irc		=	73,2500	in			
AC	=	$(BC^2 - AB^2)^{1/2}$		=	64,8811	in			
b	=	r – AC		=	13,1189	in	(tinggi head)		
tinggi head total (OA) = sf + b + th				=	15,3064	in			
				=	0,3888	m			
tinggi tangki total		=	2 x tinggi head total + tinggi shell						
		=	0,7776	+	1,3411	m			
		=	2,1187	m	=	83,4132	in		
Tekanan hidrostatis		=	densitas bahan x g x tinggi cairan dalam tangki						
		=	960,1857	kg/m3	x	9,8	m/s2	x	1,3407
		=	12615,7	Pa	=	0,124504	atm		

2. Mixer

Neraca Massa Mixer 1

NM mixer	input		output		BM
komponen	arus 1	arus 4	arus 9	(%w/w)	(Kg/mol)
	Massa (kg/jam)	Massa (kg/jam)	Massa (kg/jam)		
$C_2H_4O_2$	1102,272727	367,4242424	1469,69697	0,97	60,0500
CH_3OH	0	45,45454545	45,45454545	0,03	32,0400
	1102,272727	412,8787879			
Total	1515,151515		1515,151515		

m	=	3340,333	lb/jam	
T =	30	◦C	303	K

Log μ = A + B/T + CT + DT2 (Yaws, 1999 hal 503)

T = 30 C
303,15 K

Komponen	ρ(kg/m3)	μ (cP)
$C_2H_4O_2$	959,8766945	0,3150
CH_3OH	782,6685938	0,5060

$$\rho\ cam = \frac{1}{\frac{0,97}{959,8766945} + \frac{0,03}{782,6685938}}$$

= 953,4008 kg/m³
= 59,5199 lb/ft³
= 0,953400761 kg/L

$$\mu\ cam = \frac{1}{\frac{0,97}{0,3150} + \frac{0,03}{0,5060}}$$

= 0,3186 cP
= 0,7711 lb/ft.S
= 0,000214201 lb/ft.s

densitas	=	953,401	kg/m3
viskositas	=	0,3186	cP
	=	0,000214201	lb/ft.s
	=	0,000318647	Pa s

$$\text{Flowrate volumetrik (Fv)} = \frac{\text{massa}}{\text{densitas}}$$

$$= \frac{1515,152\ \text{kg/jam}}{0,9534\ \text{kg/L}}$$

= 1589,207 L/jam
= 1,5892 m³/jam

Volume tangki		=	$\frac{\pi}{4} \times D^2 \times H = \frac{\pi}{4} \times D^3$			
$D = \sqrt[3]{\frac{4 \times V_{tangki}}{\pi}}$		=	1,3443	m		
(D:H=1:1)		=	52,9252	in		
H		=	52,9252	in		
		=	4,4104	ft		
V head		=	2 x (Vdish + Vsf)			

$$V_{sf} = \frac{\pi}{4} \times D^2 \times \frac{sf}{144}$$

dimana:						
Ds	=	diameter shell, in				
Vdish	=	$0,000049.D^3$ (volume, ft^3)				
sf	=	2	(straight flange)			
Sehingga :						
V head		=	2 x (Vdish + Vsf)			
		=	0,0438	ft^3		
		=	0,0012	m^3		
V mixer		=	Vshell + Vhead			
		=	1,91	+	0,0012	m^3
		=	1,91	m^3		

Dengan spesifikasi mixer sebagai berikut :							
Diameter shell		**=**	**1,3443**	**m**			
Tinggi shell		**=**	**1,3443**	**m**			
Volume shell		**=**	**1,9070**	**m^3**			
Volume head		**=**	**0,0012**	**m^3**			
Volume mixer		**=**	**1,9083**	**m^3**			
Volume bottom		=	0,5 x Volume head				
		=	0,000619563	m^3			
Volume cairan dalam shell			=	volume shell - volume bottom			
			=	1,907	-	0,00062	
			=	1,906	m^3		
Tinggi cairan dalam shell			=	$h = \frac{4.V}{\pi.D^2} =$			
			=	1,3439	m		
			=	4,4090	ft		
3) Menentukan tebal shell (ts)							
Dirancang menggunakan Stainless steel SA-240 (tipe 405)							
$ts = \frac{P.r}{(f.E - 0,6.P)} + C$				(Pers. 13.1, Brownell & young, 1959; hal 254)			
Dalam hubungan ini :							
	ts	=	tebal shell, in				
	r	=	Jari-jari				
		=	½ .Diameter Mixer				
		=	0,5 x	52,9252 in		=	26,4626	in
	E	=	effisiensi penggelasan			=	0,8500
	C	=	faktor korosi			=	0,1250
	f	=	tegangan yang diizinkan			=	18750 psi
							(Brownell, hal 342)
			Poperasi = atmosferis			=	14,7000 psi
			Pdesain = 1.1* P operasi			=	16,1700 psi
			P = tekanan dalam mixer			=	16,1700 psi

Sehingga :

$$ts = \frac{P.r}{(f.E - 0{,}6.P)} + C$$

ts = 0,1518

digunakan tebal standar = 3/16 in (Brownell, Halaman 350)

= 0,0048 m

4) Menentukan tebal head (th) dan tebal bottom

Jenis head yang dipilih adalah = Torispherical, dengan alasan :

1. Tekanan operasi antara 15 psig - 200 psig.
2. Cocok untuk tangki silinder vertikal/horisontal.

(Brownell, Halaman 88)

P	=	Pdesain - Pudara luar	=	1,4700	psi
OD	=	ID + 2ts	=	53,30024	in
Dipakai OD			=	78	in

Dari tabel 5-7 Brownell, hal 90

untuk : OD	=	78	in	icr	=	4 3/4	in
ts	=	1/4	in	r	=	78	in

$$w = \frac{1}{4}\left(3 + \sqrt{\frac{r}{icr}}\right)$$

(Pers. 7.76, Brownell & young; hal 138)

= 0,8117 in

$$th = \frac{P.r.w}{(2.f.E - 0{,}2.P)} + C$$

(Pers. 7.77, Brownell & young, 1959; hal 138)

= 0,1279 in 0,1279198

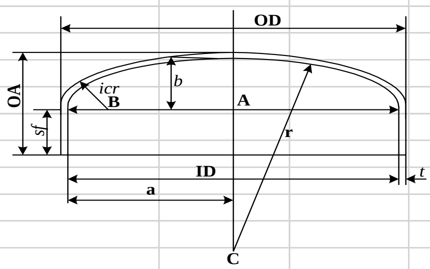
digunakan tebal standar = 3/16 in

= 0,0048 m

5) Menentukan tinggi mixer total

untuk th = 3/16 in pada tabel 5.6 Brownell & Young, hal 88 diperoleh sf = 1 1/2 - 3 1/2

Diambil sf 2



keterangan :	
ID	diameter dalam head
OD	diameter luar head
th	tebal head
r	jari-jari dish
icr	jari-jari dlm sudut dish
b	tinggi head
sf	straight flange

(Brownell & young, 1959; hal 87)

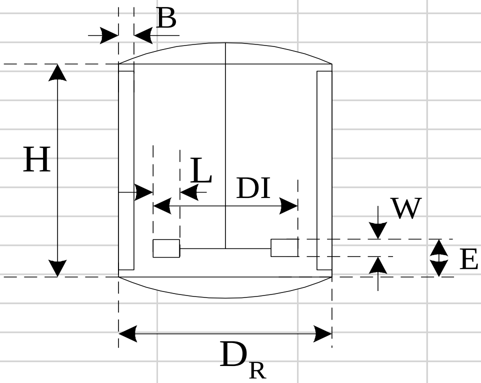
ID = OD standart - (2*ts) = 77,6250

= 38,7500 in (jari-jari dalam shell)

AB	=	a - icr		=	34,0000	in		
BC	=	r – irc		=	73,2500	in		
AC	=	$(BC^2 - AB^2)^{1/2}$		=	64,8811	in		
b	=	r – AC		=	13,1189	in	(tinggi head)	
tinggi head total (OA) = sf + b + th				=	15,3064	in		
				=	0,3888	m		
tinggi mixer total		=	2 x tinggi head total + tinggi shell					
		=	0,7776	+	1,3443	m		
		=	2,1219	m				
		=	83,538	in				

Perbandingan ukuran, umumnya:

Di/DR = 1/3	W = Di /5	B = DR/10
E/Di = 1	L = Di/4	**(Rase, hal 356)**



keterangan :		
Diameter mixer (DR)	1,3443	m
Diameter pengaduk (Di)	0,4481	m
Pengaduk dari dasar (E)	0,4481	m
Tinggi Pengaduk (W)	0,0896	m
Lebar pengaduk (L)	0,1120	m
Lebar baffle (B)	0,1344	m

Menghitung jumlah impeler (pengaduk):
Dimana WELH adalah Water Equivalen Liquid High

WELH	=	tinggi bahan		x	sg	
	=	tinggi bahan		x	ρ cairan / ρ air	
	=	1,3439	m	x	1589,2074	kg/m3
					970,175887	kg/m3
	=	2,2013	m			

Σ impeller	=	WELD				
		D				
	=	2,201	m			
		1,3443	m			
	=	1,6375		≈ 2		
Putaran pengaduk		=	WELD	=	π . DI . N	
			2 . DI		600	

$$N = \frac{600}{\pi . DI/0,3048} . \sqrt{\frac{WELH}{2.DI}}$$

		=	203,7045	rpm		
		=	3,3951	rps		
Dengan :						
N	=	203,7045	rpm	=	3,3951	rps
ρ	=	953,4008	kg/m^3	=	59,5199	lbm/ft^3
gc	=	32,2000	ft/s^2			
μ	=	0,3186	Cp	=	0,00021412	lb/ft.s
Di	=	0,4481	m			
	=	1,4701	ft			
	=	17,6418	in			

$$N_{Re} = \frac{\rho . N . Di^2}{\mu m}$$

= 2039742

Dari grafik 8.8 Rase H.F., Re = 2039742 → Np = Po = 5

$$P = \frac{N^3 . Di^5 . \rho\rho . Np}{550 . g_c}$$

= 4,52 Hp

Efisiensi motor (η) = 0,85 (fig. 14.38, Peters, hal 521)

$$Daya\ motor = \frac{P}{\eta} = 5,3\ Hp$$

Over Design 20%, maka :

= 6,0 Hp

3. Reaktor

ρ campuran	=	0,9341	kg/L		
	=	934,0639	kg/m^3		
	=	58,3127	lb/ft^3		
Flowrate volumetrik (Fv)	=	massa			
		ρ campuran			
	=	3030,4132	kg/jam		
		0,9341	kg/L		
	=	3244,3317	L/jam		
	=	3,2443	m^3/jam		
T	=	80	°C		
P	=	1	atm		
Konversi	=	75%			
Reaksi Stokiometri	(Satuan : kmol/jam)				
Reaksi	$HCOOCH_{3(l)}$ +	H2O(l) ⇌	HCOOH(l) +	CH3OH(l)	
MULA-MULA	24,47455403	84,1283462			
RX	18,35591552	18,35591552	18,35591552	18,35591552	
SETIMBANG	6,118638508	65,77243068	18,35591552	18,35591552	
Menghitung konsentrasi umpan		=	F_{Ao}	kmol/jam	
			Fv	m^3/jam	
Konsentrasi umpan C2H4O2 (C_{AO})		=	24,4746	kmol/jam	
			3,1488	m^3/jam	
			= 7,7727	kmol/m^3	
C_A	=	C_{AO} (1-X_A)			
	=	7,7727	x	(1 - 0,75)	
	=	1,9432	kmol/m^3		
Konsentrasi umpan H2O (C_{BO})		=	84,1283	kmol/jam	
			3,1488	m^3/jam	
		=	26,7176	kmol/m^3	
C_B	=	C_{BO} - (C_{BO}*X_A)			
	=	26,7176	-	24,7722* 0,75)	
	=	6,6794	kmol/m^3		

Diketahui data-data pada kinetika reaksi :							
(-ra)	=	k. C_A.C_B					
k	=	0,0003	L/mol.s				
	=	1,2276	m^3/kmol.jam				
(-ra)	=	k. C_A.C_B					
(-ra)	=	1,2276	m^3/kmol.jam x	1,9432	kmol/m^3 x	6,6794	kmol/m3
(-ra)	=	2,385431036	kmol/m^3.jam				
V	=	($F_{AO)}$. X_A					
		(-ra)					
	=	24,4746	kmol/jam	0,60			
		2,3854		kmol/m^3.jam			
	=	6,1560	m^3				
Sehingga volume reaktor			=	6,1560	m^3 x	1000	
			=	6156,00795	L/jam		

Direncanakan digunakan 1 tangki, maka volume reaktor					=	6,1560	m^3
(sebelum over design)					=	6156,0080	L/jam
					=	217,397574	ft^3
					=	1626,351251	gallon
Over design		=	20%				
Maka volume tangki		=	6156,0080	+	6156,0080	.x (20/100)	
(setelah over design)		=	7387,2095	L/jam			
		=	7,3872	m^3/jam			
		=	260,8771	ft^3			
		=	1951,621501	gallon			
Ditetapkan :		D = H	(Brownell, hal 43)				
Dimana	D	=	Diameter				
	H	=	Tinggi				
Volume head torispherical			=	0,000049 x D^3			
Dimana :	D	=	Volume dalam cuft				
	H	=	Diameter dalam in				
Sehingga ada faktor konversi							
Volume reaktor total		=	Volume silinder + (2 x volume head)				
	V	=	$\frac{1}{4}\pi D^2 H + 2\ (0{,}000049 \times D3)$				
	V	=	1/4 x π x D^3 + 2 (0,000049D^3)				
260,8771	ft^3	=	0,0005	D^3 +	0,0001	D^3	
260,8770888	ft^3	=	0,0006	D^3			
	D^3	=	472361,7603	In^3			
	D	=	77,8798	in			
	D	=	1,9781	m			
	D	=	6,4900	ft			

<u>Mencari ketinggian cairan dalam reaktor :</u>						
Volume cairan		=	Volume cairan sebelum over design			
		=	1626,351251	ft^3		
Volume head dasar		=	0,000049 x	D^3		
		=	0,000049 x	472361,7603		
		=	23,1457	ft^3		
Volume cairan dishell		=	volume cairan - volume head dasar			
		=	1626,351251	-	23,1457	ft^3
		=	1603,2055	ft^3		
Volume cairan dishell		=	1/4 x π x D^2 x Z_L			
	1603,2055	=	1/4 x 3,14 x 9,7023 x Z_L			
	Z_L	=	48,4878	ft		
	Z_L	=	14,7791	m		

Faktor (W) untuk tipe torisperical, dihitung dengan rumus:					
W	=	$\frac{1}{4}\left(3+\sqrt{\frac{r}{icr}}\right)$		Eq. 7.77, P.138, Brownell & Young	
	=	$\frac{1}{4}\left(3+\sqrt{\frac{84}{5\frac{1}{8}}}\right)$			
	=	1,7621	in		
Maka :					
th	=	1/4	in		
	=	0,006635808	m		
	=	0,0218	ft		
dirancang 1/4 in		=	0,007025	m	
		=	0,02305	ft	
<u>Menentukan tinggi head :</u>					
Dari (tabel 5.8, halaman 93, Brownell, 1979) dengan th = 4/16 in, didapat :					
sf	=	$\left(1\frac{1}{2}-2\frac{1}{4}\right) in,$			
dipilih sf	=	2,5	in	Tabel 5.4, p. 87, Brownell and Young	
a	=	ID/2	=	38,9399	
AB	=	a- icr	=	33,8149	
BC	=	r - icr	=	78,875	
AC	=	$\sqrt{BC^2 - AB^2}$	=	71,2588	
b	=	r - AC	=	12,7412	
Tinggi head (OA)		=	th + b + sf		
		=	2/7 + 13,2213+ 2,5		
		=	15,51204174	in	
		=	0,3940	m	
		=	1,2927	ft	
Tinggi reaktor total		=	**tinggi silinder + (2 x tinggi head)**		
		=	77,8798	+	(2 x 15,997) in
		=	108,9038984	in	
		=	3,8552	m	
		=	12,6483	ft	

Dari perhitungan diperoleh :									
Dt	=	6,4900	ft	=	1,9781	m	=	77,8798	in
Di	=	1/3 x Dt							
	=	1/3 x 6,9797	ft	=					
	=	2,1633	ft	=	0,6594	m	=	25,9599	in
Zi	=	1,3 x Di							
	=	1,3 x 2,3266	ft	=					
	=	2,8123	ft	=	0,8572	m	=	33,7479	in
Z_L	=	25,3109	ft	=	7,7148	m	=	303,7313	in
W	=	0,1 x Dt							
	=	0,1 x 6,9797	ft	=					
	=	0,6490	ft	=	0,1978	m	=	7,7880	in
L	=	0,25 x Di							
	=	0,25 x 2,3266	ft	=					
	=	0,5408	ft	=	0,1648	m	=	6,4900	in
T	=	0,2 x Di							
	=	0,2 x 2,3266	ft	=					
	=	0,4327	ft	=	0,1319	m	=	5,1920	in

WELH	=	ZL x (ρ cairan/ ρ air)		
	=	23,7418	ft	
N	=	$\frac{600}{\pi Di}\sqrt{\frac{WELH}{2\ Di}}$		
	=	206,9090	rpm	
	=	3,4485	rps	
Number of turbine		=	WELH / D	
		=	23,7418 / 6,4900	ft / ft
		=	3,6582	

Nre	=	3827079,016			
Karena nRe > 2100 maka alirannya turbulen.					
Six Blade Turbin dengan nRe > 10000 maka nilai Np = Km					
Dari fig. 8.8 rase, diperoleh harga Np :			2,7		
<u>Menghitung power Pengaduk</u>			1 Hp =	745,7	watt
$P = K_m N^3 \rho D^5$					
P	=	12891,74089	watt		
	=	17	kW		
	=	17,28810633	HP		
Effisiensi motor sebesar :	=	88%	Fig. 14.38, Peter		
Daya Motor	=	$\frac{P}{efisiensi}$			
	=	19,64557537	HP		
Daya Motor Standar	=	20	HP		

4. Menara Destilasi

$\alpha_{avg} = \sqrt{\alpha_{top} \times \alpha_{bottom}}$			(Coulson, 1985)		
			1		
komponen	α top	α bottom	α avg		
H2O	0,964205976	0,982735113	0,973426458		
CH2O2	0,984890428	1,015276136	0,999967874		
TOTAL			1,973394332		
α top =	Ya(1-Xa)				
	Xa(1-Ya)				
Nm=	9,155109576		Coulson ,1983,pers .11.58)		
Nm total =	Nm + 1	10,15510958			
Jadi total plate minimum berjumlah 10		10			
				1	
komponen	α	xi,F	α*xi,F	(α*xi,F)/(α-θ)	θ
H2O	1,00753893	0,781810575	0,78770459	1,552008217	0,5
CH2O2	0,983209624	0,218189425	0,214525943	0,242893575	0,1
total				2,794901792	
komponen	α	xi,D	α*xi,D	(α*xi,D)/(α-θ)	θ
H2O	0,964205976	0,985818332	0,950531927	2,609874602	0,6
CH2O2	0,984890428	0,014181668	0,013967389	0,020393611	0,3
total				2,630268213	
(α*xi,D)/(α-θ)	=	Rm + 1			
2,630268213	=	Rm + 1			
Rm	=	1,630268213			
		1,630268213			
R operasi berkisar antara 1,2-1,5 Rm (Geankoplis, 1993)					
R operasi	=	1,2 x Rm			
R operasi	=	1,2 x 1			
R operasi	=	1,956321856			
Rasio reflux aktual :					
R=L/D=1,5xRm	2,44540232				
Rd/(R+1)=1,5xRm	5,379885103				
penentuan jumlah stage ideal :					
R_{op}	=	1,956321856	=	0,661741837	
R_{op+1}		2,956321856			
R_m	=	1,630268213	=	0,619810636	
R_{m+1}		2,630268213			
berdasarkan grafik Erbar maddox correlation, (1961) diperoleh :					
Nm	=	0,15			
N					
1,630268213	=	0,15			
N					
N	=	11	plate (tidak termasuk reboiler)		
	=	12	plate (termasuk reboiler)		

Menentukan Tray Actual			
Tray actual	=	Tray ideal / efisiensi tray	
	=	12/77%	
	=	17,14285714	
		17	
Menentukan letak umpan			
Menentukan lokasi feed tray dengan persamaan Kirkbride			
$\log\left(\frac{N_r}{N_s}\right) = 0{,}206 \times \log\left[\frac{B}{D}\left(\frac{x_{HK,F}}{x_{LK,F}}\right)\left(\frac{x_{LK,B}}{x_{HK,D}}\right)^2\right]$		(Coulson, 1983. Persamaan 11.62)	
B =	19,41129267		
D =	64,71705354		
X Hk, F =	18,35591552		
X LK, F =	65,77243068		
X, LK, B =	1,97317292		
X, HK, D =	0,917795776		
Log(Nr/Ns) =	-0,084953151		
Nr/Ns =	0,822331353		
Nr =	0,822331353	Ns	
jumlah tray termasuk reboiler = 17 plate, sedangkan jumlah plate tanpa reboiler adalah 16 plate.			
Nr + Ns =	N		
Nr + Ns =	16		
Ns =	26/(1+0,657546275)		
Ns =	8,779961981	plate (tidak termasuk reboiler)	
	9		
1. LAJU ALIR MASSA BAGIAN ATAS			
dari neraca massa maka dapat diketahui :			
Feed (F)	=	2029,410844	kg/jam
Top Product (D)	=	1191,267101	kg/jam
Vapor rate (V) = (1+R operasi) x top produk	=	3521,768966	kg/jam
Liquid rate (L) = (top produk x R operasi)	=	2330,501865	kg/jam
2. LAJU ALIR MASSA BAGIAN BAWAH			
q = (L' - L)/F			
q	=	1	
V' = V + (q - 1). F	=	3521,768966	
L' = F + L	=		
L'	=	4359,912709	Kg/jam
V'	=	3521,768966	Kg/jam

a. Liquid-vapor flow factor (FLV)

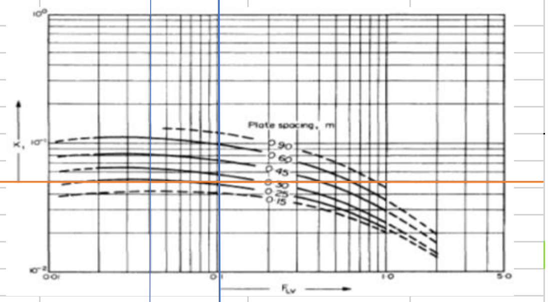
$$F_{LV} = \frac{L_w}{V_w}\sqrt{\frac{\rho_v}{\rho_L}}$$

Caulson, 1983 persamaan 11.82	$F_{LV,Top}$ =	0,013328358	m/s
	$F_{LV,Bottom}$ =	0,004871411	m/s

Tinggi plate spacing pada umumnya antara 0,3-0,6 m (Coulson, 1983, hal. 448)

Diambil plate spacing (lt) = 0,3 m

Figure 11.27 (Coulson, 1983)



untuk tray space 0,3 m, FLV =0,013328358 maka K1 = 0,052

koreksi nilai K1 top :

$$K'_{1top} = K_1\left[\frac{\sigma_{top}}{0,02}\right]^{0,2}$$

K'1 top = 0,08179885

untuk tray space 0,3 m, FLV =0,004871411 maka K1 = 0,049

$$K'_{1bottom} = K_1\left[\frac{\sigma_{bottom}}{0,02}\right]^{0,2}$$

K'1 bottom = 0,083739347

b. Kecepatan Flooding

$$u_f = K'_1\sqrt{\frac{\rho_L - \rho_v}{\rho_v}}$$

Uf, top =	4,060420834	m/s
Uf, bottom =	11,37500654	m/s

Caulson, 1983 persamaan 11.81

kecepatan uap pada umumnya 70-90% dari kecepatan flooding (Coulson, 1983, hal 459) untuk perancangan diambil Uv = 70% Uf

kecepatan uap pada bagian atas :

Uv top = 2,842294584 m/s

kecepatan uap pada bagian bawah :

Uv bottom = 7,962504579 m/s

c.Laju Alir Volumetrik Maksimum

$$Q_v = \frac{V_w}{\rho_v}$$

laju alir volumetrik maksimum, top = 2,712135061 m3/s

laju alir volumetrik maksimum, bottom = 16,36170557 m3/s

d. Luas area netto untuk kontak uap - cair

$$A_n = \frac{Q_v}{u_v}$$

Luas area netto bagian atas, An top =	0,954206181	m2
Luas area netto bagian bawah, An bottom =	2,054844102	m2

e. Luas penampang melintang menara (Ac)

$$A_c = \frac{A_n}{1 - A_d}$$

luas penampang downcomer (Ad) = 20% dari keseluruhan , sehingga :

Ac, top =	1,192757727	m2
Ac, bottom =	2,568555127	m2

f. Diameter menara berdasarkan kecepatan flooding

$$D_c = \sqrt{\frac{4.A_c}{\pi}}$$

Diameter menara bagian atas, Dc, top =	1,232654288	m
Diameter menara bagian bawah, Dc, bottom	2,308879418	m

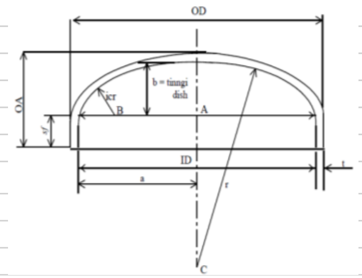
g. Penentuan Jenis Aliran (Flow Pattern)

$$Q_{L,B} = \frac{L_{w,B}}{\rho_{L,B}}$$

0,001097685 m3/s

maka jenis alirannya single pass (cross flow)

h. Perancangan Tray			
Diameter menara, Dc =	2,308879418	m	
Luas Menara, Ac =	1,880656427	m2	
Luas downcomer, Ad = 0,12Ac	0,225678771	m2	
Luas netto, An = Ac-Ad	1,654977656	m2	
Luas aktif, Aa = Ac-2.Ad	1,429298884	m2	
Luas hole, Ah = 0,03. Aa	0,042878967	m2	
Figure 11.31 (Coulson, 1983) untuk Ad/Ac = 0,12, maka :			
lw/Dc =	0,72		
Panjang weir, lw =	0,72*Dc =	1,662393181	m
Tinggi weir yang direkomendasikan adalah antara 40-50 mm (Coulson, 1983)			
tinggi weir yang digunakan (hw) =	50 mm	0,005	m
Diameter hole (dh) yang direkomendasikan	5 mm	0,005	m (Coulson, 1983)
Tebal plate untuk stainless steel =	3 mm	0,003	m
Weeping rate (Lw, max) =	0,647361629	kg/s	
	turn down ratio = 0,80		
	kecepatan aliran cairan minimum (Lw, min) :		
Lw, min =	0,517889303	kg/s	
tinggi weir liquid crest (how) :			
$h_{ow} = 750\left(\frac{L_w}{\rho_L \times I_w}\right)^{2/3}$	(Coulson, 1983 pers. 11.85)		
i. Menara Bagian atas			
how, max =	4,325364946	mm liquid	
how, min =	3,727486514	mm liquid	
pada minimum rate, (ho+how) =	54,32536495	sehingga K2 = 30,4	
kecepatan uap minimum desain dihitung dengan persamaan Enduljee :			
$\check{u}_h = \frac{[K_2 - 0{,}90(25{,}4 - d_h)]}{(\rho_v)^{1/2}}$	(Coulson, 1983 pers 11.84)		
Ûh	20,0471649	m/s	
kecepatan uap minimum aktual (Uam) =			
$u_{am} = \frac{Q_{v,t}}{A_h}$	Uam =	63,25094283	m/s

j. Menara bagian bawah				
how, max =	3,74574668	mm liquid		
how, min =	3,227986635	mm liquid		
pada minimum rate, (ho+how) =	53,74574668	sehingga K2 = 30,0		
kecepatan uap minimum desain dihitung dengan persamaan Enduljee :				
$\check{u}_h = \frac{[K_2 - 0{,}90(25{,}4 - d_h)]}{(\rho_v)^{1/2}}$	(Coulson, 1983 pers 11.84)			
Ûh	19,38114613	m/s		
kecepatan uap minimum aktual (Uam) =				
$u_{am} = \frac{Q_{v,b}}{A_h}$	Uam =	381,5788227	m/s	
Uam > Ûh min sehingga tidak terjadi *weeping*				
p. Menentukan tebal dinding dan Head menara				
	th	=	tebal head (in)	
	icr	=	Inside corner radius (in)	
	r	=	Radius of disk (in)	
	sf	=	Straight flange (in)	
	OD	=	Diameter luar (in)	
	ID	=	Diameter dalam (in)	
	b	=	Depth of dish (in)	
	OA	=	Tinggi head (in)	
• Menentukan Tebal Shell				
Data perhitungan :				
P operasi :	0,860764446	atm		
P design = 1,2 * P operasi =	1,032917336	atm		
	15,17964987	psi		
material stainless steel SA 285 (alasan pemilihan material : tahan terhadap korosifitas dan memiliki struktur kuat)				
f =	11500	psi	(Peters & Timmerhaus,1991, tabel 4	
c =	0,125	in	(Brownell & Young, 1959)	
E =	0,8		(Brownell & Young, 1959, Tabel 13.2	
D =	53,165	in		
r =	26,582	in		
$t = \frac{P.r_i}{f.E - 0{,}6.P} + c$	(Brownell & Young, 1959, Tabel 13.11)			
t =	0,168902751	in		

• menentukan tebal Head			
OD = ID+(2*ts)			
OD =	53,5028055		
OD =	54	in	
dari Tabel 5.7 Brownell & Young :			
icr :	3,25	in	
rc :	54	in	
$w = \frac{1}{4}\left(3 + \sqrt{\frac{r_c}{icr}}\right)$ w =	1,769049331	in	4,076197323
$t_h = \frac{P.r_c.w}{2f\varepsilon - 0{,}2P} + c$ th =	0,188055787	in	
untuk tebal head 0,2 in, maka sf = 1,5-4,5 in			
diambil sf =	4	in	
$b = r_c - \sqrt{(r_c - icr)^2 - (ID/2 - icr)^2}$	(rc-icr)^2	2575,5625	
	(ID/2-icr)^2	751,7193063	
	$\sqrt{(r_c - icr)^2 - (ID/2 - icr)^2}$	42,70647719	
b =	11,29352281	in	
1 in =	0,0254	m	
• Tinggi Head (OA)			
OA = th + b + sf	OA =	15,4815786	in
AB = r-icr	AB =	23,332	in
BC = rc-icr	BC =	50,75	in
AC = (BC^2-AB^2)^0,5	AC =	45,06861742	in

q. Tinggi Menara					
data perhitungan :					
Diameter kolom, Dc	=	2,308879418	m	7,575063949	ft
Luas kolom, Ac	=	1,880656427	m2		
volume head,	=	0,000049*Dc			
	=	0,000113135	m3		
volume head pada sf,	=	π/4*ID^2*sf			
	=	0	in3	0	m3
Volume total head	=	V.head tanpa sf + V.head pada sf			
	=	0,000113135	m3		
Blank diameter	=	OD+OD/24+2sf+2/3.icr			
	=	55,73208906	in	629,4116193	m
untuk bagian bottom kolom :					
Q = L/ρL	=	3,951666622	m3/jam	0,06586111	m3/menit
waktu tinggal cairan dibawah late terakhir : 5-10 menit (Ulrich, 1984)					
waktu tinggal cairan dipilih	=	5	menit		
V cairan	=	Q* waktu tinggal			
	=	0,329305552	m3		
Tinggi cairan dalam shell (HL)	=				
$V_{cairan} = \frac{\pi}{4} D_c^2 H_L$					
HL	=	0,078691331	m		
Tinggi Menara :					
jarak dari plate teratas	=	1	m		
tinggi penyangga menara	=	1	m		
jumlah plate	=	17			
Tebal Plate	=	0,003	m		
Tinggi head dengan tebal head	=	OA-sf			
	=	11,4815786	in	0,291632096	m
Tinggi dibawah plate terbawah	=	HL+(OA-sf)			
	=	0,370323427	m		
Tinggi Total	=	Jarak dari plate teratas + (Jumlah plate-1 x Tray spacing) + Tebal Plate +Tinggi head dengan tebal head +Tinggi dibawah plate terbawah			
	=	6,464955524	m	21,21048468	ft

tegangan permukaan dihitung dengan persamaan sudgen :

$$\sigma = \left[\frac{P_{ch}(\rho_L-\rho_v)}{M}\right]^4 x\ 10^{-12}$$

Coulson, 1983 persamaan 8.23

data untuk menentukan Pch :

atom, group or bond	kontribusi
C	4,8
H	17,1
H dalam OH	11,3
double bond "="	23,1
O	20

4

Perhitungan σ top — 1,00E-11

komponen	BM	Yd,D	Pch	σ	YD*σ
H_2O	18,01	0,964539885	42,6	1,95E+02	188,4008
CH_2O_2	46,026	0,035460115	96,3	1,20E+02	4,240444
Total					192,6412

σ mix top = 192,6412393 dyne/cm 0,192641239 N/m

Perhitungan σ bottom

komponen	BM	Xb,B	Pch	σ	XB*σ
H_2O	18,01	0,042399463	42,6	4,64E+02	19,66255
CH_2O_2	46,026	0,957600537	96,3	2,84E+02	271,877
Total					291,5395

σ mix bottom = 291,5395248 dyne/cm 0,291539525 N/m

k. Plate Pressure Drop

1) Menara bagian atas

maksimum vapour velocity throuh hole Ûh

$$\hat{U}_h = \frac{Q_{v,b}}{A_h}$$

Ûh = 381,5788227 m/s

dari figure 11.34, untuk ketebalan plate /diameter lubang 0,6

(Ah/Aa)*100 = 3

didapat nilai Orifice coefficient (Co) = 0,64

$$h_d = 51\left[\frac{U_h}{C_o}\right]^2 \frac{\rho_v}{\rho_L}$$

hd = 20,29982229 mm liquid

Residual Head =

$$h_r = \frac{12,5\ x\ 10^3}{\rho_L}$$

hr = 14,058502 mm liquid

Total plate pressure =

$$h_T = h_d + (h_w + h_{ow}) + h_r$$

hT = 88,68368923 mm liquid

$$\Delta P_t = 9,81\ x\ 10^{-3} h_t \rho_t$$

ΔPt = 773,5416898 Pa = 0,007634 atm

keterangan :

Uh	kecepatan uap maksimum melewati hole (m/s)
Ah	Luas hole (m2)
Qv,botton	laju alir volumetrik uap maksimum bagian bottom (m3/s)
ρv	densitas uap (kg/m3)
ρL	densitas liquid (kg/m3)
Co	Orifice coefficient
hd	Dry plate drop (mm)
hr	residual head (mm)

2) Menara bagian bawah

Ûh = 381,5788227 m/s

hd = 982,4513373 mm liquid

hr = 11,32954627 mm liquid

ht = 1047,52663 mm liquid

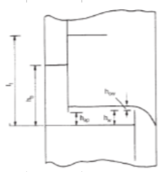
ΔPt = 11337,87267 Pa = 0,111893465 atm

l. Downcomer liquid backup

1) menara bagian atas

$$h_{dc} = 166\left[\frac{L_w}{\rho_L \cdot A_{ap}}\right]^2$$

$$h_b = (h_{ow} + h_w) + h_t + h_{dc}$$



hap = tinggi ujung apron dari plate
hw = tinggi weir, mm
Aap = luas permukaan clearance dibawah downcomer,m2
ρL = rapat massa cairan, kg/m3
Lw = kecepatan massa cairan, kg/s
hdc = head yang hilang di downcomer, mm
how = tinggi cairan diatas weir, mm
ht = plate pressure drop, mm

hap = tinggi ujung apron dari plate, mm (hw - 10 mm = 50 mm - 10 mm = 40 mm) 0,04 m

Aap = hap x lw 0,066495727 m2

hdc = 0,054997137 mm cairan

hb = 143,0640513 mm cairan 0,143064051 m

(1/2)*(lt + hw) = 0,2525 m

hb < (1/2)*(lt + hw),maka pemilihan plate spacing 0,3

2) menara bagian bawah

hap = tinggi ujung apron dari plate, mm (hw - 10 mm = 50 mm - 10 mm = 40 mm) 0,04 m

Aap = hap x lw 0,066495727 m2

hdc = 0,00827179 mm cairan

hb = 1101,280649 mm cairan 1,101280649 m

(1/2)*(lt + hw) = 0,6275

m. Check Residence time

$$t_r = \frac{A_d \cdot h_b \cdot \rho_L}{L_w}$$

jika tr < 3 detik, maka tidak terjadi gelembung udara pada cairan yang masuk melalui downcomer

1) menara bagian atas :

tr = 44,34505928 detik (>3 detik)

2) menara bagian bawah :

tr = 529,4796476 detik (> 3 detik)

keterangan :
t = downcomer resindence time, s
Ad = luas ermukaan downcomer, m2
hb = clear liquid back up, m
ρL = rapat massa cairan, kg/m3
Lw = kecepatan massa cairan, kg/s

n. Check Entrainment				
$\% flooding = \frac{u_v}{u_f} \times 100\%$	Coulson & Richardson, 1986			Uv = kecepatan uap aktual, m/s
				Uf = kepetan uap perancangan, m/s
1) menara bagian atas :				
FLV,Top =	0,013328358	m/s		
% flooding	70%			
dari figure 11.29 diperoleh nilai ψ = 0,08 < 1, sehingga tidak terjadi Entrainment				
2) menara bagian bawah :				
FLv, bottom =	0,004871411	m/s		
% flooding	70%			
dari figure 11.29 diperoleh nilai ψ = 0,065 < 1, sehingga tidak terjadi Entrainment				
0. Layout tray				
• Derajat Try Edge untuk lw/Dc = 0,72 adalah 90°				
lw/Dc	=	0,72		
(α)	=	180° - θc		
	=	180° - 90°		
	=	90°		
• Panjang rata - rata *unperforated edge strips* :				
$L_{av} = \frac{\alpha}{180} \times \pi \times (D_c - 0{,}05)$				
Lav =	3,546440686	m		
• Luas *unperforated edge strips* :				
Aup =	0,177322034	m2		
• Luas Calming Zone :				
$(A_{cz}) = 2 \times h_w \times (l_w - (2.h_w))$				
Acz =	0,016523932	m2		
• Luas total yang tersedia untuk perforasi :				
$(A_p) = A_a - (A_{up} + A_{cz})$				
Ap =	1,235452918	m2		
Ah/Ap =	0,034707083			
dari figure 11.33 hal 466, coulson diperoleh nilai :				
lp/dh =	3,8			

• Hole pitch :			
$(I_p) = \frac{I_p}{d_h} \times d_h$			
lp =	0,019	m	
luas 1 lubang =	(π/4)*(dh^2)	0,000019625	m2
jumlah lubang	=	Ah/luas 1 lubang	
	=	2184,915492	buah
jumlah lubang	=	2185	buah
• Spesifikasi Tray :			
Diameter Tray, Dc =	2,308879418	m	
Diameter lubang, dh =	0,005	m	
Hole Pitch, lp =	0,019	m	
Jumlah lubang hole pitch =	2185	buah	
Turn down Ratio =	80%		
Material Tray =	Stainless steel (SA-240)		
Material downcomer =	Stainless steel (SA-240)		
Tray Spacing =	0,3	m	
Tray Thickness =	0,003	m	
Panjang weir =	1,662393181	m	
Tinggi weir =	0,005	m	
Total Pressure Drop =	0,119527548	atm	

5. Data Grafik BEP dan SDP

fa	5,45E+10
Va	9,09E+10
Ra	1,48E+11
Sa	4,32E+11

persamaan 1	
y=fa	
x	y
0	5,45E+10
10	5,45E+10
20	5,45E+10
30	5,45E+10
40	5,45E+10
50	5,45E+10
60	5,45E+10
70	5,45E+10
80	5,45E+10
90	5,45E+10
100	5,45E+10

persamaan 2	
y=(sa*x)/100	
sa	432244500000
x	y
0	0
10	43224450000
20	86448900000
30	1,29673E+11
40	1,72898E+11
50	2,16122E+11
60	2,59347E+11
70	3,02571E+11
80	3,45796E+11
90	3,8902E+11
100	4,32245E+11

persamaan 3	
y=fa+(0.7va+0.3ra)/100*x	
(0.7va+0.3ra)	108113295115
0.3ra	44504885526
x	y
0	5,45E+10
10	6,53E+10
20	7,61E+10
30	8,70E+10
40	9,78E+10
50	1,09E+11
60	1,19E+11
70	1,30E+11
80	1,41E+11
90	1,52E+11
100	1,63E+11

Persamaan 4	
y=fa+0.3ra+(0.7ra+va)/100*x	
0.3ra	4,45E+10
0.7ra	1,04E+11
(0.7ra+va)/100	1947138894,4940
fa	5,45E+10
x	y
0	9,90E+10
10	1,18E+11
20	1,38E+11
30	1,57E+11
40	1,77E+11
50	1,96E+11
60	2,16E+11
70	2,35E+11
80	2,55E+11
90	2,74E+11
100	2,94E+11