APPENDIX A
PERHITUNGAN NERACA MASSA

Tulang kering yang diolah adalah 13500 kg/hari

Komposisi bahan penyusun tulang adalah :

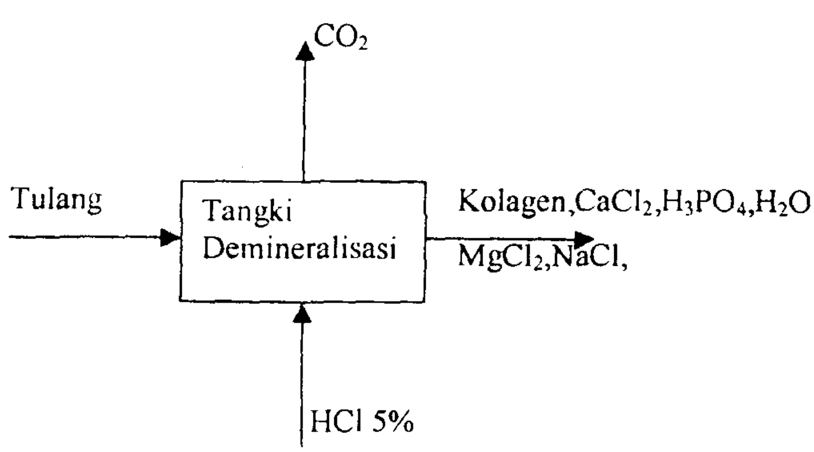
- $Ca_3(PO_4)_2$ = 57,35 %
- $CaCO_3$ = 3,85 %
- $Mg_3(PO_4)_2$ = 2,05 %
- Na_2CO_3 = 3,45 %
- Kolagen = 33,30 %

I. Unit Penyediaan Bahan Baku

Tangki Demineralisasi (F-140)

Jumlah :	$Ca_3(PO_4)_2$	= 57,35 % x 13500	= 7742,2500 kg
	$CaCO_3$	= 3,85 % x 13500	= 519,7500 kg
	$Mg_3(PO_4)_2$	= 2,05 % x 13500	= 276,7500 kg
	Na_2CO_3	= 3,45 % x 13500	= 465,7500 kg
	Kolagen	= 33,30 % x 13500	= 4495,5000 kg +
			= 13500,0000 kg

Terjadi proses penghilangan mineral dengan menambah HCl 5 % (othmer,1980)



Data : BM	$Ca_3(PO_4)_2$	= 310,19	$CaCl_2$	= 110,994
	$CaCO_3$	= 100,91	$MgCl_2$	= 95,234
	$Mg_3(PO_4)_2$	= 262,91	NaCl	= 58,448
	Na_2CO_3	= 105,993	H_3PO_4	= 97,999
	HCl	= 36,465	H_2O	= 18,016
	CO_2	= 44,011	Kolagen	= 2417,562
	Gelatin	= 2435,578		

Reaksi :

1. $Ca_3(PO_4)_{2\,(s)} + 6HCl_{(aq)} \longrightarrow 3CaCl_{2(s)} + 2H_3PO4_{(aq)}$

$Ca_3(PO_4)_2 = \dfrac{7742,25}{310,19} = 24,9597$ kmol

HCl = 6 x 24,9597 kmol x 36,465 kg/kmol = 5460,9328 kg

$CaCl_2$ = 3 x 24,9597 kmol x 110,994 kg/kmol = 8311,1308 kg

H_3PO_4 = 2 x 24,9597 kmol x 97,999 kg/kmol = 4892,0513 kg

2. $CaCO_3 + 2\,HCl \longrightarrow CaCl_2 + H_2O + CO_2$

$CaCO_3 = \dfrac{519,75}{100,91} = 5,1506$ kmol

HCl = 2 x 5,1506 kmol x 36,465 kg/kmol = 375,6333 kg

$CaCl_2$ = 5,1506 kmol x 110,994 kg/kmol = 571,6857 kg

H_2O = 5,1506 kmol x 18,016 kg/kmol = 92,7932 kg

CO_2 = 5,1506 kmol x 44,011 kg/kmol = 226,6831 kg

3. $Mg_3(PO_4)_2 + 6\,HCl \longrightarrow 3\,MgCl_2 + 2\,H_3PO_4$

$Mg_3(PO_4)_2 = \dfrac{276,75}{262,91} = 1,0526$ kmol

HCl = 6 x 1,0526 kmol x 36,465 kg/kmol = 230,2984 kg

$MgCl_2$ = 3 x 1,0526 kmol x 95,234 kg/kmol = 300,7299 kg

H_3PO_4 = 2 x 1,0526 kmol x 97,999 kg/kmol = 206,3075 kg

4. $Na_2CO_3 + 2\,HCl \longrightarrow 2\,NaCl + H_2O + CO_2$

$$Na_2CO_3 = \frac{465,75}{105,993} = 4,3942 \text{ kmol}$$

HCl = 2 x 4,3942 kmol x 36,465 kg/kmol = 320,469 kg

$NaCl$ = 2 x 4,3942 kmol x 58,448 kg/kmol = 513,6644 kg

H_2O = 4,3942 kmol x 18,016 kg/kmol = 79,1659 kg

CO_2 = 4,3942 kmol x 44,011 kg/kmol = 193,3931 kg

Jumlah HCl murni yang dibutuhkan = (5460,9328 + 375,6333 + 230,2984 + 320,469) kg

= 6387,3335 kg

Didalam tangki demineralisasi HCl yang dibutuhkan adalah HCl 5 % :

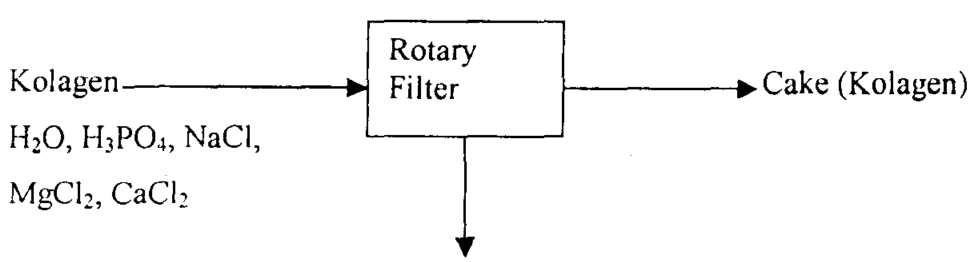
$$\text{HCl 5 \% yang dibutuhkan} = \frac{100}{5} x 6387,3335 = 127746,67 \text{ kg}$$

Air yang ditambahkan untuk membuat HCl 5 % = 127746,67 – 6387,3335

= 121359,3365 kg

Masuk :		Keluar :	
Tulang yang telah hancur	= 13500,0000 kg	Kolagen	= 4495,5000 kg
HCl	= 6387,3335 kg	Air	= 121531,2956 kg
Air	= 121359,3365 kg	$CaCl_2$	= 8882,8165 kg
		H_3PO_4	= 5098,3588 kg
		$MgCl_2$	= 300,7299 kg
		CO_2	= 424,3048 kg
	+	NaCl	= 513,6644 kg +
	141246,6700 kg		141246,6700 kg

Rotary Drum Filter (H-141)



Filtrat (H_3PO_4, NaCl, $CaCl_2$

$MgCl_2$, H_2O)

Data - data : 1. Fitrat keluar dari Rotary Filter telah bebas impurities

2. Massa cake kering yang terkumpul dalam frame 60%-80% berat cake (Ulrich,1984)

3. Massa filtrat yang terikut 20% berat cake.

Massa cake kering = 4495,5000 kg

Massa filtrat yang terikut cake = $\frac{20}{80} x 4495,5 kg$ = 1123,875 kg

Massa cake = 4495,5 kg + 1123,875 kg

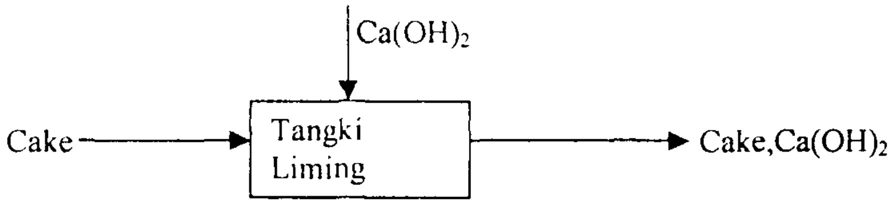
= 5619,375 kg

Massa filtrat = 136326,8652 kg – 1123,875 kg

= 135202,9902 kg

Masuk :		Keluar :	
		Cake ke tangki liming :	
Kolagen	= 4495,5000 kg	Kolagen	= 4495,5000 kg
H_2O	= 121531,2956 kg	H_2O	= 1001,9346 kg
$CaCl_2$	= 8882,8165 kg	$CaCl_2$	= 73,1643 kg
$MgCl_2$	= 300,7299 kg	$MgCl_2$	= 2,4725 kg
NaCl	= 513,6644 kg	NaCl	= 4,2707 kg
H_3PO_4	= 5098,3588 kg	H_3PO_4	= 42,0329 kg
		Filtrat ke pembuangan :	
		H_2O	= 120529,3610 kg
		$CaCl_2$	= 8809,6522 kg
		$MgCl_2$	= 298,2574 kg
		NaCl	= 509,3937 kg
	+	H_3PO_4	= 5056,3259 kg +
	140822,3652 kg		140822,3652 kg

Tangki Liming (F-150)

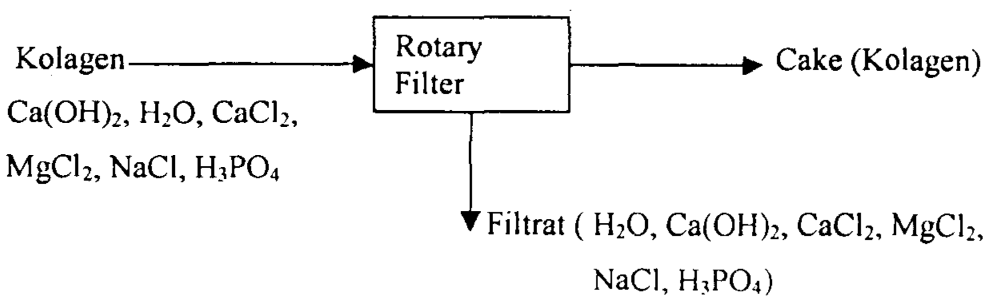


Pemakaian air kapur : kolagen kering = 4 : 1 (Ward,1977)

Berat air kapur = $\frac{4}{1} x 4495{,}5 kg$ = 17982 kg

Masuk :			Keluar :		
Cake	:		Kolagen	=	4495,5000 kg
Kolagen	=	4495,5000 kg	H_2O	=	1001,9346 kg
H_2O	=	1001,9346 kg	$CaCl_2$	=	73,1643 kg
$CaCl_2$	=	73,1643 kg	$MgCl_2$	=	2,4725 kg
$MgCl_2$	=	2,4725 kg	NaCl	=	4,2707 kg
NaCl	=	4,2707 kg	H_3PO_4	=	42,0329 kg
H_3PO_4	=	42,0329 kg	$Ca(OH)_2$	=	17982,0000 kg
$Ca(OH)_2$	=	17982,0000 kg +			+
		23601,3750 kg			23601,3750 kg

Rotary Drum Filter (H-151)



Data - data : 1. Fitrat keluar dari Rotary Filter telah bebas impurities

2. Massa cake kering yang terkumpul dalam frame 60%-80% berat cake (Ulrich,1984)

3. Massa filtrat yang terikut 20% berat cake.

Massa cake kering = 4495,5000 kg

Massa filtrat terikut cake = $\frac{20}{80} x 4495{,}5 kg$ = 1123,875 kg

Massa cake = 4495,5 kg + 1123,875 kg

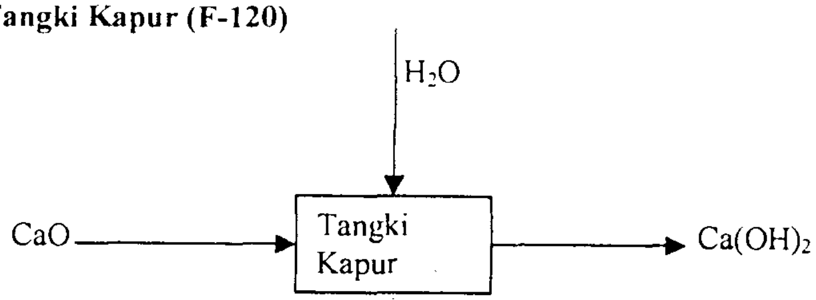
= 5619,375 kg

Massa filtrat = 1001,9346 + 73,1643 + 2,4725 + 4,2707 + 42,0329 + 17982

= 19105,875 kg

Masuk dari tangki liming :		Keluar ke tangki netralisasi :	
Kolagen	= 4495,5000 kg	Cake :	
H_2O	= 1001,9346 kg	Kolagen	= 4495,5000 kg
$CaCl_2$	= 73,1643 kg	H_2O	= 59,0034 kg
$MgCl_2$	= 2,4725 kg	$CaCl_2$	= 4,2707 kg
NaCl	= 4,2707 kg	$MgCl_2$	= 0,1124 kg
H_3PO_4	= 42,0329 kg	NaCl	= 0,2248 kg
$Ca(OH)_2$	= 17982,0000 kg	H_3PO_4	= 2,4725 kg
		$Ca(OH)_2$	= 1057,7912 kg
		Filtrat ke pembuangan :	
		H_2O	= 942,9312 kg
		$CaCl_2$	= 68,8936 kg
		$MgCl_2$	= 2,3601 kg
		NaCl	= 4,0459 kg
		H_3PO_4	= 39,5604 kg
	+	$Ca(OH)_2$	= 16924,2088 kg +
	23601,3750 kg		23601,3750 kg

Tangki Kapur (F-120)



Kadar CaO = 10%

Air kapur 10% yang digunakan adalah = 17982 kg

s.g CaO = 3,32 (Perry ed.7, Tabel 2-1)

Berat CaO = 10% x 17982 kg = 1798,2 kg

Berat H_2O = (17982-1798,2) kg = 16183,8 kg

ρH_2O pada T=30^{0}C = 0,99568 kg/lt (Geankoplis, 1983)

ρ_{CaO} = s.g CaO x ρH_2O = 3,32 x 0,99568 kg/lt = 3,3057 kg/lt

$$\frac{1}{\rho_{campuran}} = \sum \frac{x_i}{\rho_i} = \frac{1798{,}2}{17982.3{,}3057} + \frac{16183{,}8}{17982.0{,}99568} = 0{,}9342$$

$\rho_{campuran}$ = 1,0705 kg/lt

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

CaO yang bereaksi = $\frac{1798{,}2}{56{,}08}$ = 32,0649 kmol

H_2O yang bereaksi = 32,0649 kmol x 18,016 kg/kmol

= 577,6812 kg

$Ca(OH)_2$ yang terbentuk = 32,0649 kmol x 74,096 kg/kmol

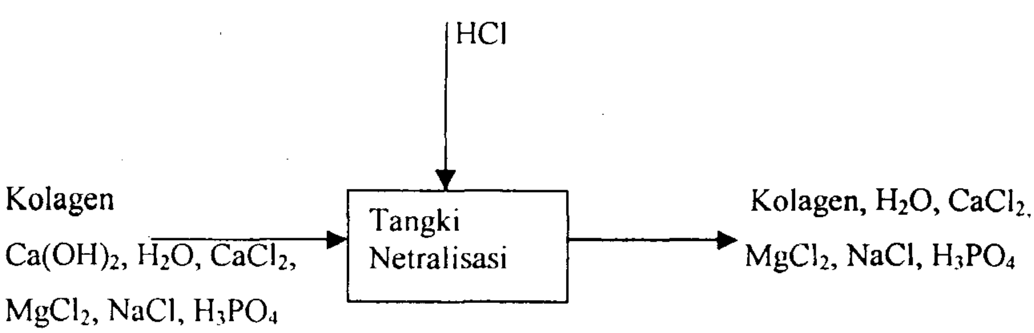
= 2375,8808 kg

Air yang tidak bereaksi = 16183,8 – 577,6812

= 15606,1188 kg

Masuk :		Keluar :	
CaO	= 1798,2000 kg	$Ca(OH)_2$	= 2375,8808 kg
Air	= 16183,8000 kg +	Air	= 15606,1188 kg +
	17982,0000 kg		17982,0000 kg

Tangki Netralisasi (F-160)



Reaksi : $Ca(OH)_2$ + 2 HCl $\longrightarrow$ $CaCl_2$ + $2H_2O$

$Ca(OH)_2$ yang terbawa masuk ke tangki netralisasi = $\dfrac{1057{,}7912kg}{74{,}096kg/kmol}$

= 14,276 kmol

HCl yang digunakan untuk netralisasi = 2 x 14,276 kmol

= 28,552 kmol x 36,465 kg/kmol

= 1041,1487 kg

H_2O = 2 x 14,276 kmol

= 28,552 kmol x 18,016 kg/kmol

= 514,3928 kg

$CaCl_2$ = 14,276 kmol x 110,994 kg/kmol

= 1584,5503 kg

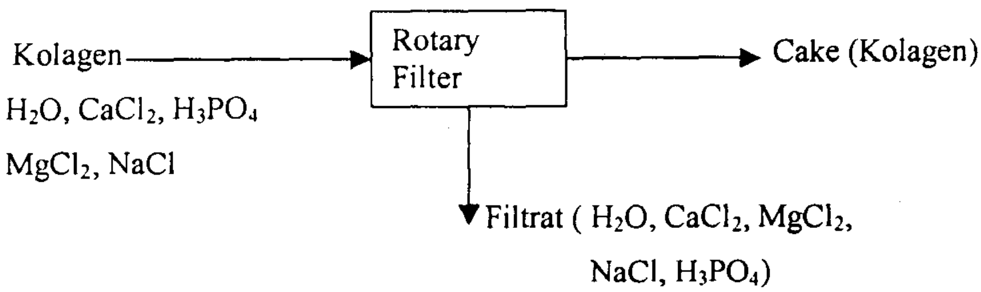
HCl 5% yang digunakan = $\dfrac{1041{,}1487}{0{,}05}$ = 20822,974 kg

Air yang ditambahkan untuk membua HCl 5% = 20822,974 – 1041,1487

= 19781,8253 kg

Masuk :			Keluar :		
Kolagen	=	4495,5000 kg	Kolagen	=	4495,5000 kg
H_2O	=	19840,8287 kg	H_2O	=	20355,2215 kg
$Ca(OH)_2$	=	1057,7912 kg	$CaCl_2$	=	1588,8210 kg
HCl	=	1041,1487 kg	$MgCl_2$	=	0,1124 kg
$CaCl_2$	=	4,2707 kg	NaCl	=	0,2248 kg
$MgCl_2$	=	0,1124 kg	H_3PO_4	=	2,4725 kg
NaCl	=	0,2248 kg			
H_3PO_4	=	2,4725 kg +			+
		26442,3522 kg			26442,3522 kg

Rotary Drum Filter (H-161)



Data - data : 1. Fitrat keluar dari Rotary Filter telah bebas impurities

2. Massa cake kering yang terkumpul dalam frame 60%-80% berat cake (Ulrich,1984)

3. Massa filtrat yang terikut 20% berat cake.

Massa cake kering = 4495,5000 kg

Massa filtrat terikut cake = $\frac{20}{80} x 4495{,}5 kg$ = 1123,875 kg

Massa cake = 4495,5 kg + 1123,875 kg

= 5619,375 kg

Massa filtrat = 20355,2215 + 1588,821 +0,1124 + 0,2248 + 2,4725

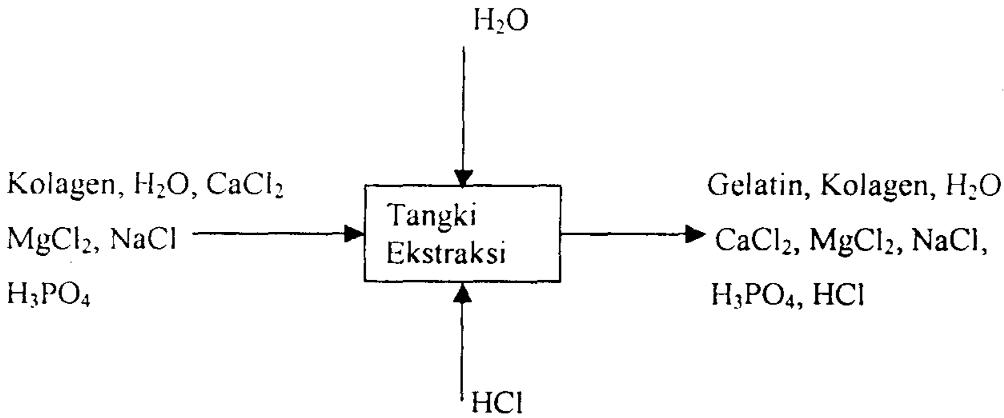
= 21946,8522

Masuk :		Keluar :	
Kolagen	= 4495,5000 kg	Cake :	
H_2O	= 20355,2215 kg	Kolagen	= 4495,5000 kg
$CaCl_2$	= 1588,8210 kg	H_2O	= 1042,3694 kg
$MgCl_2$	= 0,1124 kg	$CaCl_2$	= 81,3618 kg
NaCl	= 0,2248 kg	$MgCl_2$	= 0,0056 kg
H_3PO_4	= 2,4725 kg	NaCl	= 0,0112 kg
		H_3PO_4	= 0,1270 kg
		Filtrat :	
		H_2O	= 19312,8521 kg
		$CaCl_2$	= 1507,4592 kg
		$MgCl_2$	= 0,1068 kg
		NaCl	= 0,2136 kg

+ H_3PO_4 = 2,3455 kg +

26442,3522 kg 26442,3522 kg

II. Unit Ekstraksi



Berat kolagen kering = 4495,5 kg.

Pada ekstraksi ini gelatin terekstrak dari kolagen dengan menggunakan pengekstrak air.

Tangki Ekstraksi I (F-210)

Gelatin yang terekstrak 24% dari bahan kering (Ward, 1977)

= 24% x 4495,5 kg = 1078,92 kg

Kolagen yang belum terekstrak = (4495,5 – 1078,92) kg

= 3416,58 kg

Air yang dibutuhkan untuk ekstraksi dibanding dengan kolagen kering = 2,3:1 (Ward, 1977)

$$= \frac{2,3}{1} \times 4495,5 \text{ kg} = 10339,65 \text{ kg}$$

Air yang ditambahkan = 10339,65 kg – 1042,3694 kg

= 9297,2806 kg

pH ekstraksi = 2

pH = - log $[H^+]$

$C_{H^+} = C_{HCl} = 0{,}01$ mol/lt x 36,465 gr/mol

$= 0{,}36465$ gr/lt

Volume air yang dibutuhkan untuk ekstraksi $= \dfrac{10339{,}65 kg}{1 kg/lt} = 10339{,}65$ lt

Kebutuhan HCl = 0,36465 gr/lt x 10339,65 lt

= 3770,3534 gr = 3,7703534 kg

HCl 5% yang digunakan $= \dfrac{3{,}7703534}{0{,}05} = 75{,}4071$ kg

Masuk :		Keluar :	
Kolagen	= 4495,5000 kg	Gelatin	= 1078,9200 kg
H_2O	= 10339,6500 kg	Kolagen	= 3416,5800 kg
$CaCl_2$	= 81,3618 kg	$CaCl_2$	= 81,3618 kg
$MgCl_2$	= 0,0056 kg	$MgCl_2$	= 0,0056 kg
NaCl	= 0,0112 kg	NaCl	= 0,0112 kg
H_3PO_4	= 0,1270 kg	H_2O	= 10339,6500 kg
HCl 5%	= 75,4071 kg	H_3PO_4	= 0,1270 kg
	+	HCl 5%	= 75,4071 kg +
	14992,0627 kg		14992,0627 kg

Tangki Ekstraksi II (F-220)

Gelatin yang terbentuk 19% dari bahan kering (Ward, 1977)

= 19% x 3416,5800 kg = 649,1502 kg

Kolagen yang belum terekstrak = (3416,58 – 649,1502) kg

= 2767,4298 kg

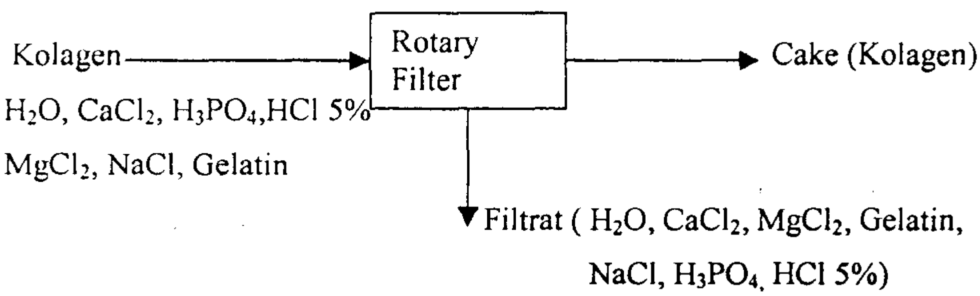
Jumlah gelatin = 1078,92 kg + 649,1502 kg

= 1728,0702 kg

Masuk :		Keluar :	
Kolagen	= 3416,5800 kg	Gelatin	= 1728,0702 kg

H_2O	=	10339,6500 kg	Kolagen	=	2767,4298 kg
$CaCl_2$	=	81,3618 kg	$CaCl_2$	=	81,3618 kg
$MgCl_2$	=	0,0056 kg	$MgCl_2$	=	0,0056 kg
NaCl	=	0,0112 kg	NaCl	=	0,0112 kg
H_3PO_4	=	0,1270 kg	H_2O	=	10339,6500 kg
HCl 5%	=	75,4071 kg	H_3PO_4	=	0,1270 kg
Gelatin	=	1078,9200 kg	HCl 5%	=	75,4071 kg +
		14992,0627 kg			14992,0627 kg

Rotary Drum Filter (H-221)



Data - data : 1. Fitrat keluar dari Rotary Filter telah bebas impurities

2. Massa cake kering yang terkumpul dalam frame 60%-80% berat cake (Ulrich,1984)

3. Massa filtrat yang terikut 20% berat cake.

Massa cake kering = 2767,4298 kg

Massa filtrat terikut cake = $\frac{20}{80} x 2767,4298 kg$ = 691,8575 kg

Massa cake = 2767,4298 kg + 691,8575 kg

= 3459,2873 kg

Masuk :			Keluar :		
Kolagen	=	2767,4298 kg	Cake	:	
H_2O	=	10339,6500 kg	Kolagen	=	2767,4298 kg
$CaCl_2$	=	81,3618 kg	H_2O	=	585,1762 kg
$MgCl_2$	=	0,0056 kg	$CaCl_2$	=	4,6047 kg
NaCl	=	0,0112 kg	$MgCl_2$	=	0,0003 kg

H_3PO_4	= 0,1270 kg		NaCl	=	0,0006 kg
Gelatin	= 649,1502 kg		H_3PO_4	=	0,0072 kg
HCl 5%	= 75,4071 kg		HCl 5%	=	4,2677 kg
			Gelatin	=	97,8008 kg
		Filtrat		:	
			Gelatin	=	1630,2694 kg
			HCl 5%	=	71,1394 kg
			H_2O	=	9754,4738 kg
			$CaCl_2$	=	76,7571 kg
			$MgCl_2$	=	0,0053 kg
			NaCl	=	0,0106 kg
	+		H_3PO_4	=	0,1198 kg +
	16070,9827 kg				16070,9827 kg

Tangki Ekstraksi III (F-230)

Gelatin yang terbentuk 12% dari bahan kering (Ward, 1977)

= 12% x 2767,4298 kg = 332,0916 kg

Jumlah gelatin = 332,0916 kg + 97,8008 kg = 429,8924 kg

Kolagen yang belum terekstraksi = (2767,4298 – 332,0916) kg

= 2435,3382 kg

Air yang dibutuhkan untuk ekstraksi dibanding dengan kolagen kering = 2,3:1 (Ward, 1977)

$$= \frac{2,3}{1} \times 2767,4298 \text{ kg} = 6365,0885 \text{ kg}$$

Air yang ditambahkan = 6365,0885 kg – 585,1762 kg

= 5779,9123 kg

pH hidrolisis = 2,5

pH = - log [H^+]

$C_{H^+} = C_{HCl} = 3,1623.10^{-3}$ mol/lt x 36,465 gr/mol

= 0,1153 gr/lt

Volume air yang dibutuhkan untuk ekstraksi = $\dfrac{6365{,}0885 kg}{1 kg/lt}$ = 6365,0885 lt

Kebutuhan HCl = 0,1153 gr/lt x 6365,0885 lt

= 733,8947 gr = 0,7338947 kg

HCl 5% yang digunakan = $\dfrac{0{,}7338947}{0{,}05}$ = 14,6779 kg

HCl 5% yang ditambahkan = 14,6779 kg – 4,2677 kg

= 10,4102 kg

Masuk :			Keluar :		
Kolagen	=	2767,4298 kg	Kolagen	=	2435,3382 kg
Gelatin	=	97,8008 kg	Gelatin	=	429,8924 kg
H_2O	=	6365,0885 kg	H_2O	=	6365,0885 kg
$CaCl_2$	=	4,6047 kg	$CaCl_2$	=	4,6047 kg
$MgCl_2$	=	0,0003 kg	$MgCl_2$	=	0,0003 kg
NaCl	=	0,0006 kg	NaCl	=	0,0006 kg
H_3PO_4	=	0,0072 kg	H_3PO_4	=	0,0072 kg
HCl 5%	=	14,6779 kg +	HCl 5%	=	14,6779 kg +
		9249,6098 kg			9249,6098 kg

Tangki Ekstraksi IV (F-240)

Gelatin yang terbentuk 8 % dari bahan kering (Ward, 1977)

= 8 % x 2435,3382 kg = 194,8271 kg

Jumlah gelatin = 429,8924 kg + 194,8271 kg = 624,7195 kg

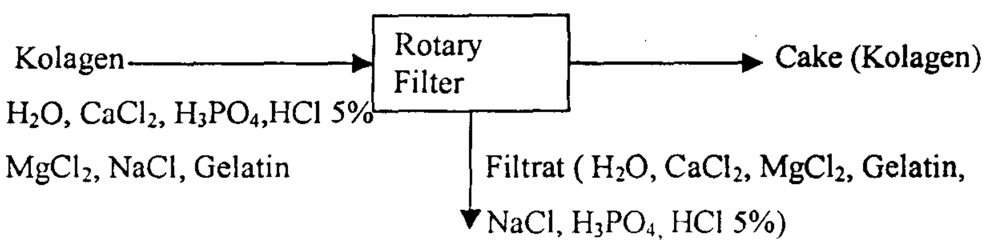
Kolagen yang belum terekstraksi = (2435,3382 – 194,8271) kg

= 2240,5111 kg

Masuk :			Keluar :		
Kolagen	=	2435,3382 kg	Kolagen	=	2240,5111 kg

Gelatin	= 429,8924 kg	Gelatin	= 624,7195 kg
H_2O	= 6365,0885 kg	H_2O	= 6365,0885 kg
$CaCl_2$	= 4,6047 kg	$CaCl_2$	= 4,6047 kg
$MgCl_2$	= 0,0003 kg	$MgCl_2$	= 0,0003 kg
NaCl	= 0,0006 kg	NaCl	= 0,0006 kg
H_3PO_4	= 0,0072 kg	H_3PO_4	= 0,0072 kg
HCl 5%	= 14,6779 kg +	HCl 5%	= 14,6779 kg +
	9249,6098 kg		9249,6098 kg

Rotary Drum Filter (H-241)



Data - data : 1. Fitrat keluar dari Rotary Filter telah bebas impurities

2. Massa cake kering yang terkumpul dalam frame 60%-80% berat cake (Ulrich,1984)

3. Massa filtrat yang terikut 20% berat cake.

Massa cake kering = 2240,5111 kg

Massa filtrat terikut cake = $\frac{20}{80} x 2240,5111 kg$ = 560,1278 kg

Massa cake = 2240,5111 kg + 560,1278 kg

= 2800,6389 kg

Masuk :		Keluar :	
Kolagen	= 2240,5111 kg	Cake :	
H_2O	= 6365,0885 kg	Kolagen	= 2240,51110 kg

$CaCl_2$	= 4,6047 kg	H_2O	= 508,66212 kg
$MgCl_2$	= 0,0003 kg	$CaCl_2$	= 0,36798 kg
NaCl	= 0,0006 kg	$MgCl_2$	= 0,00002 kg
H_3PO_4	= 0,0072 kg	NaCl	= 0,00005 kg
Gelatin	= 624,7195 kg	H_3PO_4	= 0,00058 kg
HCl 5%	= 14,6779 kg	HCl 5%	= 1,17298 kg
		Gelatin	= 49,92407 kg
		Filtrat	:
		Gelatin	= 574,79543 kg
		HCl 5%	= 13,50492 kg
		H_2O	= 5856,42638 kg
		$CaCl_2$	= 4,23672 kg
		$MgCl_2$	= 0,00028 kg
		NaCl	= 0,00055 kg
	+	H_3PO_4	= 0,00662 kg +
	9249,60980 kg		9249,60980 kg

Tangki Ekstraksi V (F-250)

Gelatin yang terbentuk 14 % dari bahan kering (Ward, 1977)

= 14 % x 2240,5111 kg = 313,6716 kg

Jumlah gelatin = 49,92407 kg + 313,6716 kg = 363,59567 kg

Kolagen yang belum terekstraksi = (2240,5111 – 313,6716) kg

= 1926,8395 kg

Air yang dibutuhkan untuk hidrolisis dibanding dengan kolagen kering = 2,3:1 (Ward, 1977)

$$= \frac{2,3}{1} \times 2240,5111 \text{ kg} = 5153,1755 \text{ kg}$$

Air yang ditambahkan = 5153,1755 kg – 508,66212 kg

= 4644,51338 kg

pH hidrolisis = 2,8

pH = - log $[H^+]$

$C_{H^+} = C_{HCl} = 1{,}5849.10^{-3}$ mol/lt x 36,465 gr/mol

$= 0{,}0578$ gr/lt

Volume air yang dibutuhkan untuk hidrolisis $= \dfrac{5153{,}1755 kg}{1 kg/lt} = 5153{,}1755$ lt

Kebutuhan HCl = 0,0578 gr/lt x 5153,1755 lt

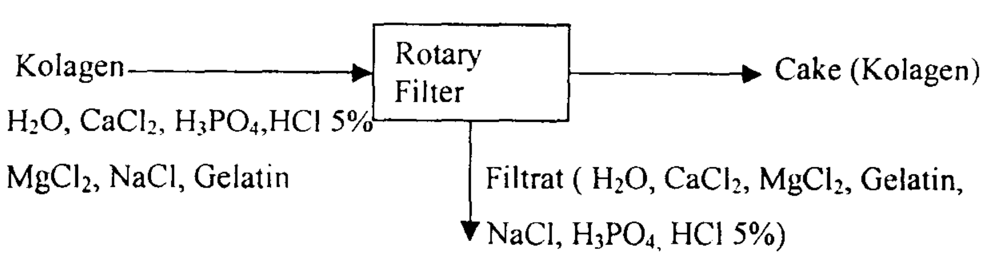
= 297,8535 gr = 0,29978535 kg

HCl 5% yang digunakan $= \dfrac{0{,}29978535}{0{,}05} = 5{,}9957$ kg

HCl 5% yang ditambahkan = 5,9957 kg – 1,17298 kg = 4,82272 kg

Masuk :		Keluar :	
Kolagen	= 2240,51110 kg	Kolagen	= 1926,83950 kg
Gelatin	= 49,92407 kg	Gelatin	= 363,59567 kg
H_2O	= 5153,17550 kg	H_2O	= 5153,17550 kg
$CaCl_2$	= 0,36798 kg	$CaCl_2$	= 0,36798 kg
$MgCl_2$	= 0,00002 kg	$MgCl_2$	= 0,00002 kg
NaCl	= 0,00005 kg	NaCl	= 0,00005 kg
H_3PO_4	= 0,00058 kg	H_3PO_4	= 0,00058 kg
HCl 5%	= 5,99570 kg +	HCl 5%	= 5,99570 kg +
	7449,97500 kg		7449,97500 kg

Rotary Drum Filter (H-251)



Data - data : 1. Fitrat keluar dari Rotary Filter telah bebas impurities

2. Massa cake kering yang terkumpul dalam frame 60%-80% berat cake (Ulrich,1984)

3. Massa filtrat yang terikut 20% berat cake.

Massa cake kering = 1926,8395 kg

Massa filtrat terikut cake = $\frac{20}{80} x 1926{,}8395 kg$ = 481,7099 kg

Massa cake = 1926,8395 kg + 481,7099 kg

= 2408,5494 kg

Masuk :			Keluar :		
Kolagen	=	1926,83950 kg	Cake	:	
H_2O	=	5153,17550 kg	Kolagen	=	1926,839500 kg
$CaCl_2$	=	0,36798 kg	H_2O	=	449,443193 kg
$MgCl_2$	=	0,00002 kg	$CaCl_2$	=	0,032094 kg
NaCl	=	0,00005 kg	$MgCl_2$	=	0,000002 kg
H_3PO_4	=	0,00058 kg	NaCl	=	0,000004 kg
Gelatin	=	363,59567 kg	H_3PO_4	=	0,000051 kg
HCl 5%	=	5,99570 kg	HCl 5%	=	0,522925 kg
			Gelatin	=	31,711631 kg
			Filtrat	:	
			Gelatin	=	331,884039 kg
			HCl 5%	=	5,472775 kg
			H_2O	=	4703,732307 kg
			$CaCl_2$	=	0,335886 kg
			$MgCl_2$	=	0,000018 kg
			NaCl	=	0,000046 kg
		+	H_3PO_4	=	0,000529 kg +
		7449,97500 kg			7449,975000 kg

Tangki Penampung Hasil Ekstraksi (F-253)

Berat total larutan gelatin = berat total gelatin + berat impurities + berat total air untuk ekstraksi + berat total HCl untuk ekstraksi

Berat total gelatin = 1078,92 + 649,1502 + 332,0916 + 194,8271 + 313,6716
= 2568,6605 kg – 31,711631 kg
= 2536,948869 kg

Berat impurities = (81,3618 + 0,0056 + 0,0112 + 0,127) – (0,032094 + 0,000002 + 0,000004 + 0,000051)
= 81,473449 kg

Berat total H_2O = 10339,65 + 5779,9123 + 4644,51338 – 449,443193
= 20314,63249 kg

Berat HCl 5% = 75,4071 + 10,4102 + 4,82272 – 0,522925
= 90,117095 kg

Berat total larutan gelatin = 2536,948869 kg + 81,473449 kg + 20314,63249 kg + 90,117095 kg
= 23023,1719 kg

Masuk :

Dari rotary filter H-221 :

Gelatin	=	1630,2694 kg
HCl 5%	=	71,1394 kg
H_2O	=	9754,4738 kg
$CaCl_2$	=	76,7571 kg
$MgCl_2$	=	0,0053 kg
NaCl	=	0,0106 kg
H_3PO_4	=	0,1198 kg

Dari rotary filter H-241 :

Gelatin	=	574,79543 kg
HCl 5%	=	13,50492 kg
H_2O	=	5856,42638 kg

Keluar :

Larutan gelatin = 23023,1719 kg

$CaCl_2$	=	4,23672 kg
$MgCl_2$	=	0,00028 kg
NaCl	=	0,00055 kg
H_3PO_4	=	0,00662 kg

Dari rotary filter H-251 :

Gelatin	=	331,884039 kg	
HCl 5%	=	5,472775 kg	
H_2O	=	4703,732307 kg	
$CaCl_2$	=	0,335886 kg	
$MgCl_2$	=	0,000018 kg	
NaCl	=	0,000046 kg	
H_3PO_4	=	0,000529 kg +	+
		23023,1719 kg	23023,1719 kg

Tangki HCl 5% (F-110)

HCl yang dibutuhkan adalah 5%, sedangkan HCl yang tersedia adalah 36% jadi dibutuhkan tangki pengenceran HCl.

Data-data :

ρHCl 36% pada 20^0C = 1,1789 kg/lt

ρHCl 5% pada 20^0C = 1,023 kg/lt

HCl murni yang digunakan untuk proses :

Demineralisasi	=	6387,3335 kg
Netralisasi	=	1041,1487 kg
Ekstraksi	=	4,5320 kg +
		7433,0142 kg

$$\text{HCl 36\% yang dibutuhkan} = \frac{7433{,}0142 kg}{0{,}36}$$

$$= 20647{,}2617 \text{ kg}$$

$$\text{HCl 5\% yang dibutuhkan} = \frac{7433{,}0142 kg}{0{,}05}$$

= 148660,284 kg

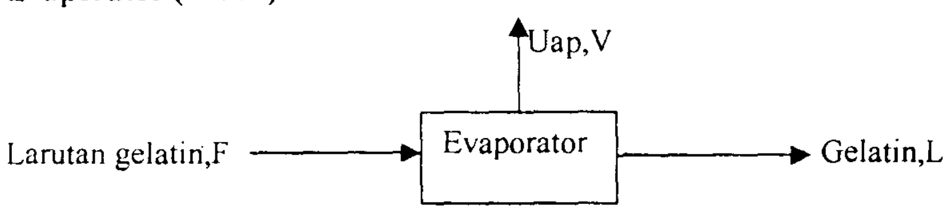
Air yang ditambahkan = 148660,284 kg – 20647,2617 kg

= 128013,0223 kg

Masuk :			Keluar :		
HCl 36%	=	20647,2617 kg	Demineralisasi	=	127746,6700 kg
Air	=	128013,0223 kg +	Netralisasi	=	20822,9740 kg
			Ekstraksi	=	90,6400 kg +
		148660,2840 kg			148660,2840 kg

III. Unit Pengeringan

Evaporator (V-310)



Feed = 23023,1719 kg

$$\% \text{ Gelatin} = \frac{2536,948869 kg}{23023,1719 \text{ kg}} x100\% = 11,02 \%$$

Feed masuk pada konsentrasi 11,02 % dan keluar evaporator dengan konsentrasi 35%.

Neraca Massa Total :

$F = L + V$ ....(1)

Neraca Massa Komponen :

$F.x_F = L.x_L + V.x_V$ ....(2)

$x_V = 0$

Dari persamaan (2) :

$F.x_F = L.x_L + V.x_V$

23023,1719 x 0,1102 = L x 0,35 + 0

L = 7249,0101 kg

Dari persamaan (1) :

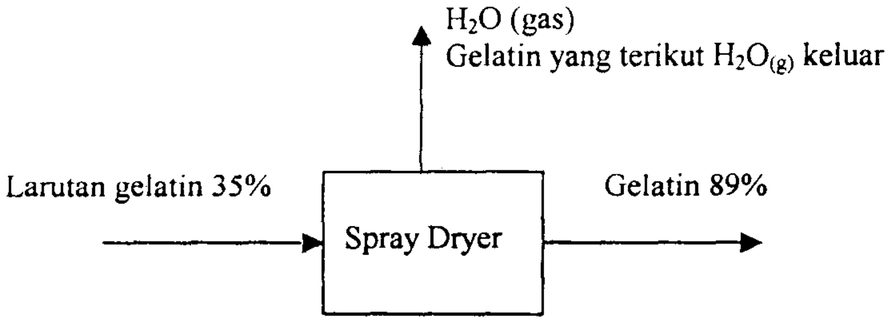
$$F = L + V$$

$$23023{,}1719 = 7249{,}0101 + V$$

$$V = 15774{,}1618 \text{ kg}$$

Masuk :		Keluar :	
Feed larutan gelatin	= 23023,1719 kg	Larutan gelatin	= 7249,0101 kg
	+	Uap	= 15774,1618 kg +
	23023,1719 kg		23023,1719 kg

Spray Dryer (B-330)



Effisiensi spray dryer = 99 % (Perry 6th)

Larutan gelatin dengan kadar air 65% masuk spray dryer terdiri dari :

Gelatin = 2536,948869 kg

H_2O = 4712,061231 kg

Gelatin keluar dari dryer dengan kadar air 11% :

Gelatin keluar = 99% . Gelatin masuk

= 99% . 2536,948869 kg

= 2511,57938 kg

H_2O yang terkandung dalam gelatin :

$$= \frac{11\%}{(100-11)\%} x 2511{,}57938 kg$$

= 310,4199 kg

Gelatin yang terikut $H_2O_{(gas)}$:

= (2536,948869 – 2511,57938)kg

= 25,369489 kg

H_2O yang terkandung dalam gelatin :

$$= \frac{11\%}{(100-11)\%} x 25,369489 kg$$

= 3,1356 kg

H_2O yang menguap (H_2O gas) = (4712,061231 - 310,4199 - 3,1356) kg

= 4398,505731 kg

Masuk :

Gelatin = 2536,948869 kg

H_2O = 4712,061231 kg

+

7249,0101 kg

Keluar :

Gelatin = 2511,579380 kg

H_2O = 310,419900 kg

Gelatin yang terikut $H_2O_{(gas)}$:

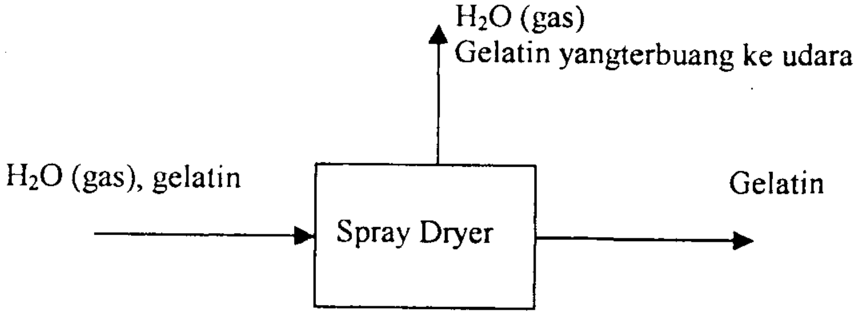
= 25,369489 kg

H_2O = 3,135600 kg

$H_2O_{(gas)}$ = 4398,505731 kg +

7249,0101 kg

Cyclone (H-333)



Effisiensi cyclone = 95% (Van't land)

Bahan masuk :

H_2O gas = 4398,505731 kg

Gelatin = 28,505089 kg

Gelatin keluar = 95% . 28,505089 kg

= 27,079835 kg

Gelatin yang terbuang ke udara = (28,505089 – 27,079835) kg

= 1,425254 kg

H_2O gas yang terbuang ke udara = 4398,505731 kg

Masuk :		Keluar :	
Gelatin =	28,505089 kg	Gelatin =	27,079835 kg
H_2O gas =	4398,505731 kg	Gelatin yang terbuang ke udara :	
		=	1,425254 kg
	+	$H_2O_{(gas)}$ =	4398,505731 kg +
	4427,01082 kg		4427,01082 kg

APPENDIKS B.

PERHITUNGAN NERACA PANAS

APPENDIX B
PERHITUNGAN NERACA PANAS

Kapasitas produksi = 13500 kg/hari

Suhu referensi = 25 °C

Menentukan data-data ΔH_f untuk setiap komponen yang didapat dari Himmelblau adalah :

ΔH_f $Ca_3(PO_4)_2$ = -988,4726 kkal/mol

ΔH_f HCl = -25,9113 kkal/mol

ΔH_f $CaCl_2$ = -189,9857 kkal/mol

ΔH_f $CaCO_3$ = -288,3284 kkal/mol

ΔH_f H_2O = -68,2782 kkal/mol

ΔH_f CO_2 = -94,0520 kkal/mol

ΔH_f $Mg_3(PO_4)_2$ = -961,5 kkal/mol

ΔH_f $MgCl_2$ = -153,333 kkal/mol

ΔH_f H_3PO_4 = -306,0309 kkal/mol

ΔH_f Na_2CO_3 = -269,9570 kkal/mol

ΔH_f $NaCl$ = -98,1879 kkal/mol

ΔH_f $Ca(OH)_2$ = -235,7950 kkal/mol

Menghitung Cp dari setiap komponen yang didapat dari App.E hal 676 dan hukum kopps hal 386 :

Komponen	Solid	Liquid
H	2,3	4,3
P	5,4	7,4
O	4,0	6,0
N	4,4	
F	5,0	7,0
C	1,8	2,8
Lainnya	6,2	8,0

Dimana Cp dari $Ca_3(PO_4)_2$, $Mg_3(PO_4)_2$, $Ca(OH)_2$, HCl, tulang ($C_{102}H_{149}N_{31}O_{38}$), dan H_3PO_4 menggunakan rumus hokum kopps:

Cp $Ca_3(PO_4)_2$: Ca = 6,2 kal/gmol°C

P = 5,4 kal/gmo

O = 4 kal/gmol°C

Cp $Ca_3(PO_4)_2$ = (3 x 6,2) + (2 x 5,4) + (8 x 4)

= 61,4 kal/gmol °C

= 0,1981 kal/gr °C

= 0,1981 kkal/kg °C

Cp $Mg_3(PO_4)_2$: Mg = 6,2 kal/gmol °C

P = 5,4 kal/gmol °C

O = 4 kal/gmol °C

Cp $Mg_3(PO_4)_2$ = (3 x 6,2) + (2 x 5,4) + (8 x 4)

= 61,4 kal/gmol °C

= 0,2344 kal/gr °C

= 0,2344 kkal/kg °C

Cp $Ca(OH)_2$: Ca = 8 kal/gmol °C

O = 6 kal/gmol °C

H = 4,3 kal/gmol °C

Cp $Ca(OH)_2$ = (8 x 1) + (6 x 2) + (4,3 x 2)

= 28,6 kal/gmol °C

= 0,2860 kkal/kg °C

Cp HCl 36% = 0,5818 kkal/kg °C

Cp HCl 5% = 0,8377 kkal/kg °C

Cp H_3PO_4 : H = 4,3 kal/gmol °C

P = 7,4 kal/gmol °C

O = 6 kal/gmol °C

Cp H_3PO_4 = (3 x 4,3) + 7,4 + (4 x 6)

= 44,3 kal/gmol °C

= 0,4520 kkal/kg °C

Cp tulang ($C_{102}H_{149}N_{31}O_{38}$) : C = 1,8 kal/gmol °C

H = 2,3 kal/gmol °C

O = 4 kal/gmol °C

N = 4,4 kal/gmol °C

Cp tulang = (102 x 1,8) + (149 x 2,3) + (4,4 x 31) + (38 x 4)

= 814,7 kal/gmol °C

= 0,3369 kkal/kg °C

Cp $MgCl_2$: Mg = 8 kal/gmol °C

Cl = 8 kal/gmol °C

Cp $MgCl_2$ = 8 + (8 x 2)

= 24 kal/gmol °C

0,2520 kkal/kg °C

Cp $CaCl_2$: Ca = 8 kal/gmol °C

Cl = 8 kal/gmol °C

Cp $CaCl_2$ = 8 + (8 x 2)

= 24 kal/gmol °C

= 0,2162 kkal/kg °C

Cp NaCl : Na = 8 kal/gmol °C

Cl = 8 kal/gmol °C

Cp NaCl = 8 + 8

= 16 kal/gmol °C

= 0,2737 kkal/kg °C

Cp untuk CO_2, $CaCO_3$ dan Na_2CO_3 dihitung dengan persamaan Cp :

Untuk Cp CO_2 dimana : a = 36,11 c = $-2,887.10^{-5}$

b = $4,233.10^{-2}$ d = $7,464.10^{-9}$

$$Cp\ CO_2 = a + \frac{b}{2}x(T_2 + T_1) + \frac{c}{3}x\left[T_2^2 + (T_2.T_1) + T_1^2\right] + \frac{d}{4}x\left(T_2^2 + T_1^2\right)(T_2 + T_1)$$

$= 37{,}2524$ J/gmol °C

$= 0{,}2023$ kkal/kg °C

Untuk Cp $CaCO_3$ dimana : a = 82,34 c = $-12{,}87.10^5$

b = $4{,}975.10^{-2}$

$$\text{Cp } CaCO_3 = a + \frac{b}{2}.(T_2 + T_1) + \frac{C}{T_2.T_1}$$

$= 83{,}3037$ J/gmol °C

$= 0{,}1989$ kkal/kg °C

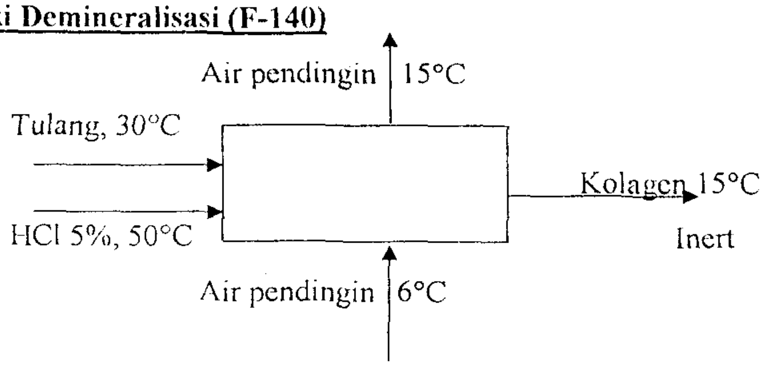
Untuk Cp Na_2CO_3 dimana : a = 121

$$\text{Cp } Na_2CO_3 = a + \frac{b}{2}x(T_2 + T_1) + \frac{c}{3}x\left[T_2^2 + (T_2.T_1) + T_1^2\right] + \frac{d}{4}x\left(T_2^2 + T_1^2\right)(T_2 + T_1)$$

$= 121$ J/gmol °C

$= 0{,}2729$ kkal/kg °C

<u>Tangki Demineralisasi (F-140)</u>



ΔHin + ΔHr = ΔHout + ΔHair pendingin

Dimana : ΔHin = panas dari bahan masuk

ΔHout = panas dari bahan keluar

<u>Menghitung panas dari bahan masuk (ΔHin)</u>

Suhu bahan masuk = 30°C

$Ca_3(PO_4)_2$ = 7742,2500 kg/hari

Na_2CO_3 = 465,7500 kg/hari

$Mg_3(PO_4)_2$ = 276,7500 kg/hari

$CaCO_3$ = 519,7500 kg/hari

Kolagen = 4495,5000 kg/hari

$\Delta Hin = \Delta H(Ca_3(PO_4)_2) + \Delta H(Na_2CO_3) + \Delta H(Mg_3(PO_4)_2 + \Delta H(CaCO_3) + \Delta H_{kolagen}$
$+ \Delta H_{HCl}$

$\Delta H(Ca_3(PO_4)_2) = m.Cp.\ (T_1\text{-}25)$
$= 7742{,}2500\ .\ 0{,}1981\ .\ (30\text{-}25)$
$= 7668{,}698625$ kkal

$\Delta H(Na_2CO_3) = m.Cp.(T_1\text{-}25)$
$= 465{,}7500\ .\ 0{,}2729\ .\ (30\text{-}25)$
$= 635{,}515875$ kkal

$\Delta H(Mg_3(PO_4)_2) = m.Cp.(T_1\text{-}25)$
$= 276{,}7500\ .\ 0{,}2344\ .\ (30\text{-}25)$
$= 324{,}35100$ kkal

$\Delta H(CaCO_3) = m.Cp.(T_1\text{-}25)$
$= 519{,}7500\ .\ 0{,}1989\ .\ (30\text{-}25)$
$= 516{,}891375$ kkal

$\Delta H_{kolagen} = m.Cp.(T_1\text{-}25)$
$= 4495{,}5000\ .\ 0{,}3369\ .\ (30\text{-}25)$
$\Delta H_{kolagen} = 7572{,}66975$ kkal

Untuk larutan HCl 5% masuk pada suhu 50°C :

$\Delta H_{HCl} = m.Cp.(T_1\text{-}25)$
$= (5460{,}9328+375{,}6333+230{,}2984+320{,}4690)\ .\ 0{,}8377\ .\ (50\text{-}25)$
$= 133766{,}7318$ kkal

ΔHin = 7668,698625+ 133766,7318+ 516,891375+ 324,351+ 635,515875 + 7572,66975

ΔHin = 150484,8584 kkal/hari

Menghitung panas reaksi dari setiap reaksi yang ada (ΔHr) :

- untuk reaksi 1 :

$$Ca_3(PO_4)_{2\,(s)} + 6HCl_{(aq)} \longrightarrow 3CaCl_{2(s)} + 2H_3PO4_{(aq)}$$

mol $Ca_3(PO_4)_2$ = 24,9597 kmol/hari

mol HCl = 149,7582 kmol/hari

mol $CaCl_2$ = 74,8791 kmol/hari

mol H_3PO_4 = 49,9194 kmol/hari

ΔHr_1 = ((3x 74,8791x -189,9857)+(2x 49,9194x -306,0309))

- ((24,9597x -988,4726)+(6x 149,7582x -25,9113))

= -25277,0751 kkal/hari

- untuk reaksi 2 :

$$CaCO_3 + 2\ HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

mol $CaCO_3$ = 5,1506 kmol/hari

mol HCl = 10,3012 kmol/hari

mol $CaCl_2$ = 5,1506 kmol/hari

mol H_2O = 5,1506 kmol/hari

mol CO_2 = 5,1506 kmol/hari

ΔHr_2 = ((5,1506x -189,9857)+(5,1506x -68,2782)+(5,1506x -94,0520))

- ((5,1506x -288,3284)+(6x 10,3012x -25,9113))

= 204,2609 kkal/hari

- untuk reaksi 3 :

$$Mg_3(PO_4)_2 + 6\ HCl \longrightarrow 3\ MgCl_2 + 2\ H_3PO_4$$

mol $Mg_3(PO_4)_2$ = 1,0526 kmol/hari

mol HCl = 6,3156 kmol/hari

mol $MgCl_2$ = 3,1578 kmol/hari

mol H_3PO_4 = 2,1052 kmol/hari

ΔHr_3 =((3x 3,1578x -153,333)+(2x 2,1052x -306,0309))
- ((6x 6,3156x -25,9113)+(1,0526x -961,5))
= -3324,175009 kkal/hari

- untuk reaksi 4 :

$Na_2CO_3 + 2\ HCl \longrightarrow 2\ NaCl + H_2O + CO_2$

mol Na_2CO_3 = 4,3942 kmol/hari

mol HCl = 8,7884 kmol/hari

mol NaCl = 8,7884 kmol/hari

mol H_2O = 4,3942 kmol/hari

mol CO_2 = 4,3942 kmol/hari

ΔHr_4 =((2x 8,7884x -98,1879)+(4,3942x -189,9857)+(4,3942x
-68,2782))-((4,3942x -269,9570)+(2x 8,7884x -25,9113))
= -797,4576583 kkal/hari

ΔHr = -25277,0751 + 204,2609 + -3324,175009 + -797,4576583
= -29194,4468 kkal/hari

Menghitung panas dari bahan keluar ($\Delta Hout$) :

Suhu bahan keluar = 15°C

$CaCl_2$ = 8882,8165 kg/hari

H_3PO_4 = 5098,3588 kg/hari

H_2O = 171,9591 kg/hari

CO_2 = 420,0762 kg/hari

$MgCl_2$ = 300,7299 kg/hari

NaCl = 513,6644 kg/hari

Kolagen = 4495,5000kg/hari

$\Delta Hout = \Delta H(CaCl_2) + \Delta H(H_3PO_4) + \Delta H(H_2O) + \Delta H(CO_2) + \Delta H(MgCl_2)$
$+ \Delta H(NaCl) + \Delta H_{kolagen}$

$\Delta H(CaCl_2) = m.Cp.(T_2\text{-}25)$

$= 8882,8165 \,.\, 0,2162 \,.\, (15\text{-}25)$

$= -19204,6493$ kkal/hari

$\Delta H(H_3PO_4) = m.Cp.(T_2\text{-}25)$

$= 5098,3588 \,.\, 0,452 \,.\, (15\text{-}25)$

$= -23044,5818$ kkal/hari

$\Delta H(H_2O) = m.Cp.(T_2\text{-}25)$

$= 171,9591 \,.\, 1 \,.\, (15\text{-}25)$

$= -1719,591$ kkal/hari

$\Delta H(CO_2) = m.Cp.(T_2\text{-}25)$

$= 420,0762 \,.\, 0,2033 \,.\, (15\text{-}25)$

$= -854,015$ kkal/hari

$\Delta H(MgCl_2) = m.Cp.(T_2\text{-}25)$

$= 300,7299 \,.\, 0,2520 \,.\, (15\text{-}25)$

$= -757,8393$ kkal/hari

$\Delta H(NaCl) = m.Cp.(T_2\text{-}25)$

$= 513,6644 \,.\, 0,2737 \,.\, (15\text{-}25)$

$= -1405,8995$ kkal/hari

$\Delta H_{kolagen} = m.Cp.(T_2\text{-}25)$

$= 4495,5000 \,.\, 0,3369 \,.\, (15\text{-}25)$

$= -15145,3395$ kkal/hari

$\Delta Hout = -19204,6493 + -23044,5818 + -854,015 + -757,8393 + -1405,8995$

$+ -1719,591 + -15145,3395$

$= -62131,9154$ kkal/hari

$\Delta Hin + \Delta Hr = \Delta Hout + \Delta Hair$ pendingin

150484,8584 + 29194,4468 + 62131,9154 = ΔHair pendingin

ΔHair pendingin = 241811,2206 kkal/hari

Suhu air masuk = 6 °C

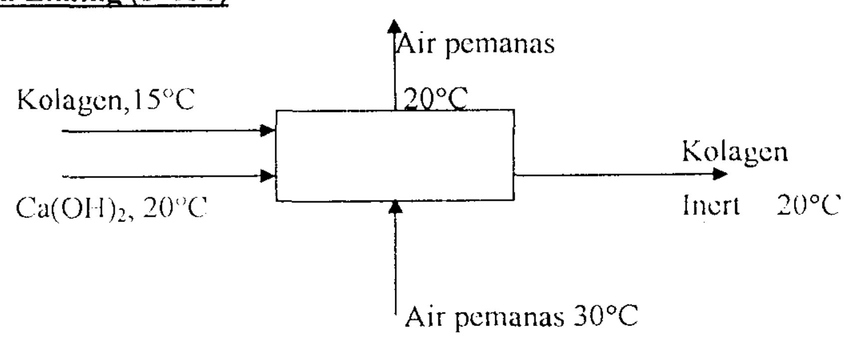
Suhu air keluar = 15 °C

$$\text{Massa air pendingin yang dibutuhkan} = \frac{241811{,}2206}{1x(15-6)}$$

$$= 26867{,}9134 \text{ kg/hari}$$

Masuk :		Keluar :	
Panas masuk	= 150484,8584 kkal/hari		
Panas reaksi	= 29194,4468 kkal/hari		
Panas keluar	= 62131,9154 kkal/hari	Qpendingin	= 241811,2206 kkal/hari
	= 2411811,2206 kkal/hari		= 241811,2206 kkal/hari

Tangki Liming (F-150)



Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 15°C

Kolagen = 4495,5000 kg/hari

H_2O = 1001,9346 kg/hari

$CaCl_2$ = 73,1643 kg/hari

$MgCl_2$ = 2,4725 kg/hari

NaCl = 4,2707 kg/hari

H_3PO_4 = 42,0329 kg/hari

$\Delta Hin = \Delta H_{kolagen} + \Delta H_{H2O} + \Delta H_{Ca(OH)2} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4}$

$\Delta H_{kolagen} = m.Cp.(T1\text{-}25)$

$= 4495{,}5000 \ .\ 0{,}3369 \ .\ (15\text{-}25)$

$= -15145{,}3395$ kkal/hari

$\Delta H_{H2O} = m.Cp.(T1\text{-}25)$

$= 1001{,}9346 \ .\ 1 \ .\ (15\text{-}25)$

$= -10019{,}346$ kkal/hari

$\Delta H_{HCl} = 1041{,}1487 \ .\ 0{,}8377 \ .\ (15\text{-}25)$

$= -8721{,}7027$ kkal/hari

$\Delta H_{CaCl2} = 4{,}2707 \ .\ 0{,}2162 \ .\ (15\text{-}25)$

$= -9{,}2333$ kkal/hari

$\Delta H_{MgCl2} = 0{,}1124 \ .\ 0{,}252 \ .\ (15\text{-}25)$

$= -0{,}2832$ kkal/hari

$\Delta H_{NaCl} = 0{,}2248 \ .\ 0{,}2737 \ .\ (15\text{-}25)$

$= -0{,}6153$ kkal/hari

$\Delta H_{H3PO4} = 2{,}4725 \ .\ 0{,}452 \ .\ (15\text{-}25)$

$= -11{,}1757$ kkal/hari

Untuk $Ca(OH)_2$ masuk pada suhu 20°C :

$Ca(OH)_2 = 17982$ kg/hari

$\Delta H_{Ca(OH)2} = 1057{,}7912 \ .\ 0{,}286 \ .\ (20\text{-}25)$

$= -1512{,}6414$ kkal/hari

ΔHin = -15145,3395 + -10019,346 + -8721,7027 + -1512,6414 + -9,2333

+ -0,2832 + -0,6153 + -11,1757

= -33907,6957 kkal/hari

Menghitung panas keluar (ΔHout) :

Suhu bahan keluar = 20°C

Kolagen = 4495,5000 kg/hari

H_2O = 1001,9346 kg/hari

$Ca(OH)_2$ = 17982 kg/hari

$CaCl_2$ = 73,1643 kg/hari

$MgCl_2$ = 2,4725 kg/hari

NaCl = 4,2707 kg/hari

H_3PO_4 = 42,0329 kg/hari

$\Delta H_{out} = \Delta H_{H2O} + \Delta H_{kolagen} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4} + \Delta H_{Ca(OH)2}$

$\Delta H_{kolagen}$ = m.Cp.(T1-25)

= 4495,5000 . 0,3369 . (20-25)

= -7572,6698 kkal/hari

ΔH_{H2O} = m.Cp.(T1-25)

= 1001,9346 . 1 . (20-25)

= -5009,673 kkal/hari

ΔH_{HCl} = 1041,1487 . 0,8377 . (20-25)

= -4360,8513 kkal/hari

$\Delta H_{Ca(OH)2}$ = 1057,7912 . 0,286 . (20-25)

= -1512,6414 kkal/hari

ΔH_{CaCl2} = 4,2707 . 0,2162 . (20-25)

= -4,6166 kkal/hari

$\Delta H_{MgCl2} = 0{,}1124 \ . \ 0{,}252 \ . \ (20\text{-}25)$

$= -0{,}1416$ kkal/hari

$\Delta H_{NaCl} = 0{,}2248 \ . \ 0{,}2737 \ . \ (20\text{-}25)$

$= -0{,}3076$ kkal/hari

$\Delta H_{H3PO4} = 2{,}4725 \ . \ 0{,}452 \ . \ (20\text{-}25)$

$= -5{,}5879$ kkal/hari

ΔHout = -7572,6698 + -5009,673 + -4360,8513 + -1512,6414 + -4,6166 + -0,1416 + -0,3076 + -5,5879

= -18466,4892 kkal/hari

ΔHin + Qpemanas = ΔHout

dimana : ΔHin = panas dari bahan masuk

ΔHout = panas dari bahan keluar

ΔHin + Qpemanas = ΔHout

18466,4892 + Qpemanas = 33907,6957

Qpemanas = 15441,2065 kkal/hari

Suhu air masuk = 30°C

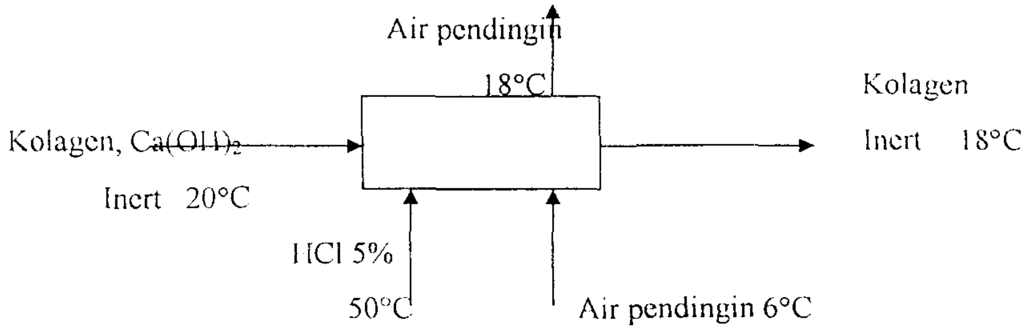
Suhu air keluar = 20°C

Massa air pendingin yang dibutuhkan $= \dfrac{15441{,}2065}{1x(30-20)}$

= 1544,1207 kg/hari

Masuk :		Keluar :	
Qpemanas	= 15441,2065 kkal/hari		
Panas keluar	= 18466,4892 kkal/hari	Panas masuk	= 33907,6957 kkal/hari
	= 33907,6957 kkal/hari		= 33907,6957 kkal/hari

Tangki Netralisasi (F-160)



ΔHin + ΔHr = ΔHout + ΔHair pendingin

dimana : ΔHin = panas dari bahan masuk

ΔHout = panas dari bahan keluar

Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 20°C

Kolagen = 4495,5000 kg/hari

H_2O = 19840,8287 kg/hari

$Ca(OH)_2$ = 1057,7912 kg/hari

$CaCl_2$ = 4,2707 kg/hari

$MgCl_2$ = 0,1124 kg/hari

NaCl = 0,2248 kg/hari

H_3PO_4 = 2,4725 kg/hari

$\Delta Hin = \Delta H_{kolagen} + \Delta H_{H2O} + \Delta H_{Ca(OH)2} + \Delta H_{HCl} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl}$
$+ \Delta H_{H3PO4}$

$\Delta H_{kolagen}$ = m.Cp.(T1-20)
= 4495,5000 . 0,3369 . (20-25)
= -7572,6698 kkal/hari

ΔH_{H2O} = m.Cp.(25-T1)
= 19840,8287 . 1 . (20-25)
= -99204,1435 kkal/hari

$\Delta H_{Ca(OH)2}$ = 1057,7912 . 0,286 . (20-25)

= -1512,6414 kkal/hari

ΔH_{CaCl2} = 4,2707 . 0,2162 . (20-25)

= -4,6166 kkal/hari

ΔH_{MgCl2} = 0,1124 . 0,252 . (20-25)

= -0,1416 kkal/hari

ΔH_{NaCl} = 0,2248 . 0,2737 . (20-25)

= -0,3076 kkal/hari

ΔH_{H3PO4} = 2,4725 . 0,452 . (20-25)

= -5,5879 kkal/hari

Untuk larutan HCl 5% masuk pada suhu 50°C :

HCl = 1041,1487 kg/hari

ΔH_{HCl} = 1041,1487 . 0,8377 . (50-25)

= 21804,2567 kkal/hari

ΔHin = -7572,6698 + -99204,1435 + 21804,2567 + -1512,6414 + -4,6166

+ -0,1416 + -0,3076 + -5,5879

= -86495,8517 kkal/hari

Menghitung panas reaksi (ΔHr) :

Reaksi : $Ca(OH)_2 + 2\ HCl \longrightarrow CaCl_2 + 2H_2O$

mol $Ca(OH)_2$ yang bereaksi = 14,276 kmol/hari

mol HCl yang bereaksi = 28,552 kmol/hari

mol H_2O yang bereaksi = 28,552 kmol/hari

mol $CaCl_2$ yang bereaksi = 14,276 kmol/hari

$\Delta Hr = ((2x\ 28{,}552x\ -68{,}2782)+(\ 14{,}276x\ -189{,}9857)) - ((14{,}276x\ -235{,}7950)$
$+(2x\ 28{,}552x\ -25{,}9113))$
$= -2496998{,}354$ kkal/hari

Menghitung panas keluar (ΔHout) :

Suhu bahan keluar = 18°C

Kolagen = 4495,5000 kg/hari

H_2O = 20355,2215 kg/hari

$CaCl_2$ = 1588,8210 kg/hari

$MgCl_2$ = 0,1124 kg/hari

NaCl = 0,2248 kg/hari

H_3PO_4 = 2,4725 kg/hari

$\Delta Hout = \Delta H_{H2O} + \Delta H_{kolagen} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4}$

$\Delta H_{kolagen}$ = m.Cp.(T2-25)
= 4495,5000 . 0,3369 . (18-25)
= -10601,7377 kkal/hari

ΔH_{H2O} = m.Cp.(T2-25)
= 20355,2215 . 1 . (18-25)
= -142486,5505 kkal/hari

ΔH_{CaCl2} = m.Cp.(T2-25)
= 1588,8210 . 0,2162 . (18-25)
= -2404,5217 kkal/hari

ΔH_{MgCl2} = m.Cp.(T2-25)
= 0,1124 . 0,252 . (18-25)
= -0,1983 kkal/hari

ΔH_{NaCl} = m.Cp.(T2-25)

= 0,2248 . 0,2737 . (18-25)

= -0,4307 kkal/hari

ΔH_{H3PO4} = m.Cp.(T2-25)

= 2,4725 . 0,452 . (18-25)

= -7,823 kkal/hari

ΔHout = -10601,7377 + -142486,5505 + -2404,5217 + -0,1983 + -0,4307 + -7,823

= -155501,2619 kkal/hari

ΔHin + ΔHr = ΔHout + ΔHair pendingin

155501,2619 + 2496998,354 = 86495,8517 + ΔHair pendingin

ΔHair pendingin = 2566003,764 kkal/hari

Suhu air masuk = 6°C

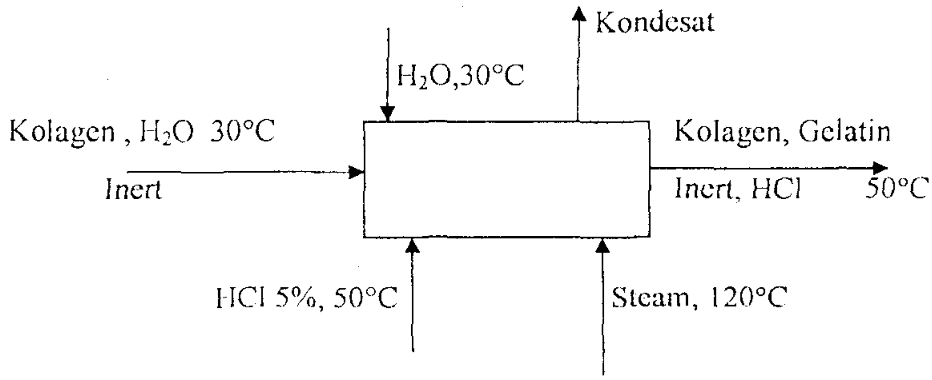
Suhu air keluar = 18°C

Massa air pendingin yang dibutuhkan = $\dfrac{2566003,764}{1x(18-6)}$

= 213833,647 kg/hari

Masuk :	Keluar :
Panas reaksi = 2496998,354 kkal/hari	Qpendingin = 2566003,764 kkal/hari
Panas keluar = 155501,2619 kkal/hari	
	Panas masuk = 86495,8517 kkal/hari
= 2652499,616 kkal/hari	= 2652499,616 kkal/hari

Tangki Ekstraksi I (F-210)



Pada tangki ekstraksi ini digunakan steam suhu 120°C dan tekanan 198,53 kPa

$\Delta Hin + Qsteam = \Delta Hout + Qloss$

dimana : ΔHin = panas dari bahan masuk

$\Delta Hout$ = panas dari bahan keluar

Qloss = panas yang hilang = 0,05 dari suplai panas

Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 30°C

Kolagen = 4495,5000 kg/hari

H_2O = 10339,6500 kg/hari

$CaCl_2$ = 81,3618 kg/hari

$MgCl_2$ = 0,0056 kg/hari

NaCl = 0,0112 kg/hari

H_3PO_4 = 0,1270 kg/hari

$$\Delta Hin = \Delta H_{kolagen} + \Delta H_{H2O} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4} + \Delta H_{HCl\ 5\%}$$

$$\Delta H_{kolagen} = m.Cp.(T1-25)$$
$$= 4495,5000 \cdot 0,3369 \cdot (30-25)$$
$$= 7572,6698 \text{ kkal/hari}$$

$$\Delta H_{H2O} = m.Cp.(T1-25)$$
$$= 10339,6500 \cdot 1 \cdot (30-25)$$
$$= 51698,2500 \text{ kkal/hari}$$

ΔH_{CaCl2} = m.Cp.(T1-25)

= 81,3618 . 0,2162 . (30-25)

= 87,9521 kkal/hari

ΔH_{MgCl2} = m.Cp.(T1-25)

= 0,0056 . 0,252 . (30-25)

= 0,0071 kkal/hari

ΔH_{NaCl} = m.Cp.(T1-25)

= 0,0112 . 0,2737 . (30-25)

= 0,0153 kkal/hari

ΔH_{H3PO4} = m.Cp.(T1-25)

= 0,1270 . 0,452 . (30-25)

= 0,2870 kkal/hari

Untuk larutan HCl 5% masuk pada suhu 50°C :

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T1-25)

= 75,4071 . 0,8377 . (50-25)

= 1579,2132 kkal/hari

ΔHin = 7572,6698 + 51698,2500 + 87,9521+ 0,0071 + 0,0153 + 0,2870

+ 1579,2132

= 60938,3945 kkal/hari

Menghitung panas keluar (ΔHout) :

Suhu bahan keluar = 50°C

Kolagen = 3416,5800 kg/hari

Gelatin = 1078,9200 kg/hari

$CaCl_2$ = 81,3618 kg/hari

$MgCl_2$ = 0,0056 kg/hari

NaCl = 0,0112 kg/hari

H_2O = 10339,6500 kg/hari

H_3PO_4 = 0,1270 kg/hari

HCl 5% = 75,4071 kg/hari

ΔHout = $\Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H2O} + \Delta H_{H3PO4}$
$+ \Delta H_{HCl\ 5\%}$

$\Delta H_{kolagen}$ = m.Cp.(T2-25)
= 3416,5800 . 0,3369 . (50-25)
= 28776,1451 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T2-25)
= 1078,9200 . 0,3613 . (50-25)
= 9745,3449 kkal/hari

ΔH_{CaCl2} = m.Cp.(T2-25)
= 81,3618 . 0,2162 . (50-25)
= 439,7605 kkal/hari

ΔH_{MgCl2} = m.Cp.(T2-25)
= 0,0056 . 0,252 . (50-25)
= 0,0353 kkal/hari

ΔH_{NaCl} = m.Cp.(T2-25)
= 0,0112 . 0,2737 . (50-25)
= 0,0766 kkal/hari

ΔH_{H3PO4} = m.Cp.(T2-25)
= 0,1270 . 0,452 . (50-25)
ΔH_{H3PO4} = 1,4351 kkal/hari

ΔH_{H2O} = m.Cp.(T2-25)

= 10339,6500 . 1 . (50-25)

= 258491,2500 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T2-25)

= 75,4071 . 0,8377 . (50-25)

= 1822,7121 kkal/hari

ΔHout = 28776,1451 + 9745,3449 + 439,7605 + 0,0353 + 0,0766 + 1,4351

+ 258491,2500 + 1822,7121

= 299276,7596 kkal/hari

Δ*Hin* + Q*steam* = ΔHout + 0,05 . Qsteam

60938,3945 + Qsteam = 299276,7596 + 0,05 . Qsteam

Qsteam = 250882,4896 kkal/hari

Digunakan steam pada suhu 120°C dan tekanan 198,53 kPa didapat :

Hv = 2706,3 kJ/kg = 646,8057 kkal/kg

H_L = 503,71 kJ/kg = 120,3843 kkal/kg

λ = Hv – H_L = (646,8057 – 120,3843) kkal/hari = 526,4214 kkal/hari

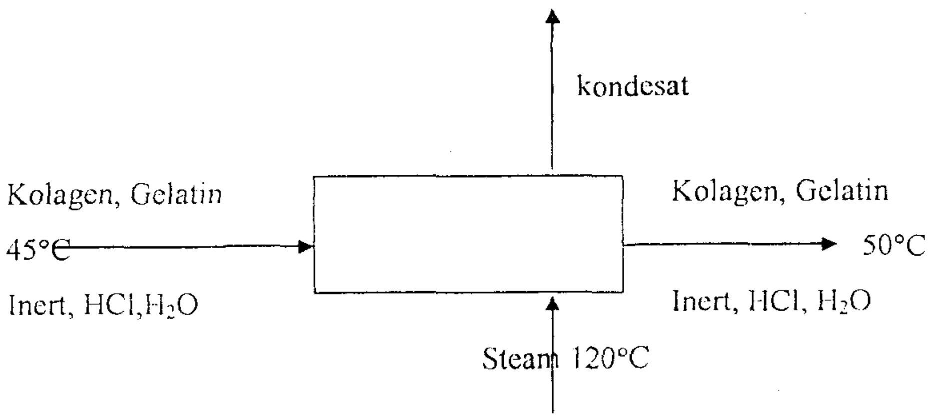
Jumlah steam yang digunakan = $\frac{250882,4896}{526,4214}$ = 476,5811 kg/hari

Panas yang hilang = 0,05 x 250882,4896

= 12544,1245 kkal/hari

Masuk :	Keluar :
Panas masuk = 60938,3945 kkal/hari	Panas keluar = 299276,7596 kkal/hari
Panas Steam = 250882,4896 kkal/hari	
	Panas hilang = 12544,1245 kkal/hari
= 311820,8841 kkal/hari	= 311820,8841 kkal/hari

Tangki Ekstraksi II (F-220)



Pada tangki ekstraksi ini digunakan steam suhu 120°C dan tekanan 198,53 kPa

ΔHin + Qsteam = ΔHout + Qloss

dimana : ΔHin = panas dari bahan masuk

ΔHout = panas dari bahan keluar

Qloss = panas yang hilang = 0,05 dari suplai panas

Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 45°C

Kolagen = 3416,5800 kg/hari

H_2O = 10339,6500 kg/hari

$CaCl_2$ = 81,3618 kg/hari

$MgCl_2$ = 0,0056 kg/hari

NaCl = 0,0112 kg/hari

H_3PO_4 = 0,1270 kg/hari

HCl 5% = 75,4071 kg/hari

Gelatin = 1078,9200 kg/hari

$\Delta Hin = \Delta H_{kolagen} + \Delta H_{H2O} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4} + \Delta H_{HCl\,5\%}$
$+ \Delta H_{gelatin}$

$\Delta H_{kolagen}$ = m.Cp.(T1-25)
= 3416,5800 . 0,3369 . (45-25)
= 23020,9160 kkal/hari

ΔH_{H2O} = m.Cp.(T1-25)
= 10339,6500 . 1 . (45-25)
= 206793,0000 kkal/hari

ΔH_{CaCl2} = m.Cp.(T1-25)
= 81,3618 . 0,2162 . (45-25)
= 351,8084 kkal/hari

ΔH_{MgCl2} = m.Cp.(T1-25)
= 0,0056 . 0,252 . (45-25)
= 0,0282 kkal/hari

ΔH_{NaCl} = m.Cp.(T1-25)
= 0,0112 . 0,2737 . (45-25)
= 0,0613 kkal/hari

ΔH_{H3PO4} = m.Cp.(T1-25)
= 0,1270 . 0,452 . (45-25)
= 1,1481 kkal/hari

$\Delta H_{HCl\,5\%}$ = m.Cp.(T1-25)
= 75,4071 . 0,8377 . (45-25)

= 1458,1697 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T1-25)

= 1078,9200 . 0,3613 . (45-25)

= 7796,2759 kkal/hari

ΔHin = 23020,9160 + 206793,0000 + 1458,1697 + 351,8084 + 0,0282 + 0,0613 + 1,1481 + 7796,2759

= 239421,4077 kkal/hari

Menghitung panas keluar (ΔHout) :

Suhu bahan keluar = 50°C

Kolagen = 2767,4298 kg/hari

Gelatin = 1728,0702 kg/hari

$CaCl_2$ = 81,3618 kg/hari

$MgCl_2$ = 0,0056 kg/hari

NaCl = 0,00112 kg/hari

H_2O = 10339,6500 kg/hari

H_3PO_4 = 0,1270 kg/hari

HCl 5% = 75,4071 kg/hari

ΔHout = $\Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H2O} + \Delta H_{H3PO4} + \Delta H_{HCl\ 5\%}$

$\Delta H_{kolagen}$ = m.Cp.(T2-25)

= 2767,4298 . 0,3369 . (50-25)

= 23308,6775 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T2-25)

= 1728,0702 . 0,3613 . (50-25)

= 15608,7941 kkal/hari

ΔH_{CaCl2} = m.Cp.(T2-25)

= 81,3618 . 0,2162 . (50-25)

= 439,7605 kkal/hari

ΔH_{MgCl2} = m.Cp.(T2-25)

= 0,0056 . 0,252 . (50-25)

= 0,0353 kkal/hari

ΔH_{NaCl} = m.Cp.(T2-25)

= 0,00112 . 0,2737 . (50-25)

= 0,0077 kkal/hari

ΔH_{H3PO4} = m.Cp.(T2-25)

= 0,1270 . 0,452 . (50-25)

= 1,4351 kkal/hari

ΔH_{H2O} = m.Cp.(T2-25)

= 10339,6500 . 1 . (50-25)

= 258491,2500 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T2-25)

= 75,4071 . 0,8377 . (50-25)

= 1822,7121 kkal/hari

ΔHout = 23308,6775 + 258491,2500 + 1822,7121 + 439,7605 + 0,0353 + 0,0077

+ 1,4351 + 15608,7941

= 299672,6723 kkal/hari

ΔHin + Qsteam = ΔHout + ΔHr + 0,05 . Qsteam

239421,4077 + Qsteam = 299672,6723 + 0,05 . Qsteam

Qsteam = 63422,38377 kkal/hari

Digunakan steam pada suhu 120°C dan tekanan 198,53 kPa didapat :

$H_V = 2706{,}3\ kJ/kg = 646{,}8057\ kkal/kg$

$H_L = 503{,}71\ kJ/kg = 120{,}3843\ kkal/kg$

$\lambda = H_V - H_L = (646{,}8057 - 120{,}3843)\ kkal/hari = 526{,}4214\ kkal/hari$

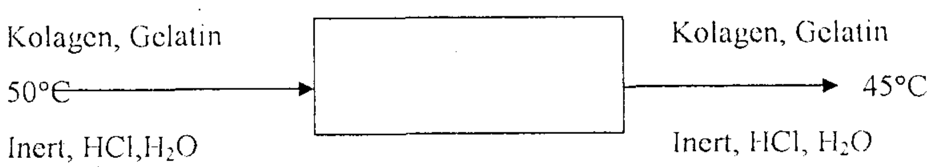
$$\text{Jumlah steam yang digunakan} = \frac{63422{,}3877}{526{,}4214} = 120{,}4948\ kg/hari$$

Panas yang hilang = 0,05 x 63422,3877

= 3171,1192 kkal/hari

Masuk :	Keluar :
Panas masuk = 239421,4077 kkal/hari	Panas keluar = 299672,6723 kkal/hari
Panas Steam = 63422,3877 kkal/hari	
	Panas hilang = 3171,1192 kkal/hari
= 302843,7954 kkal/hari	= 302843,7954 kkal/hari

Rotary Drum Vaccum Filter II (H-221)



$\Delta Hin = \Delta Hout + Qloss$

dimana : ΔHin = panas dari bahan masuk

$\Delta Hout$ = panas dari bahan keluar

Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 50°C

Kolagen = 2767,4298 kg/hari

Gelatin = 649,1502 kg/hari

$CaCl_2$ = 81,3618 kg/hari

$MgCl_2$ = 0,0056 kg/hari

NaCl = 0,0112 kg/hari

H_3PO_4 = 0,1270 kg/hari

H_2O = 10339,6500 kg/hari

HCl 5% = 75,4071 kg/hari

$\Delta Hin = \Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4} + \Delta H_{H2O}$
$+ \Delta H_{HCl\ 5\%}$

$\Delta H_{kolagen}$ = m.Cp.(T1-25)
= 2767,4298 . 0,3369 . (50-25)
= 23308,67749 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T1-25)
= 649,1502 . 0,3613 . (50-25)
= 5863,449182 kkal/hari

ΔH_{CaCl2} = m.Cp.(T1-25)
= 81,3618 . 0,2162 . (50-25)
= 439,760529 kkal/hari

ΔH_{MgCl2} = m.Cp.(T1-25)
= 0,0056 . 0,252 .(50-25)
= 0,03528 kkal/hari

ΔH_{NaCl} = m.Cp.(T1-25)
= 0,0112 . 0,2737 . (50-25)
= 0,076636 kkal/hari

ΔH_{H3PO4} = m.Cp.(T1-25)

= 0,1270 . 0,452 . (50-25)

= 1,4351 kkal/hari

ΔH_{H2O} = m.Cp.(T1-25)

= 10339,6500 . 1 . (50-25)

= 258491,25 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T1-25)

= 75,4071 . 0,8377 . (50-25)

= 1822,712144 kkal/hari

ΔHin = 23308,67749 + 258491,25 + 1822,712144 + 439,760529 + 0,03528

+ 0,076636 + 1,4351 + 5863,449182

= 289927,3964 kkal/hari

Menghitung panas keluar (ΔHout) :

Suhu bahan keluar = 45°C

Cake keluar :

Kolagen = 2767,4298 kg/hari

H_2O = 585,1762 kg/hari

$CaCl_2$ = 4,6047 kg/hari

$MgCl_2$ = 0,0003 kg/hari

NaCl = 0,0006 kg/hari

H_3PO_4 = 0,0072 kg/hari

HCl 5% = 4,2677 kg/hari

Gelatin = 97,8008 kg/hari

Filtrat keluar :

Gelatin = 1630,2694 kg/hari

H_2O = 9754,4738 kg/hari

$HCl\ 5\% = 71{,}1394$ kg/hari

$CaCl_2 = 76{,}7571$ kg/hari

$MgCl_2 = 0{,}0053$ kg/hari

$NaCl = 0{,}0106$ kg/hari

$H_3PO_4 = 0{,}1198$ kg/hari

$$\Delta Hout = \Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{H2O} + \Delta H_{CaCl2} + \Delta H_{HCl\ 5\%} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4}$$

$\Delta H_{kolagen} = m.Cp.(T2\text{-}25)$

$= 2767{,}4298\ .\ 0{,}3369\ .\ (45\text{-}25)$

$= 18646{,}94199$ kkal/hari

$\Delta H_{gelatin}$ = $m.Cp.(T2\text{-}25)$

$= (97{,}8008 + 1630{,}2694)\ .\ 0{,}3613\ .\ (45\text{-}25)$

$= 12487{,}03527$ kkal/hari

$\Delta H_{H2O} = m.Cp.(T2\text{-}25)$

$= (585{,}1762 + 9754{,}4738)\ .\ 1\ .\ (45\text{-}25)$

$= 206793$ kkal/hari

$\Delta H_{CaCl2} = m.Cp.(T2\text{-}25)$

$= (4{,}6047 + 76{,}7571)\ .\ 0{,}2162\ .\ (45\text{-}25)$

$= 351{,}8084232$ kkal/hari

$\Delta H_{MgCl2} = m.Cp.(T2\text{-}25)$

$= (0{,}0003 + 0{,}0053)\ .\ 0{,}252\ .\ (45\text{-}25)$

$= 0{,}028224$ kkal/hari

$\Delta H_{NaCl} = m.Cp.(T2\text{-}25)$

$= (0{,}0006 + 0{,}0106)\ .\ 0{,}2737\ .\ (45\text{-}25)$

$= 0{,}0613088$ kkal/hari

ΔH_{H3PO4} = m.Cp.(T2-25)

= (0,0072 + 0,1198) . 0,452 . (45-25)

= 1,14808 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T2-25)

= (4,2677 + 71,1394) . 0,8377 . (45-25)

= 1458,169715 kkal/hari

ΔHout = 18646,94199 + 206793 + 1458,169715 + 351,8084232 + 0,028224 + 0,0613088 + 1,14808 + 12487,03527

= 239738,193 kkal/hari

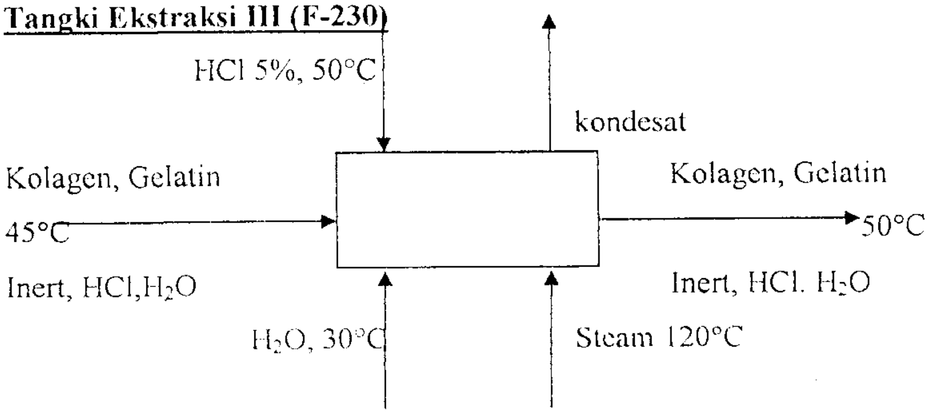
ΔHin = ΔHout + Qloss

289927,3964 = 239738,193 + Qloss

Qloss = 50189,20335 kkal/hari

Masuk :	Keluar :
Panas masuk = 289927,3964 kkal/hari	Panas keluar = 239738,193 kkal/hari
	Panas hilang = 50189,20335 kkal/hari
= 289927,3964 kkal/hari	= 289927,3964 kkal/hari

Tangki Ekstraksi III (F-230)



Pada tangki ekstraksi ini digunakan suhu steam 120°C dan tekanan 198,53 kPa

ΔHin + Qsteam = ΔHout + Qloss

dimana : ΔHin = panas dari bahan masuk

ΔHout = panas dari bahan keluar

Qloss = panas yang hilang = 0,05 dari suplai panas

Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 45°C

Kolagen = 2767,4298 kg/hari

H_2O = 585,1762 kg/hari

$CaCl_2$ = 4,6047 kg/hari

$MgCl_2$ = 0,0003 kg/hari

NaCl = 0,0006 kg/hari

H_3PO_4 = 0,0072 kg/hari

Gelatin = 97,8008 kg/hari

HCl 5% = 4,2677 kg/hari

$$\Delta Hin = \Delta H_{kolagen} + \Delta H_{H2O} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4} + \Delta H_{HCl\ 5\%} + \Delta H_{gelatin}$$

$\Delta H_{kolagen}$ = m.Cp.(T1-25)

= 2767,4298 . 0,3369 . (45-25)

= 18646,94199 kkal/hari

ΔH_{H2O} = m.Cp.(T1-25)

= 585,1762 . 1 . (45-25)

ΔH_{H2O} = 11703,524 kkal/hari

ΔH_{CaCl2} = m.Cp.(T1-25)

= 4,6047 . 0,2162 . (45-25)

= 19,91072 kkal/hari

ΔH_{MgCl2} = m.Cp.(T1-25)

= 0,0003 . 0,252 . (45-25)

= 0,00151 kkal/hari

ΔH_{NaCl} = m.Cp.(T1-25)

= 0,0006 . 0,2737 . (45-25)

= 0,00328 kkal/hari

ΔH_{H3PO4} = m.Cp.(T1-25)

= 0,0072 . 0,452 . (45-25)

= 0,06509 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T1-25)

= 97,8008 . 0,3613 . (45-25)

= 706,70858 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T1-25)

= 4,2677 . 0,8377 . (45-25)

= 71,5010 kkal/hari

Untuk larutan HCl 5% masuk pada suhu 50°C:

HCl 5% = 10,4102 kg/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T1-25)

= 10,4102 . 0,8377 . (50-25)

= 218,0156 kkal/hari

Untuk air yang ditambahkan pada tangki ini masuk pada suhu 30°C :

H_2O = 5779,9123 kg/hari

ΔH_{H2O} = m.Cp.(T1-25)

= 5779,9123 . 1 . (30-25)

ΔH_{H2O} = 28899,5615 kkal/hari

ΔHin = 18646,94199 + 11703,524 + 218,0156 + 19,91072 + 0,00151

+ 0,00328 + 0,06509 + 706,70858 + 28899,5615 + 71,5010

= 60266,2333 kkal/hari

<u>Menghitung panas keluar ($\Delta Hout$) :</u>

Suhu bahan keluar = 50°C

Kolagen = 2435,3382 kg/hari

Gelatin = 429,8924 kg/hari

$CaCl_2$ = 4,60470 kg/hari

$MgCl_2$ = 0,0003 kg/hari

NaCl = 0,0006 kg/hari

H_2O = 6365,0885 kg/hari

H_3PO_4 = 0,0072 kg/hari

HCl 5% = 14,67790 kg/hari

$\Delta Hout = \Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H2O} + \Delta H_{H3PO4}$
$+ \Delta H_{HCl\ 5\%}$

$\Delta H_{kolagen}$ = m.Cp.(T2-25)

= 2435,3382 . 0,3369 . (50-25)

= 20511,6360 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T2-25)

= 429,8924 . 0,3613 . (50-25)

= 3883,00310 kkal/hari

ΔH_{CaCl2} = m.Cp.(T2-25)

= 4,60470 . 0,2162 . (50-25)

= 24,88840 kkal/hari

ΔH_{MgCl2} = m.Cp.(T2-25)

= 0,0003 . 0,252 . (50-25)

= 0,00189 kkal/hari

ΔH_{NaCl} = m.Cp.(T2-25)

= 0,0006 . 0,2737 . (50-25)

= 0,00411 kkal/hari

ΔH_{H3PO4} = m.Cp.(T2-25)

= 0,0072 . 0,452 . (50-25)

= 0,08136 kkal/hari

ΔH_{H2O} = m.Cp.(T2-25)

= 6365,0885 . 1 . (50-25)

= 159127,2125 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T2-25)

= 14,67790 . 0,8377 . (50-25)

= 354,7887 kkal/hari

ΔHout = 20511,6360 + 159127,2125 + 354,7887 + 24,88840 + 0,00189 + 0,00411

+ 0,08136 + 3883,00310

= 183876,6403 kkal/hari

ΔHin + Qsteam = ΔHout + ΔHr + 0,05 . Qsteam

60266,2333 + Qsteam = 183876,6403 + 0,05 . Qsteam

Qsteam = 130116,2179 kkal/hari

Digunakan steam pada suhu 120°C dan tekanan 198,53 kPa didapat :

H_V = 2706,3 kJ/kg = 646,8057 kkal/kg

H_L = 503,71 kJ/kg = 120,3843 kkal/kg

$\lambda = Hv - H_L = (646{,}8057 - 120{,}3843)$ kkal/hari = 526,4214 kkal/hari

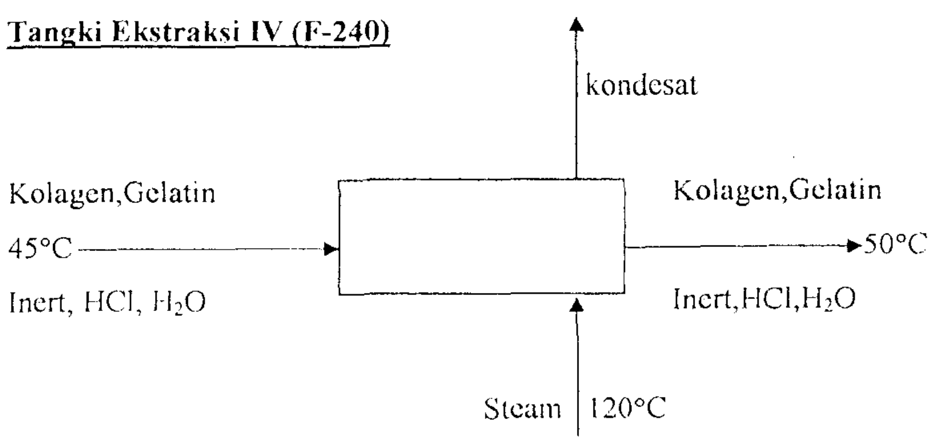
Jumlah steam yang digunakan = $\dfrac{130116{,}2179}{526{,}4214}$ = 247,1712 kg/hari

Panas yang hilang = 0,05 x 130116,2179

= 6505,8109 kkal/hari

Masuk :		Keluar :	
Panas masuk	= 60266,2333 kkal/hari	Panas keluar	= 183876,6403 kkal/hari
Panas Steam	= 130116,2179 kkal/hari		
		Panas hilang	= 6505,8109 kkal/hari
	= 190382,4512 kkal/hari		= 190382,4512 kkal/hari

Tangki Ekstraksi IV (F-240)



Pada tangki ekstraksi ini digunakan steam pada suhu 120°C dan tekanan 198,53 kPa.

$\Delta Hin + Qsteam = \Delta Hout + \Delta Hr + Qloss$

dimana : ΔHin = panas dari bahan masuk

$\Delta Hout$ = panas dari bahan keluar

Qloss = panas yang hilang = 0,05 dari suplai panas

Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 45°C

Kolagen = 2435,3382 kg/hari

H_2O = 6365,0885 kg/hari

$CaCl_2$ = 4,60470 kg/hari

$MgCl_2$ = 0,0003 kg/hari

NaCl = 0,0006 kg/hari

H_3PO_4 = 0,0072 kg/hari

HCl 5% = 14,67790 kg/hari

Gelatin = 429,8924 kg/hari

$\Delta Hin = \Delta H_{kolagen} + \Delta H_{H2O} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4} + \Delta H_{HCl\ 5\%}$
$+ \Delta H_{gelatin}$

$\Delta H_{kolagen}$ = m.Cp.(T1-25)
= 2435,3382 . 0,3369 . (45-25)
= 16409,3088 kkal/hari

ΔH_{H2O} = m.Cp.(T1-25)
= 6365,0885 . 1 . (45-25)
ΔH_{H2O} = 127301,7700 kkal/hari

ΔH_{CaCl2} = m.Cp.(T1-25)
= 4,60470 . 0,2162 . (45-25)
= 19,9107 kkal/hari

ΔH_{MgCl2} = m.Cp.(T1-25)
= 0,0003 . 0,252 . (45-25)
= 0,001512 kkal/hari

ΔH_{NaCl} = m.Cp.(T1-25)
= 0,0006 . 0,2737 . (45-25)
= 0,0032844 kkal/hari

$\Delta H_{H3PO4} = m.Cp.(T1\text{-}25)$

$= 0{,}0072 \; . \; 0{,}452 \; . \; (45\text{-}25)$

$= 0{,}0650880$ kkal/hari

$\Delta H_{HCl\ 5\%} = m.Cp.(T1\text{-}25)$

$= 14{,}67790 \; . \; 0{,}8377 \; . \; (45\text{-}25)$

$= 283{,}8310$ kkal/hari

$\Delta H_{gelatin} = m.Cp.(T1\text{-}25)$

$= 429{,}8924 \; . \; 0{,}3613 \; . \; (45\text{-}25)$

$= 3106{,}4025$ kkal/hari

$\Delta Hin = 16409{,}3088 + 127301{,}7700 + 283{,}8310 + 19{,}9107 + 0{,}001512$

$+ 0{,}0032844 + 0{,}0650880 + 3106{,}4025$

$= 143994{,}9145$ kkal/hari

Menghitung panas keluar ($\Delta Hout$) :

Suhu bahan keluar = 50°C

Kolagen = 2240,5111 kg/hari

Gelatin = 624,7195 kg/hari

$CaCl_2$ = 4,60470 kg/hari

$MgCl_2$ = 0,0003 kg/hari

NaCl = 0,0006 kg/hari

H_2O = 6365,0885 kg/hari

H_3PO_4 = 0,0072 kg/hari

HCl 5% = 14,6779 kg/hari

$\Delta Hout = \Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H2O} + \Delta H_{H3PO4}$

$+ \Delta H_{HCl\ 5\%}$

$\Delta H_{kolagen}$ = m.Cp.(T2-25)

2240,5111 . 0,3369 . (50-25)

= 18870,70474 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T2-25)

= 624,7195 . 0,3613 . (50-25)

= 5642,7789 kkal/hari

ΔH_{CaCl2} = m.Cp.(T2-25)

= 4,60470 . 0,2162 . (50-25)

= 24,8884 kkal/hari

ΔH_{MgCl2} = m.Cp.(T2-25)

= 0,0003 . 0,252 . (50-25)

= 0,00189 kkal/hari

ΔH_{NaCl} = m.Cp.(T2-25)

= 0,0006 . 0,2737 . (50-25)

= 0,004106 kkal/hari

ΔH_{H3PO4} = m.Cp.(T2-25)

= 0,0072 . 0,452 . (50-25)

= 0,081360 kkal/hari

ΔH_{H2O} = m.Cp.(T2-25)

= 6365,0885 . 1 . (50-25)

= 159127,2125 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T2-25)

= 14,6779_. 0,8377 . (50-25)

= 354,7887 kkal/hari

ΔHout = 18870,70474 + 159127,2125 + 354,7887 + 24,8884 + 0,00189

+ 0,004106 + 0,081360 + 5642,7789

= 183995,4848 kkal/hari

ΔHin + Qsteam = ΔHout + 0,05 . Qsteam

143994,9145 + Qsteam = 183995,4848 + 0,05 . Qsteam

Qsteam = 42105,86345 kkal/hari

Digunakan steam pada suhu 120°C dan tekanan 198,53 kPa didapat :

H_v = 2706,3 kJ/kg = 646,8057 kkal/kg

H_L = 503,71 kJ/kg = 120,3843 kkal/kg

$\lambda = H_v - H_L$ = (646,8057 – 120,3843) kkal/hari = 526,4214 kkal/hari

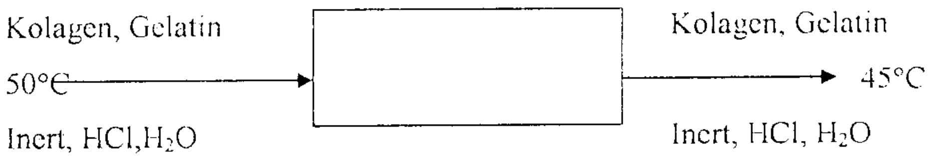
$$\text{Jumlah steam yang digunakan} = \frac{42105{,}86345}{526{,}4214} = 79{,}9960 \text{ kg/hari}$$

Panas yang hilang = 0,05 x 42105,86345

= 2105,2932 kkal/hari

Masuk :	Keluar :
Panas masuk = 143994,9145 kkal/hari	Panas keluar = 183995,4848 kkal/hari
Panas Steam = 42105,86345 kkal/hari	
	Panas hilang = 2105,2932 kkal/hari
= 186100,778 kkal/hari	= 186100,778 kkal/hari

Rotary Drum Vaccum Filter IV (H-241)



ΔHin = ΔHout + Qloss

dimana : ΔHin = panas dari bahan masuk

ΔHout = panas dari bahan keluar

Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 50°C

Kolagen = 2240,5111 kg/hari

Gelatin = 624,7195 kg/hari

$CaCl_2$ = 4,6047 kg/hari

$MgCl_2$ = 0,0003 kg/hari

NaCl = 0,0006 kg/hari

H_3PO_4 = 0,0072 kg/hari

H_2O = 6365,08850 kg/hari

HCl 5% = 14,6779 kg/hari

$\Delta Hin = \Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4} + \Delta H_{H2O}$
$+ \Delta H_{HCl\ 5\%}$

$\Delta H_{kolagen}$ = m.Cp.(T1-25)

= 2240,5111 . 0,3369 . (50-25)

= 18870,70474 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T1-25)

= 624,7195 . 0,3613 . (50-25)

= 5642,778884 kkal/hari

ΔH_{CaCl2} = m.Cp.(T1-25)

= 4,6047 . 0,2162 . (50-25)

= 24,8884035 kkal/hari

ΔH_{MgCl2} = m.Cp.(T1-25)

= 0,0003 . 0,252 .(50-25)

= 0,00189 kkal/hari

ΔH_{NaCl} = m.Cp.(T1-25)

= 0,0006 . 0,2737 . (50-25)

= 0,0041055 kkal/hari

ΔH_{H3PO4} = m.Cp.(T1-25)

= 0,0072 . 0,452 . (50-25)

ΔH_{H3PO4} = 0,08136 kkal/hari

ΔH_{H2O} = m.Cp.(T1-25)

= 6365,08850 . 1 . (50-25)

= 159127,2125 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T1-25)

= 14,6779 . 0,8377 . (50-25)

= 354,7886946 kkal/hari

ΔHin = 18870,70474 + 159127,2125 + 354,7886946 + 24,8884035 + 0,00189 + 0,0041055 + 0,08136 + 5642,778884

= 184020,4606 kkal/hari

Menghitung panas keluar (ΔHout) :

Suhu bahan keluar = 45°C

Cake keluar :

Kolagen = 2240,5111 kg/hari

H_2O = 508,66212 kg/hari

$CaCl_2$ = 0,36798 kg/hari

$MgCl_2$ = 0,00002 kg/hari

NaCl = 0,00005 kg/hari

H_3PO_4 = 0,00058 kg/hari

HCl 5% = 1,17298 kg/hari

Gelatin = 49,92407 kg/hari

Filtrat keluar :

Gelatin = 574,79543 kg/hari

H_2O = 5856,42638 kg/hari

HCl 5% = 13,50492 kg/hari

$CaCl_2$ = 4,23672 kg/hari

$MgCl_2$ = 0,00028 kg/hari

NaCl = 0,00055 kg/hari

H_3PO_4 = 0,00662 kg/hari

$\Delta Hout = \Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{H2O} + \Delta H_{CaCl2} + \Delta H_{HCl\ 5\%} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4}$

$\Delta H_{kolagen}$ = m.Cp.(T2-25)

= 2240,5111 . 0,3369 . (45-25)

= 15096,56379 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T2-25)

= (49,92407 + 574,79543) . 0,3613 . (45-25)

= 4514,223107 kkal/hari

ΔH_{H2O} = m.Cp.(T2-25)

= (508,66212 + 5856,42638) . 1 . (45-25)

= 127301,77 kkal/hari

ΔH_{CaCl2} = m.Cp.(T2-25)

= (4,23672 + 0,36798) . 0,2162 . (45-25)

= 19,9107228 kkal/hari

ΔH_{MgCl2} = m.Cp.(T2-25)

= (0,0003 + 0,00002) . 0,252 . (45-25)

= 0,001512 kkal/hari

ΔH_{NaCl} = m.Cp.(T2-25)

= (0,0006 + 0,00005) . 0,2737 . (45-25)

= 0,0032844 kkal/hari

ΔH_{H3PO4} = m.Cp.(T2-25)

= (0,0072 + 0,00058) . 0,452 . (45-25)

= 0,065088 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T2-25)

= (1,17298 + 13,50492) . 0,8377 . (45-25)

= 283,8309557 kkal/hari

ΔHout = 15096,56379 + 127301,77 + 283,8309557 + 19,9107228

+ 0,001512 + 0,0032844 + 0,065088 + 4514,223107

= 147216,3685 kkal/hari

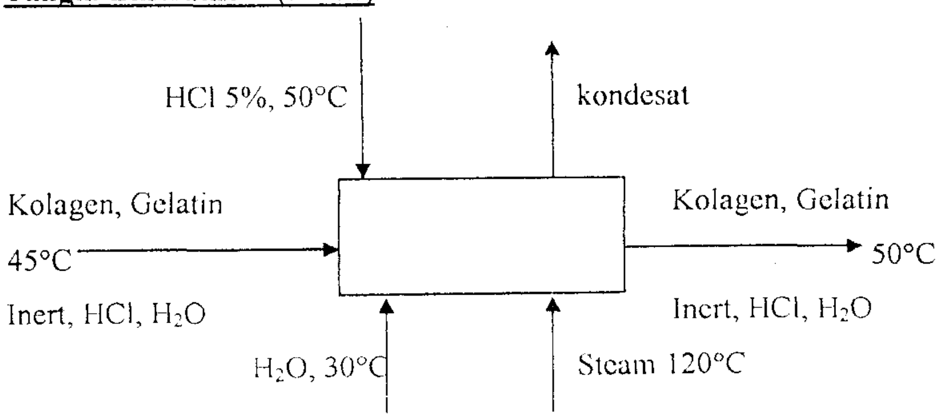
ΔHin = ΔHout + Qloss

184020,4606 = 147216,3685 + Qloss

Qloss = 36804,09212 kkal/hari

Masuk :	Keluar :
Panas masuk = 184020,4606 kkal/hari	Panas keluar = 147216,3685 kkal/hari
	Panas hilang = 36804,09212 kkal/hari
= 184020,4606 kkal/hari	= 184020,4606 kkal/hari

Tangki Ekstraksi V (F-250)



Pada tangki ekstraksi ini digunakan steam pada suhu 120°C dan tekanan 198,53 kPa.

$\Delta Hin + Qsteam = \Delta Hout + \Delta Hr + Qloss$

dimana : ΔHin = panas dari bahan masuk

$\Delta Hout$ = panas dari bahan keluar

Qloss = panas yang hilang = 0,05 dari suplai panas

Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 45°C

Kolagen = 2240,5111 kg/hari

H_2O = 508,66212 kg/hari

$CaCl_2$ = 0,36798 kg/hari

$MgCl_2$ = 0,00002 kg/hari

NaCl = 0,00005 kg/hari

H_3PO_4 = 0,00058 kg/hari

HCl 5% = 1,17298 kg/hari

Gelatin = 22,1717140 kg/hari

$$\Delta Hin = \Delta H_{kolagen} + \Delta H_{H2O} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4} + \Delta H_{HCl\ 5\%} + \Delta H_{gelatin}$$

$\Delta H_{kolagen}$ = m.Cp.(T1-25)

= 2240,5111 . 0,3369 . (45-25)

= 15096,5638 kkal/hari

ΔH_{H2O} = m.Cp.(T1-25)

= 508,66212 . 1 . (45-25)

ΔH_{H2O} = 10173,2424 kkal/hari

ΔH_{CaCl2} = m.Cp.(T1-25)

= 0,36798 . 0,2162 . (45-25)

= 1,5911 kkal/hari

ΔH_{MgCl2} = m.Cp.(T1-25)

= 0,00002 . 0,252 . (45-25)

= 0,0001008 kkal/hari

ΔH_{NaCl} = m.Cp.(T1-25)

= 0,00005 . 0,2737 . (45-25)

= 0,0002737 kkal/hari

ΔH_{H3PO4} = m.Cp.(T1-25)

= 0,00058 . 0,452 . (45-25)

= 0,0052432 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T1-25)

= 1,17298. 0,8377 . (45-25)

= 19,6521 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T1-25)

= 22,1717140 . 0,3613 . (45-25)

= 160,2128 kkal/hari

Untuk larutan HCl 5% yang ditambahkan masuk pada suhu 50°C :

Massa HCl 5% = 4,82272 kg/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T1-25)

= 4,82272. 0,8377 . (50-25)

= 100,9998 kkal/hari

Untuk air yang ditambahkan masuk pada suhu 30°C :

Massa air = 4644,51338 kg/hari

ΔH_{H2O} = m.Cp.(T1-25)

= 4644,51338 . 1 . (30-25)

ΔH_{H2O} = 23222,5669 kkal/hari

ΔHin = 15096,5638 + 10173,2424 + 19,6521 + 1,5911 + 0,0001008
+ 0,0002737 + 0,0052432 + 160,2128 + 100,9998 + 23222,5669
= 48774,8345 kkal/hari

Menghitung panas keluar (ΔHout) :

Suhu bahan keluar = 50°C

Kolagen = 1926,83950 kg/hari

Gelatin = 363,59567 kg/hari

$CaCl_2$ = 0,36798 kg/hari

$MgCl_2$ = 0,00002 kg/hari

NaCl = 0,00005 kg/hari

H_2O = 5153,17550 kg/hari

H_3PO_4 = 0,00058 kg/hari

HCl 5% = 5,9957000 kg/hari

$\Delta Hout = \Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H2O} + \Delta H_{H3PO4} + \Delta H_{HCl\ 5\%}$

$\Delta H_{kolagen}$ = m.Cp.(T2-25)
= 1926,83950 . 0,3369 . (50-25)
16228,80569 kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T2-25)
= 363,59567 . 0,3613 . (50-25)
= 3284,1779 kkal/hari

ΔH_{CaCl2} = m.Cp.(T2-25)
= 0,36798 . 0,2162 . (50-25)
= 1,9889 kkal/hari

ΔH_{MgCl2} = m.Cp.(T2-25)
= 0,00002 . 0,252 . (50-25)
= 0,000126 kkal/hari

ΔH_{NaCl} = m.Cp.(T2-25)

= 0,00005 . 0,2737 . (50-25)

= 0,000342 kkal/hari

ΔH_{H3PO4} = m.Cp.(T2-25)

= 0,00058 . 0,452 . (50-25)

= 0,006554 kkal/hari

ΔH_{H2O} = m.Cp.(T2-25)

= 5153,17550 . 1 . (50-25)

= 128829,3875 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T2-25)

= 5,9957000 . 0,8377 . (50-25)

= 144,9258 kkal/hari

ΔHout = 16228,80569 + 128829,3875 + 144,9258 + 1,9889 + 0,000126

+ 0,000342 + 0,006554 + 3284,1779

= 148487,2969 kkal/hari

ΔHin + Qsteam = ΔHout + 0,05 . Qsteam

48774,8345 + Qsteam = 148487,2969 + 0,05 . Qsteam

Qsteam = 104960,4867 kkal/hari

Digunakan steam pada suhu 120°C dan tekanan 198,53 kPa didapat :

Hv = 2706,3 kJ/kg = 646,8057 kkal/kg

H_L = 503,71 kJ/kg = 120,3843 kkal/kg

λ = Hv – H_L = (646,8057 – 120,3843) kkal/hari = 526,4214 kkal/hari

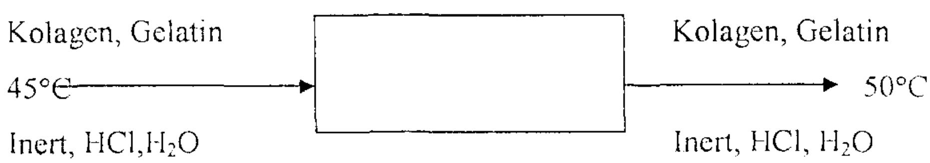
$$\text{Jumlah steam yang digunakan} = \frac{104960,4867}{526,4214} = 199,3849 \text{ kg/hari}$$

Panas yang hilang 0,05 x 104960,4867

= 5248,0243 kkal/hari

Masuk :	Keluar :
Panas masuk = 48774,8345 kkal/hari	Panas keluar = 148487,2969 kkal/hari
Panas Steam = 104960,4867 kkal/hari	
	Panas hilang = 5248,0243 kkal/hari
= 153735,3212 kkal/hari	= 153735,3212 kkal/hari

Rotary Drum Vaccum Filter V (H-251)



ΔHin = ΔHout + Qloss

dimana : ΔHin = panas dari bahan masuk

ΔHout = panas dari bahan keluar

Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 50°C

Kolagen = 1926,8395 kg/hari

Gelatin = 363,59567 kg/hari

$CaCl_2$ = 0,36798 kg/hari

$MgCl_2$ = 0,00002 kg/hari

NaCl = 0,00005 kg/hari

H_3PO_4 = 0,00058 kg/hari

H_2O = 5153,1755 kg/hari

HCl 5% = 5,9957 kg/hari

$\Delta Hin = \Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{CaCl2} + \Delta H_{MgCl2} + \Delta H_{NaCl} + \Delta H_{H3PO4} + \Delta H_{H2O}$

$+ \Delta H_{HCl\ 5\%}$

$\Delta H_{kolagen} = m.Cp.(T1\text{-}25)$

$= 1926{,}8395 \ . \ 0{,}3369 \ . \ (50\text{-}25)$

$= 16228{,}80569$ kkal/hari

$\Delta H_{gelatin} = m.Cp.(T1\text{-}25)$

$= 363{,}59567 \ . \ 0{,}3613 \ . \ (50\text{-}25)$

$= 3284{,}177889$ kkal/hari

$\Delta H_{CaCl2} = m.Cp.(T1\text{-}25)$

$= 0{,}36798 \ . \ 0{,}2162 \ . \ (50\text{-}25)$

$= 1{,}9889319$ kkal/hari

$\Delta H_{MgCl2} = m.Cp.(T1\text{-}25)$

$= 0{,}00002 \ . \ 0{,}252 \ .(50\text{-}25)$

$= 0{,}000126$ kkal/hari

$\Delta H_{NaCl} = m.Cp.(T1\text{-}25)$

$= 0{,}00005 \ . \ 0{,}2737 \ . \ (50\text{-}25)$

$= 0{,}000342125$ kkal/hari

$\Delta H_{H3PO4} = m.Cp.(T1\text{-}25)$

$= 0{,}00058 \ . \ 0{,}452 \ . \ (50\text{-}25)$

$= 0{,}006554$ kkal/hari

$\Delta H_{H2O} = m.Cp.(T1\text{-}25)$

$= 5153{,}1755 \ . \ 1 \ . \ (50\text{-}25)$

$= 128829{,}3875$ kkal/hari

$\Delta H_{HCl\ 5\%} = m.Cp.(T1\text{-}25)$

$= 5{,}9957 \ . \ 0{,}8377 \ . \ (50\text{-}25)$

$= 144{,}925812$ kkal/hari

$\Delta Hin = 16228{,}80569 + 128829{,}3875 + 144{,}925812 + 1{,}9889319$
$+ 0{,}000126 + 0{,}000342125 + 0{,}006554 + 3284{,}177889$
$= 148489{,}2928$ kkal/hari

Menghitung panas keluar ($\Delta Hout$) :

Suhu bahan keluar = 45°C

Cake keluar :

Kolagen = 1926,8395 kg/hari

H_2O = 449,443193 kg/hari

$CaCl_2$ = 0,032094 kg/hari

$MgCl_2$ = 0,000002 kg/hari

NaCl = 0,000004 kg/hari

H_3PO_4 = 0,000051 kg/hari

HCl 5% = 0,522925 kg/hari

Gelatin = 31,711631 kg/hari

Filtrat keluar :

Gelatin = 331,884039 kg/hari

H_2O = 4703,732307 kg/hari

HCl 5% = 5,472775 kg/hari

$CaCl_2$ = 0,335886 kg/hari

$MgCl_2$ = 0,000018 kg/hari

NaCl = 0,000046 kg/hari

H_3PO_4 = 0,000529 kg/hari

$\Delta Hout = \Delta H_{kolagen} + \Delta H_{gelatin} + \Delta H_{H2O} + \Delta H_{CaCl2} + \Delta H_{HCl\ 5\%} + \Delta H_{MgCl2} + \Delta H_{NaCl}$
$+ \Delta H_{H3PO4}$

$\Delta H_{kolagen} = m.Cp.(T2\text{-}25)$
$= 1926{,}8395 \;.\; 0{,}3369 \;.\; (45\text{-}25)$
$= 12983{,}04455$ kkal/hari

$\Delta H_{gelatin}$ = m.Cp.(T2-25)

= (31,711631 + 331,884039) . 0,3613 . (45-25)

= 2627,342311 kkal/hari

ΔH_{H2O} = m.Cp.(T2-25)

= (449,443193 + 4703,732307) . 1 . (45-25)

= 103063,51 kkal/hari

ΔH_{CaCl2} = m.Cp.(T2-25)

= (0,032094 + 0,335886) . 0,2162 . (45-25)

= 1,59114552 kkal/hari

ΔH_{MgCl2} = m.Cp.(T2-25)

= (0,000002 + 0,000018) . 0,252 . (45-25)

= 0,0001008 kkal/hari

ΔH_{NaCl} = m.Cp.(T2-25)

= (0,000004 + 0,000046) . 0,2737 . (45-25)

= 0,0002737 kkal/hari

ΔH_{H3PO4} = m.Cp.(T2-25)

= (0,000051 + 0,000529) . 0,452 . (45-25)

= 0,0052432 kkal/hari

$\Delta H_{HCl\ 5\%}$ = m.Cp.(T2-25)

= (0,522925 + 5,472775) . 0,8377 . (45-25)

= 115,9406496 kkal/hari

ΔHout = 12983,04455 + 103063,51 + 115,9406496 + 1,59114552

+ 0,0001008 + 0,0002737 + 0,0052432 + 2627,342311

= 118791,4343 kkal/hari

$\Delta Hin = \Delta Hout + Qloss$

148489,2928 = 118791,4343 + Qloss
Qloss = 29697,85857 kkal/hari

Masuk :		Keluar :	
Panas masuk	= 148489,2928 kkal/hari	Panas keluar	= 118791,4343 kkal/hari
		Panas hilang	= 29697,85857 kkal/hari
	= 148489,2928 kkal/hari		= 148489,2928 kkal/hari

Tangki Penampung Ekstraksi (F-253)

$\Delta Hin = \Delta Hout + Qloss$

dimana : ΔHin = Panas bahan masuk

$\Delta Hout$ = Panas bahan keluar

Menghitung panas masuk (ΔHin) :

Suhu bahan masuk = 45°C

Massa total larutan gelatin = 2536,948869 kg/hari

Massa total air = 20314,63249 kg/hari

Massa total impurities = 81,473449 kg/hari

Massa total HCl 5% = 90,117095 kg/hari

$$\Delta H_{larutan\ gelatin} = m_{larutan\ gelatin} \cdot Cp_{larutan\ gelatin} \cdot (T1-25)$$
$$= 2536,948869 \cdot 0,92961526 \cdot (45-25)$$
$$= 47167,72765 \text{ kkal/hari}$$

$$\Delta H_{air} = m_{air} \cdot Cp_{air} \cdot (T1-25)$$
$$= 20314,63249 \cdot 1 \cdot (45-25)$$
$$= 406292,6498 \text{ kkal/hari}$$

$\Delta H_{impurities} = m_{impuritis} . Cp_{impurities} . (T1-25)$

$= 81,473449 . 1,1939 . (45-25)$

$= 1945,423015$ kkal/hari

$\Delta H_{HCl\ 5\%} = m_{HCl\ 5\%} . Cp_{HCl\ 5\%} . (T1-25)$

$= 90,117095 . 0,8377 . (45-25)$

$= 1509,8218$ kkal/hari

$\Delta Hin = 47167,72765 + 1945,423015 + 1509,8218 + 406292,6498$

$= 457148,4218$ kkal/hari

Panas yang hilang = 0,05 x 457148,4218

= 22857,42109 kkal/hari

$\Delta Hout = \Delta Hin$ – panas hilang

= 457148,4218 - 22857,42109

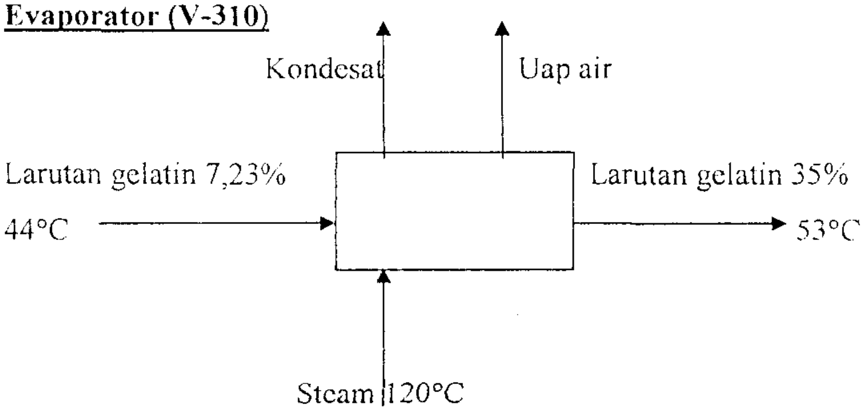
= 434291,0007 kkal/hari

Suhu larutan gelatin keluar $= \dfrac{434291,0007}{\left(\sum m.Cp\right)} + 25$

$= 44\ ^{\circ}C$

Masuk :	Keluar :
Panas masuk = 457148,4218 kkal/hari	Panas keluar = 434291,0007 kkal/hari
	Panas hilang = 22857,42109 kkal/hari
= 457148,4218 kkal/hari	= 457148,4218 kkal/hari

Evaporator (V-310)



Pada tangki evaporator ini digunakan steam pada suhu 120°C dan proses evaporasi beroperasi pada tekanan 4 inHg (= 13,5457 kPa = 0,13 atm).

ΔHin + Qsteam = ΔHout + Qv + Qloss

dimana : ΔHin = panas bahan masuk

ΔHout = panas bahan keluar

Qv = panas penguapan

Qloss = 0,05. Qs

Berat total gelatin = 1078,92 + 649,1502 + 332,0916 + 194,8271 + 313,6716

= 2568,6605 kg – 31,711631 kg

= 2536,948869 kg

Berat total H_2O = 10339,65 + 5779,9123 + 4644,51338 – 449,443193

= 20314,63249 kg

$\Delta tb_{H2O} = Kb \cdot m_{H2O}$

dimana : Δtb = kenaikan titik didih air

Kb = tetapan kenaikan titik didih molal (untuk air, K_b = 0,52)

m = molalitas air

$$\Delta tb_{H2O} = 0{,}52x\left(\frac{2536{,}948869}{2435{,}578}x\frac{1000}{20314{,}63249}\right)$$

= 0,026662695

Titik didih larutan = Tb air + Δtbair

= 53 + 0,026662695

= 53,026662695 °C ≈ 53°C

Titik didih larutan = 53 °C

Cp gelatin (11,02%) = (0,1102 x 0,3613) + (0,8898 x 1)

= 0,92961526 kkal/kg °C

ΔHin = $m_{larutan\ gelatin}$. Cp . (T1-25)

= 23023,1719 . 0,92961526 . (44-25)

= 406651,1467 kkal/hari

<u>Menghitung panas penguapan (Qv) :</u>

Jumlah uap = 15774,1618 kg/hari

ΔHuap air jenuh pada 53°C = 567,7605 kkal/kg

Cp_{H2O} pada53°C=

$$a+\frac{b}{2}.(T2+T1)+\frac{C}{3}.(T2^2+T2.T1+T1^2)+\frac{d}{4}.(T2+T1).(T2^2+T1^2)$$

dimana : a = 33,46 c = $0,7604.10^{-5}$

b = $0,688.10^{-2}$ d = $-3,593.10^{-9}$

T_2 = 53°C T_1 = 25°C

$Cp_{H2O\ pada\ 53°C}$ = 0,4476 kkal/kg °C

Qv_{H2O} = 15774,1618 x (ΔHuap air jenuh+(Cp_{H2O} x Δtbair))

= 15774,1618 x (567,7605+(0,4476 x (53-25))

= 9153640,406 kkal/hari

ΔHout = $m_{larutan\ gelatin\ keluar}$.Cp. (T2-25)

Cp gelatin 35% = (0,35x0,3613) + (1x0,65)

= 0,777 kkal/kg °C

$\Delta Hout = 7249{,}0101 \cdot 0{,}777 \cdot (53\text{-}25)$

$= 157709{,}4637$ kkal/hari

$\Delta Hin + Qsteam = \Delta Hout + Qv_{H2O} + Qloss$

$406651{,}1467 + Qsteam = 9153640{,}406 + 157709{,}4637 + 0{,}05.Qsteam$

$Qsteam = 9373367{,}077$ kkal/hari

Digunakan steam pada suhu 120°C dan tekanan 198,53 kPa didapat :

$Hv = 2706{,}3$ kJ/kg $= 646{,}8057$ kkal/kg

$H_L = 503{,}71$ kJ/kg $= 120{,}3843$ kkal/kg

$\lambda = Hv - H_L = (646{,}8057 - 120{,}3843)$ kkal/hari $= 526{,}4214$ kkal/hari

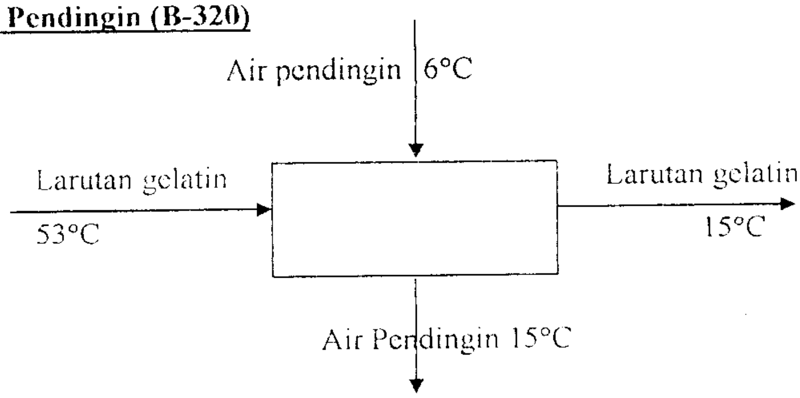
$$\text{Jumlah steam yang digunakan} = \frac{9373367{,}077}{526{,}4214} = 17805{,}8245 \text{ kg/hari}$$

Panas hilang = 0,05 x 9373367,077

= 468668,3539 kkal/hari

Masuk :		Keluar :	
Panas masuk	= 406651,1467 kkal/hari	Panas keluar	= 157709,4637 kkal/hari
Panas Steam	= 9373367,067 kkal/hari	Panas Penguapan	= 9153640,406 kkal/hari
		Panas hilang	= 468668,3539 kkal/hari
	= 9780018,214 kkal/hari		= 9780018,214 kkal/hari

Alat Pendingin (B-320)



$\Delta Hin = \Delta Hout + Qair\ pendingin$

dimana : ΔHin = panas bahan masuk

$\Delta Hout$ = panas bahan keluar

Suhu larutan masuk = 53°C

Suhu larutan keluar = 15°C

Suhu referensi = 25°C

Massa larutan gelatin masuk=massa lar. gelatin keluar = 7249,0101kg/hari

$Cp_{gelatin\ 35\%}$ = 0,777 kkal/kg°C

ΔHin = m.Cp.(T1-25)

= 7249,0101 . 0,777 . (53-25)

= 157709,4637 kkal/hari

$\Delta Hout$ = m.Cp.(T2-25)

= 7249,0101 . 0,777 . (15-25)

= -56375,55155 kkal/hari

$\Delta Hin = \Delta Hout + Qair\ pendingin$

157709,4637 + 56375,55155 = Qair pendingin

Qair pendingin = 214085,0153 kkal/hari

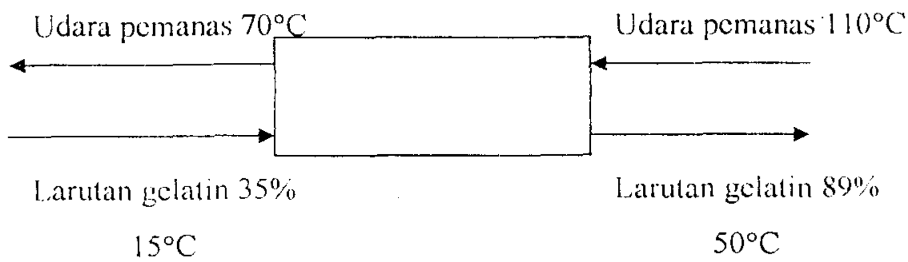
Suhu air masuk = 6°C

Suhu air keluar = 15°C

Jumlah air yang digunakan = $\dfrac{214085{,}0153}{1.(15-6)}$ = 23787,224 kg/hari

Masuk :	Keluar :
Panas masuk = 157709,4637 kkal/hari	
Panas keluar = 56375,55155 kkal/hari	Q air pendingin= 214085,0153 kkal/hari
= 214085,0153 kkal/hari	= 214085,0153 kkal/hari

Spray Dryer (B-330)



ΔHin + Qpemanas = ΔHout + ΔHpenguapan

dimana : ΔHin = panas bahan masuk

ΔHout = panas bahan keluar

Qpemanas = panas dari udara pemanas

ΔHpenguapan = panas penguapan air

Suhu larutan masuk = 15°C

Suhu larutan keluar = 50°C

Massa larutan masuk = 7249,0101 kg/hari

Massa larutan keluar = 2850,5043 kg/hari

Kadar air = 11%

Kadar gelatin = 89%

$Cp_{gelatin\ 35\%}$ = 0,7777 kkal/kg °C

$Cp_{gelatin\ 89\%}$ = (0,89 x 0,3613) + (1 x 0,11)

= 0,431557 kkal/kg °C

ΔHin = $m_{larutan\ gelatin\ masuk}$.Cp.(T1-25)

= 7249,0101 . 0,7777 . (15-25)

= -56375,55155 kkal/hari

ΔHout = $m_{larutan\ gelatin\ keluar}$ .Cp.(T2-15)

= 2850,504347 . 0,431557 . (50-15)

= 43055,42866 kkal/hari

$$\text{mol air yang diuapkan} = \frac{4398,5058}{18,016} = 244,1444135 \text{ kmol/hari}$$

$$\Delta\text{Hpenguapan} = 244,1444135 \frac{kmol}{hari} x1000 \frac{mol}{kmol} x40,65 \frac{kJoule}{mol}$$

$$= 9924470409 \text{ kJ/hari} = 9924470409 \frac{kJ}{hari} \times 0,239 \frac{kkal}{kJ}$$

$$= 2371948,428 \text{ kkal/hari}$$

ΔHin + Qpemanas = ΔHout + ΔHpenguapan

Qpemanas = 43055,42866 + 2371948,428 + 56375,55155
Qpemanas = 2471379,408 kkal/hari

Suhu udara masuk = 110°C

Suhu udara keluar = 70°C

Cp (N_2 gas)

$$= 29 + \left(\frac{2,199.10^{-3}}{2} \times (110 + 70)\right) + \left(\frac{5,723.10^{-6}}{3} \times \left(70^2 + (70.110) + 110^2\right)\right) +$$
$$\left(\frac{-2,871.10^{-9}}{4}\left(70^2 + 110^2\right)(70 + 110)\right)$$

= 29,2749 J/mol °C = 0,2450 kkal/kg °C

Cp (O_2 gas)

$$= 29,1 + \left(\frac{11,58.10^{-3}}{2} \times (110 + 70)\right) + \left(\frac{-6,076.10^{-6}}{3} \times \left(70^2 + (70.110) + 110^2\right)\right) +$$
$$\left(\frac{1,311.10^{-9}}{4}\left(70^2 + 110^2\right) \times (70 + 110)\right)$$

= 30,6198 J/mol °C = 0,2287 kkal/kg °C

Cp udara = (0,79 x 0,2450)+(0,21 x 0,2287)
= 0,2416 kkal/kg °C

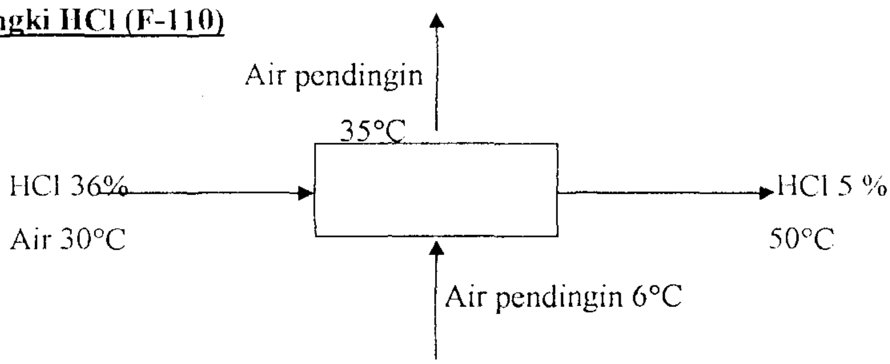
$$\text{Jumlah udara yang dibutuhkan} = \frac{Qpemanas}{Cp_{udara}.(T2 - T1)}$$

$$= \frac{2471379{,}408}{0{,}2416.(110 - 70)}$$

$$= 91332{,}3161 \text{ kg/hari}$$

Masuk :		Keluar :	
		Panas keluar	= 18452,32657 kkal/hari
Q pemanas	= 2471379,408 kkal/hari	Panas masuk	= 56375,55155 kkal/hari
		Panas penguapan	= 2371948,428 kkal/hari
	= 2471379,408 kkal/hari		= 2471379,408 kkal/hari

Tangki HCl (F-110)



ΔHin = ΔHout + Panas pengenceran + Qair pendingin

dimana : ΔHin = panas bahan masuk

ΔHout = panas bahan keluar

Menghitung panas masuk (ΔHin) :

Suhu larutan masuk = 30°C

Massa larutan HCl 36% = 20647,2617 kg/hari

Massa larutan air = 128013,0223 kg/hari

$Cp_{HCl\ 36\%}$ = 0,5818 kkal/kg°C

$\Delta H_{HCl\ 36\%}$ = m.Cp.(T1-25)

= 20647,2617 . 0,5818 . (30-25)

= 60062,8843 kkal/hari

ΔHair = m.Cp.(T1-25)

= 128013,0223 . 1 . (30-25)

= 640337,0655 kkal/hari

ΔHin = 60062,8843 + 640337,0655

= 700399,9498 kkal/hari

Menghitung panas pengenceran (ΔHs) :

Pada HCl 36% didapat ΔH = -48 kJ/mol (Smith Van Ness)

= -314,4 kkal/kg

ΔH_1 = -314,4 x 20647,2617

= -6491499,078 kkal/hari

Pada HCl 5% didapat ΔH = -70 kJ/mol (Smith Van Ness)

= -458,5 kkal/kg

ΔH_2 = -458,5 x 148660,2840

= -68160740,21 kkal/hari

ΔHs = -68160740,21 + 6491499,078

= -61669241,13 kkal/hari

Menghitung panas keluar (ΔHout) :

Suhu larutan keluar = 50°C

massa larutan HCl 5% = 148660,284 kg/hari

$Cp_{HCl\ 5\%}$ = 0,8377 kkal/kg°C

$\Delta Hout = \Delta H_{HCl\ 5\%} = m.Cp.(T2\text{-}25)$

$= 148660{,}284 \ .\ 0{,}8377 \ .\ (50\text{-}25)$

$= 3113317{,}998$ kkal/hari

$\Delta Hin = \Delta Hout$ + Panas pengenceran + Qair pendingin

700399,9498 + 61669241,13 = 3113317,998 + Qair pendingin

Qair pendingin = 59256323,08 kkal/hari

Suhu air masuk = 6°C

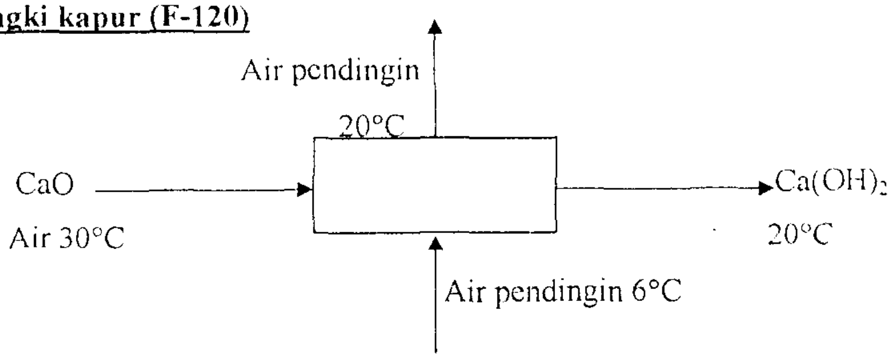
Suhu air keluar = 35°C

Massa air pendingin yang dibutuhkan = $\dfrac{59256323{,}08}{1x(35-6)}$

= 2043321,486 kg/hari

Masuk :		Keluar :	
Panas masuk	= 700399,9498 kkal/hari	Panas keluar	= 3113317,998 kkal/hari
Panas Pengencer	= 61669241,13kkal/hari	Qair pendingin	= 59256323,08 kkal/hari
	= 62369641,08 kkal/hari		= 62369641,08 kkal/hari

Tangki kapur (F-120)



$\Delta Hin + \Delta Hr = \Delta Hout$ + Qair pendingin

dimana : ΔHr = panas reaksi

ΔHin = panas bahan masuk

$\Delta Hout$ = panas bahan keluar

Menghitung panas masuk (ΔHin) :

Suhu larutan masuk = 30°C

Massa CaO = 1798,2 kg/hari

Massa air = 16183,8000 kg/hari

$\Delta H_{CaO} = m_{CaO} \cdot Cp_{CaO} \cdot (T1-25)$

$= 1798,2 \cdot 0,2668 \cdot (30-25)$

$= 2398,7988$ kkal/hari

$\Delta Hair = m_{air} \cdot Cpair \cdot (T1-25)$

$= 16183,8 \cdot 1 \cdot (30-25)$

$= 80919$ kkal/hari

$\Delta Hin = 80919 + 2398,7988$

$= 83818,28059$ kkal/hari

Menghitung panas reaksi (ΔHr) :

$CaO + H_2O \longrightarrow Ca(OH)_2$

Mol CaO yang bereaksi = 32,0649 kmol/hari

Mol air yang bereaksi = 32,0649 kmol/hari

Mol $Ca(OH)_2$ = 32,0649 kmol/hari

$\Delta Hr = (32,0649 \times -235,7950) - ((32,0649 \times -68,2782)+(32,0649 \times -151,9084))$

$= -500,48179$ kkal/hari

Menghitung panas keluar (ΔHout) :

Suhu bahan keluar = 20°C

Massa $Ca(OH)_2$ = 2375,8808 kg/hari

Massa air = 15606,1188 kg/hari

$\Delta Hair = m_{air} \cdot Cp_{air} \cdot (T2-25)$

$= 15606,1188 \cdot 1 \cdot (20-25)$

$= -78030,594$ kkal/hari

$$\Delta H_{Ca(OH)2} = m_{Ca(OH)2} \cdot Cp_{Ca(OH)2} \cdot (T2\text{-}25)$$
$$= 2375{,}8808 \cdot 0{,}286 \cdot (20\text{-}25)$$
$$= -3397{,}509544 \text{ kkal/hari}$$

ΔHout = -3397,509544 + -78030,594

= -81428,10354 kkal/hari

ΔHin + ΔHr = ΔHout + Qair pendingin

83818,28059 + 500,48179 + 81428,10354 = Qair pendingin

Qair pendingin = 165746,8659 kkal/hari

Suhu air masuk = 6°C

Suhu air keluar = 20°C

Jumlah air pendingin yang dibutuhkan = $\dfrac{165746{,}8659}{1.x(20-6)}$ = 11839,0619 kg/hari

Masuk :		Keluar :	
Panas masuk	= 83818,28059 kkal/hari		
Panas reaksi	= 500,48179 kkal/hari		
Panas keluar	= 81428,10354 kkal/hari	Qair pendingin	= 165746,8659 kkal/hari
	= 165746,8659 kkal/hari		= 165746,8659 kkal/hari

APPENDIKS C.

PERHITUNGAN SPESIFIKASI PERALATAN

APPENDIX C
PERHITUNGAN SPESIFIKASI ALAT

1. WAREHOUSE TULANG (F-130)

Fungsi : menyimpan bahan baku tulang

Tipe : gedung dengan bahan konstruksi concrete beton

Dasar pemilihan : cocok digunakan untuk menampung bahan yang berbentuk padat

Kondisi operasi : T = 30^0C

Jumlah :1 buah

Perhitungan :

Rate tulang masuk =13500 kg/hari

Persediaan tulang/bulan = 13500 kg/hari x 4 hari

= 54000 kg = 119070 lbm

ρ_{tulang} = 1,9 gr/cm^3 x 62,43

= 118,617 lbm/cuft

Volume tulang = 119070 lbm / (118,617 lbm/cuft)

= 1003,819 cuft

Diambil volume ruang kosong = 15% x volume tulang

= 0,15 x 1003,8190 cuft

= 150,5729 cuft

$$\varepsilon = \text{void fraction} = \frac{\text{volume ruang kosong}}{\text{volume ruang kosong + volume tulang}}$$

$$= \frac{150{,}5729}{150{,}5729 + 1003{,}819} = 0{,}1304$$

$\rho_{tulang\ bulk}$ = 118,617 lbm/cuft x (1 - 0,1304)

= 103,1493 lbm/cuft

Volume tulang = 119070 lbm / (103,1493 lbm/cuft)

= 1154,3462 cuft

Diambil : volume warehouse = 2 x volume tulang

= 2 x 1154,3462 cuft = 2308,6924 cuft

Warehouse dengan alas bujursangkar dengan ketentuan :

- Tinggi bangunan = 15 ft
- Panjang = lebar = $\sqrt{\dfrac{2308{,}6924 cuft}{15 ft}}$ = 12,5 ft

Spesifikasi :

Kapasitas : 54000 kg = 119070 lbm

Waktu tinggal : 4 hari

Panjang : 12,5 ft

Lebar : 12,5 ft

Tinggi : 15 ft

Jumlah : 1 buah

2. TANGKI HCl (F-110)

Fungsi : menyiapkan bahan baku HCl 5 %

Tipe : silinder tegak dengan tutup atas dan tutup bawah berbentuk dished head dan dilengkapi dengan pengaduk dan coil pendingin.

Dasar pemilihan : cocok digunakan untuk menampung bahan yang berbentuk liquida

Kondisi operasi : T = 50^0C

Kebutuhan HCl 5 % = 148660,284 kg/hari x 2,2046

= 327736,4621 lbm/hari

$\rho_{HCl\ 5\%}$ = 1,01185 gr/cm^3 x 62,43

= 63,1698 lbm/cuft

Rate volume = $\dfrac{327736{,}4621 lbm/hari}{63{,}1698 lbm/cuft}$

= 5188,1827 cuft/hari

Volume larutan HCl 5% per hari = 5188,1827 cuft

Diambil : tinggi shell (Hs) = 1,5 . Diameter shell(D)

Volume shell = $(\pi/4).D^2.Hs = (\pi/4).D^2.1{,}5.D = 1{,}5.(\pi/4).D^3$

Volume torispherical dished head (cuft) = 0,000049 x D^3 (inch)

(Brownell & Young, pers.5.11,p.88)

Volume tangki penampung = vol.shell + (2.vol.dished head)

Diambil : volume tangki penampung = 1,2.volume larutan total

$$1{,}2.\ 5188{,}1827\ \text{cuft} = \frac{\pi}{4}.1{,}5.D^3.\left(\frac{1ft}{12in}\right)^3 + (2.0{,}000049.D^3)$$

$$6225{,}8192\ \text{cuft} = 6{,}8177.10^{-4}.D^3 + 9{,}8.10^{-5}.D^3$$

$$6225{,}8192\ \text{cuft} = 7{,}7977.10^{-4}.D^3$$

$$D = 199{,}868\ \text{in} = 16{,}6557\ \text{ft} \approx 16{,}7\ \text{ft}$$

$$Hs = 1{,}5.D = 1{,}5.(16{,}7\ \text{ft}) = 25{,}05\ \text{ft}$$

Volume larutan dalam dish = $0{,}000049.D^3$

$= 0{,}000049.(\ 199{,}868\ \text{in})^3$

$= 391{,}2244$ cuft

Volume larutan dalam shell = vol. larutan total – vol. larutan dalam dish

$= (6225{,}8192 - 391{,}2244)$ cuft

$= 5834{,}5948$ cuft

$$\text{Tinggi larutan dalam shell (H)} = \frac{\text{Volume larutan dalam shell}}{\frac{\pi}{4}.D^2}$$

$$= \frac{5834{,}5948}{\frac{\pi}{4}.(16{,}7\ ft)^2}$$

$$= 26{,}6372\ \text{ft}$$

$$P_{operasi} = P_{hidrostatis} = \left(\frac{\rho.H}{144}\right)\text{psi}$$

$$= \left(\frac{63{,}1698 lbm/cuft.26{,}6372 ft}{144}\right)\text{psi}$$

$$= 11{,}6852\ \text{psi}$$

$$P_{desain} = 1{,}5.P_{operasi} = 1{,}5.(\ 11{,}6852\ \text{psi}) = 17{,}5278\ \text{psi}$$

Tebal shell

$$t_s = \frac{P.ID}{2(f.E - 0{,}6.P)} + c$$ (Brownell & Young, pers. 13.1)

dimana :

$P = P_{desain} = 17,5278$ psi

ID = 16,7 ft = 199,868 in

Konstruksi :

Bahan konstruksi = High Alloy steel SA-240, grade M type 316

T = 50°C (122°F)

f = stress maksimum yang diijinkan = 18750 psi

(Brownell & Young, p 342-343)

tipe sambungan = *double-welded butt joint*, dengan

E = *welded-joint efficiency* = 0,8

(Brownell & Young, table 13.2)

c = *corrosion allowance* = $\frac{1}{8}$ in

$$t_s = \frac{(17,5278\,psi).(199,868\,in)}{2.(18750.0,8 - 0,6.17,5278)\,psi} + \frac{1}{8}\,in$$

$t_s = 0,2419$ in $\approx \frac{3}{8}$ in

Tebal dished head

$t_s = \frac{3}{8}$ in

$OD = ID + 2.t_s$

$= 199,868$ in + (2. $\frac{3}{8}$) in

= 200,618 in

Dari table 5.7 Brownell & Young diperoleh :

OD standar = 204 in dan $t_s = \frac{7}{8}$

r (crown radius / radius of dish) = 170 in

icr (inside corner radius / knuckle radius) = 12 ¼ in

$$W = \frac{1}{4}\left(3+\sqrt{\frac{r}{icr}}\right)$$ (Brownell & Young, pers. 7.76, p.138)

$$= \frac{1}{4}\left(3+\sqrt{\frac{170}{12\,1/4}}\right)$$

$= 1,6813$

a = ID/2 = 199,868 in / 2 = 99,934 in

AB = ID/2 – icr =(99,934 – 12,25) in = 87,684 in

BC = r – icr = (170 –12,25) in = 157,75 in

b = r - $\sqrt{BC^2 - AB^2}$ = 170 - $\sqrt{157,75^2 - 87,684^2}$ = 38,8643 in

$$t_d = \frac{P.rc.W}{2.f.E - 0,2.P} + c$$ (Brownell & Young, pers. 7.77, p.138)

dimana :

P = P_{desain} = 14,4105 psi

Konstruksi : bahan konstruksi = High Alloy steel SA-240, grade M type 316

f = stress maksimum yang diijinkan = 18750 psi

(Brownell & Young, p.342-343)

tipe sambungan = *double-welded butt joint*, dengan

E = *welded-joint efficiency* = 0,8

(Brownell & Young, table 13.2)

c = *corrosion allowance* = $\frac{1}{8}$ in

$$t_d = \frac{(14,4105\,psi).(170\,in).1,6813}{2.(18750\,psi).(0,8) - 0,2.(14,4105\,psi)} + \frac{1}{8}\,in$$

$= 0,1373 \text{ in} \approx \frac{3}{8}$ in

Dari table 5.7 Brownell & Young diperoleh :

OD standar = 204 in dan t_s = td = $\frac{7}{8}$

Dipilih panjang straight-flange (sf) = 8 in

(Brownell & Young, table 5.8,p.93)

OA = t + b +sf

$= (7/8 + 38{,}8643 + 8)$ in

$= 47{,}7393$ in $= 3{,}9783$ ft ≈ 4 ft

Tinggi tangki keseluruhan = tinggi shell + (2 x tinggi dish)

= 25.05 ft + (2 x 4 ft)

= 33,05 ft

Perhitungan Pengaduk

Dipilih tipe pengaduk : flat six-blade turbine agitator with disk.

Kecepatan agitator antara 20 – 200 rpm (Geankoplis),diambil 200 rpm.

N = 50 rpm = 0,8333 rps.

$\rho_{\text{larutan HCl 5\%}} = 1{,}01185\ g/cm^3 = 1011{,}85\ kg/m^3$

$\mu_{\text{larutan HCl 5\%}} = 0{,}6744\ cp = 0{,}6744.10^{-3}\ kg/m.s$ (Reid c.,Robert)

Dari table 3.4-1, p.144 Geankoplis diperoleh :

Da/Dt = 0,3 W/Da = 1/5 L/Da = ¼ C/Dt = 1/3 J/Dt = 1/12

dimana :

Dt = diameter tangki = 16,7 ft / 3,2808 (m/ft) = 5,0902 m

Da = diameter pengaduk = 0,3 x 16,7 ft = 5,01 ft = 1,5271 m

W = lebar blade = (5,01 ft)/5 = 1,002 ft = 0,3054 m

L = panjang blade = (5,01 ft)/4 = 1,2525 ft = 0,3818 m

C = jarak dari dasar tangki ke pusat pengaduk = (16,7 ft)/3 = 5,5667 ft

= 1,6968 m

$$J = \text{lebar baffle} = \frac{1}{12} \times 5{,}0902\ m = 0{,}4242\ m$$

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

$$= \frac{(1{,}5271)^2.0{,}8333.1011{,}85}{0{,}6744.10^{-3}}$$

= 2915646,786 (turbulen)

Dari fig. 3.4-4, p.145 Geankoplis, dengan memotong kurva 1 dengan N_{Re}, diperoleh Np = 5.

$$Np = \frac{P}{\rho.N^3.Da^5}$$ (Geankoplis, pers. 3.4-2, p.145)

Dimana :

Np = power number

P = power pengaduk

N = kecepatan pengaduk

P $= Np.\rho.N^3.Da^5$

$= 5 . 1011{,}85\ kg/m^3 . (0{,}8333\ rps)^3 . (1{,}5271\ m)^5$

$= 24312{,}391\ W\ /\ 745{,}7\ (hp/W) = 32{,}6034\ hp$

Power input = 110% x 32,6034 hp = 35,8637 hp

Transmission system losses = 20% dari total hp

35,8637 hp + 0,2.total hp = total hp

total hp = 44,8296 hp

Efisiensi motor = 88% (Peter & Timmerhaus, fig.14-38, p.521)

Power yang dibutuhkan = (44,8296 hp)/88% = 50,9427 hp ≈ 51 hp

Perhitungan Coil Pendingin

Dari perhitungan neraca panas didapatkan data sebagai berikut :

- Q = 59256323,08 kkal/hari = 2869487,445 W = 979113,333 btu/h
- Suhu bahan masuk tangki pada 30^0C (86^oF) yaitu HCl 36% dan air
- Suhu HCl 5% keluar 50^0C (122^oF)
- Pendingin berupa air dengan suhu masuk 6^0C ($42{,}8^o$F) dan suhu keluar 35^0C (95^oF)
- Massa air pendingin = 2043321,486 kg/hari = 187696,1062 lb/h

$\rho_{larutan\ HCl\ 5\%} = 1{,}01185\ g/cm^3 = 1011{,}85\ kg/m^3 = 63{,}1698\ lbm/cuft$

$\mu_{larutan\ HCl\ 5\%} = 0{,}6744\ cp = 0{,}6744.10^{-3}\ kg/m.s$

CpHCl 5% = 0,966865 kkal/kg °C x 4,1868

= 4,0481 kJ/kg.K = 4048,1 J/kg.K

$t_f = (T + t)/2 = (86 + 42{,}8)^oF / 2 = 64{,}4^oF$

$\Delta t = (T - t) = (86-42{,}8)^oF = 43{,}2^oF$

Berdasarkan kern tabel 11, p.844, trial ukuran pipa coil = 10 in IPS. sch 40

Do = 10,75 in

Di = 10,02 in

a ' = 78,8 in^2

a " = 2,814 ft^2/ft

Evaluasi Perpindahan Panas

Sisi bejana : fluida panas	Sisi pipa : air, fluida dingin
ρcamp = 63,1698 lb/ft^3 $\mu_{\text{larutan HCl 5\%}}$ = 1,6314 lb/ft.h Da = 5,0101 ft N = 50 rpm = 3000 rph $Nre = \frac{\rho.Da^2.N}{\mu}$ $= \frac{63,1698.(5,0101)^2.3000}{1,6314}$ = 2915835,958 Jc = 2000 (kern fig 20-2, p-718) $ho = Jc.\frac{k}{Divessel}.\left(\frac{Cp.\mu}{k}\right)^{1/3}.\left(\frac{\mu}{\mu w}\right)^{0,14}$ Dimana : Di = 16,7 ft k = 0,45 W/m.K = 0,26 Btu/hr.ft.°F Cp rata-rata = 4,0481 kJ/kg.K = 0,9669 Btu/lbm.°F $ho = 2000.\frac{0,26}{16,7}.\left(\frac{0,9669.1,6314}{0,26}\right)^{1/3}$ = 56,7906 Btu/hr.ft^2.°F	Ap = 78,8 in^2 = 0,5472 ft^2 $Gp = \frac{W}{ap} = \frac{187696,1062}{0,5472}$ =343017,2019 lb/h.ft^2 $Nre = \frac{Dp.Gp}{\mu}$ Dimana : Dp = 10,02 in = 0,835 ft μ = 3,5629 lb/ft.h $Nre = \frac{343017,2019.0,835}{3,5629}$ = 80389,39167 J_H = 250 (Kern, fig.24, p.834) $hi = J_H.\frac{k}{Divessel}.\left(\frac{Cp.\mu}{k}\right)^{1/3}.\left(\frac{\mu}{\mu w}\right)^{0,14}$ dimana : Cp = 4205 J/kg.K = 1,0043 btu/lbm.°F k = 0,5784W/m.K = 0,3342 btu/hr.ft.°F (Geankoplis, App.A.2-11, p.862) $hi = 250.\frac{0,3342}{0,835}.\left(\frac{1,0043.1,6314}{0,3342}\right)^{1/3}$ = 169,9805 btu/fr.ft^2.°F $hio = hi.\frac{di}{do}$ $= 169,9805.\frac{10,02}{10,75}$ = 158,4376btu/fr.ft^2.°F

$$Uc = \frac{hioxho}{hio + ho} = \frac{158,4376x56,7906}{158,4376 + 56,7906} = 41,8057 \text{ btu/hr ft}^2.\text{°F}$$

$$Rd = \frac{Uc - Ud}{Uc x Ud}$$ Diambil Rd = 0,004

$$0{,}004 = \frac{41{,}8057 - Ud}{41{,}8057 x Ud}\ ;\ Ud = 35{,}8164\ Btu/hr.ft^2.{}^\circ F$$

$$Acoil = \frac{Q}{Ud.\Delta T_{LMTD}} = \frac{979113{,}333 btu/h}{(35{,}8164 btu/hr.ft^2.{}^\circ F).43{,}2{}^\circ F} = 632{,}8012\ ft^2$$

$$L = \frac{Acoil}{a"} = \frac{632{,}8012 ft^2}{2{,}814 ft^2/ft} = 224{,}876\ ft$$

dc = diameter coil = 0,65 . di vessel

= 0,65 . (16,7 ft)

= 10,855 ft

$$nc = \frac{L}{\pi.dc}\ \frac{224{,}876 ft}{\pi.10{,}855 ft} = 6{,}5942\ buah \approx 7\ buah$$

sc = Spasi coil, diambil 2 in

hc = ((nc-1).(do+sc)) + do

= ((7-1).(10,75+2)) + 10,75

= 87,25 in = 7,2708 ft

Pengecekan :

Tinggi liquida dibagian silinder (Hs) = 26,6372 ft

hc < Hs (memenuhi)

Spesifikasi :

Tangki

Kapasitas	: 6225,8192 cuft
Diameter	: 16,7 ft
Tinggi tutup atas (dished head)	: 4 ft
Tinggi tutup bawah (dished head)	: 4 ft
Tinggi shell	: 25,05 ft
Tinggi tangki total	: 33,05 ft
Tebal shell	: 7/8 in

Tebal tutup atas (dished head) : 7/8 in

Tebal tutup bawah (dished head) : 7/8 in

Bahan konstruksi : High Alloy stell SA-240, grade M type 316

Jumlah tangki : 1 buah

Pengaduk

Tipe : flat six-blade turbine agitator with disk

Diameter : 5,01 ft = 1,5271 m

Kecepatan pengaduk : 50 rpm

Power motor : 51 hp

Jumlah pengaduk : 1 buah

Coil pendingin

Diameter : 10,855 ft

Spasi coil : 2 in

Tinggi coil : 7,2708 ft

3. TANGKI KAPUR (F-120)

Fungsi : menyiapkan bahan baku larutan kapur 10%

Tipe : silinder tegak dengan tutup atas berbentuk dished head dan tutup bawah berebentuk konis yang dilengkapi dengan pengaduk coil pendingin.

Dasar pemilihan : cocok digunakan untuk menampung bahan yang berbentuk slurry

Kondisi operasi : T = 20^0C

Kadar CaO = 10%

Air kapur 10% yang digunakan adalah = 17982 kg = 39643,1172lbm

s.g CaO = 3,32 (Perry ed.7, Tabel 2-1)

Berat CaO = 10% x 17982 kg = 1798,2 kg x 2,2046 =3964,3117 lbm

Berat H_2O = (17982-1798,2) kg = 16183,8 kg x 2,2046 = 35678,8055 lbm

ρH_2O pada 20^0C = 0,99823 g/cm^3 (= 62,3195 lbm/cuft) (Geankoplis, 1983)

ρ_{CaO} = s.g CaO x ρH_2O = 3,32 x 62,3195 lbm/cuft

206,9007 lbm/cuft

$$\frac{1}{\rho_{campuran}} = \sum \frac{x_i}{\rho_i} = \frac{1798,2}{17982.206,9007} + \frac{16183,8}{17982.62,3195} = 0,0149$$

$\rho_{campuran}$ = 67,0015 lbm/cuft = 1,0732 g/cm^3 = 1073,2 kg/m^3

$$\mu_{campuran} = \frac{\mu}{\varphi_p}$$ (Geankoplis,1985)

$$\varphi_p = \frac{1}{10^{1.82(1-\varepsilon)}}$$

$$\varepsilon = \frac{\dfrac{16183,8kg}{998,23kg/m^3}}{\dfrac{16183,8kg}{998,23kg/m^3} + \dfrac{1798,2kg}{1073,2kg/m^3}}$$

ε = 0,9063

$$\varphi_p = \frac{1}{10^{1.82(1-0,9063)}}$$

φ_p = 0,6753

μ_{air} pada 20^{0}C = 1,005.10^{-3} kg/m.s (Geankoplis, table A.2-4)

$$\mu_{campuran} = \frac{(1.005.10^{-3})kg/m.s}{0,6753}$$

$\mu_{campuran}$ = 1,4882.10^{-3} kg/m.s

$$\text{Volume air kapur 10\% per hari} = \frac{39643,1172lbm}{67,0015lbm/cuft}$$

= 591,6751 cuft

Q = panas yang diserap = 165749,8659 kkal/hari = 80262,9198 W = 273869,4503 btu/h

Suhu bahan masuk tangki pada 30°C (=86°F) dan suhu air kapur keluar 20°C

Pendingin berupa air dengan suhu masuk 6°C dan suhu keluar 20°C dengan massa air pendingin = 11839,0619 kg/hari = 1087,5333 lb/h

$Cp_{air\ kapur\ 10\%}$ = 3,9186 kJ/kg.K

Dengan cara perhitungan yang sama pada tangki HCl (F-110), maka didapat :

Spesifikasi :

Tangki

Kapasitas	: 710,0101 cuft
Diameter	: 8,1 ft
Tinggi tutup atas (dished head)	: 1,8 ft
Tinggi tutup bawah (konis)	: 6,6 ft
Tinggi shell	: 12,15 ft
Tinggi tangki total	: 20,6 ft
Tebal shell	: 5/16 in
Tebal tutup atas (dished head)	: 5/16 in
Tebal tutup bawah (konis)	: 5/16 in
Bahan konstruksi	: Carbon steel SA-283, grade D
Jumlah tangki	: 1 buah

Pengaduk

Tipe	: flat six-blade turbine agitator with disk
Diameter	: 0,7407 m
Kecepatan pengduk	: 50 rpm
Power motor	: 1,75 hp
Jumlah pengaduk	: 1 buah

Coil pendingin

Diameter	: 5,265 ft
Spasi coil	: 2 in
Tinggi coil	: 8,4513 ft

3. BUCKET ELEVATOR (J-141)

Fungsi	: memindahkan tulang dari gudang bahan baku (F-130) ke crusher (C-142)
Tipe	: centrifugal discharge bucket.
Dasar pemilihan	: cocok untuk partikel kering
Kondisi operasi	: T = 30^0C

Jumlah : 1 buah

Perhitungan :

Rate tulang = 13500 kg/hari = 0,5625 ton/jam.

Jarak vertikal = 25 ft

Sudut elevasi = 90^0 (Perry 6th ed., table 7-9)

Dari Perry 6th ed. Table 7-9, diperoleh data-data untuk kapasitas 14 ton/jam sebagai berikut :

- Ukuran bucket : 6 x 4 x 4 $\frac{1}{4}$ (in)
- Spasi bucket : 12 in
- Kecepatan bucket : 225 ft/menit
- Putaran head shaft : 43 rpm
- Shaft diameter : *Head* = 1 $\frac{15}{16}$ in, *Tail* = 1 $\frac{11}{16}$ in
- Diameter of pulleys : *Head* = 20 in, *Tail* = 14 in
- Lebar belt : 7 in

Maka untuk kapasitas 0,5625 ton/jam diperoleh spesifikasi bucket sebagai berikut :

$$\text{Kecepatan bucket} = \frac{0{,}5625 ton/jam}{14 ton/jam} \times 225 \text{ ft/menit} = 9{,}04 \text{ ft/menit}$$

$$\text{Putaran head shaft} = \frac{0{,}5625 ton/jam}{14 ton/jam} \times 43 \text{ rpm} = 1{,}7277 \text{ rpm}$$

$$\text{Power bucket elevator (hp)} = \frac{TPH x L}{500}$$ (Perry 6th ed., table 7-13)

Dimana : TPH = kapasitas dalam ton/jam = 0,5625 ton/jam

L = tinggi elevasi bucket (diambil =25 ft)

(Perry 6th ed., table 7-13)

$$\text{Power bucket elevator (hp)} = \frac{0{,}5625 ton/jam x 25 ft}{500} = 0{,}0281 \text{ hp}$$

Efisiensi motor = 80% (Peters & Timmerhaus, 4th ed., fig.14-38, p.521)

$$\text{Power motor yang dipakai} = \frac{0{,}0281 hp}{0{,}8} = 0{,}0351 \text{ hp, dipilih } 0{,}5 \text{ hp}$$

Spesifikasi :

Kapasitas : 0,5625 ton/jam

Kecepatan bucket : 9,04 ft/menit

Putaran head shaft : 1,7277 rpm

Shaft diameter : *Head* = $1\frac{15}{16}$ in, *Tail* = $1\frac{11}{16}$ in

Diameter of pulleys : *Head* = 20 in, *Tail* = 14 in

Lebar belt : 7 in

Tinggi elevator : 50 ft

Ukuran bucket : 6 x 4 x 4 $\frac{1}{4}$ (in)

Spasi bucket : 12 in

Power motor : 0,5 hp

Bahan konstruksi :

- Driving head and boat : carbon steel
- Roda : carbon steel
- Bucket : cast iron
- Belt : karet

Jumlah : 1 buah

4. CRUSHER (C-142)

Fungsi : menghancurkan tulang dengan ukuran 1 – 8 cm

Tipe : Jaw crusher

Kondisi operasi : T = 30°C

Tulang yang harus dihancurkan = 13500 kg/hari = 0,5625 ton/jam ≈ 1 ton/jam

Dasar pemilihan :

- Kapasitas 1 ton/jam dapat digunakan Dodge jaw crusher

(Perry 6th ed., table 8-7)

Spesifikasi :

- Fungsi : menghancurkan tulang dengan ukuran 1-8 cm
- Tipe : Dodge jaw crusher
- Kecepatan putaran jaw : 275 rpm

- Power : 3 Hp
- Setting : 1 in
- Crusher size : 4 x 6 in
- Jaw motion : ½ in
- Jumlah : 1 buah

5. BUCKET ELEVATOR (J-143)

Fungsi : memindahkan tulang dari crusher (C-132) ke tangki demineralisasi (F-130)

Tipe : centrifugal discharge bucket.

Dasar pemilihan : cocok untuk partikel kering

Kondisi operasi : T = 30°C

Jumlah : 1 buah

Perhitungan :

Rate tulang = 13500 kg/hari = 0,5625 ton/jam.

Jarak vertikal = 25 ft

Sudut elevasi = 90° (Perry 6th ed., table 7-9)

Dari Perry 6th ed. Table 7-9, diperoleh data-data untuk kapasitas 14 ton/jam sebagai berikut :

- Ukuran bucket : 6 x 4 x 4 ¼ (in)
- Spasi bucket : 12 in
- Kecepatan bucket : 225 ft/menit
- Putaran head shaft : 43 rpm
- Shaft diameter : *Head* = 1 15/16 in, *Tail* = 1 11/16 in
- Diameter of pulleys : *Head* = 20 in, *Tail* = 14 in
- Lebar belt : 7 in

Maka untuk kapasitas 0,5625 ton/jam diperoleh spesifikasi bucket sebagai berikut :

$$\text{Kecepatan bucket} = \frac{0{,}5625 \, ton/jam}{14 \, ton/jam} \times 225 \text{ ft/menit} = 9{,}04 \text{ ft/menit}$$

Putaran head shaft = $\frac{0{,}5625 ton/jam}{14 ton/jam}$ x 43 rpm = 1,7277 rpm

Power bucket elevator (hp) = $\frac{TPHxL}{500}$ (Perry 6th ed., table 7-13)

Dimana : TPH = kapasitas dalam ton/jam = 0,5625 ton/jam

L = tinggi elevasi bucket (diambil =25 ft)

(Perry 6th ed., table 7-13)

Power bucket elevator (hp) = $\frac{0{,}5625 ton/jam x 25 ft}{500}$ = 0,0281 hp

Efisiensi motor = 80% (Peters & Timmerhaus, 4th ed., fig.14-38, p.521)

Power motor yang dipakai = $\frac{0{,}0281 hp}{0{,}8}$ = 0,0351 hp, dipilih 0,5 hp

Spesifikasi :

Kapasitas	: 0,5625 ton/jam
Kecepatan bucket	: 9,04 ft/menit
Putaran head shaft	: 1,7277 rpm
Shaft diameter	: *Head* = 1 $^{15}/_{16}$ in, *Tail* = 1 $^{11}/_{16}$ in
Diameter of pulleys	: *Head* = 20 in, *Tail* = 14 in
Lebar belt	: 7 in
Tinggi elevator	: 50 ft
Ukuran bucket	: 6 x 4 x 4 ¼ (in)
Spasi bucket	: 12 in
Power motor	: 0,5 hp
Bahan konstruksi	:

- Driving head and boat : carbon steel
- Roda : carbon steel
- Bucket : cast iron
- Belt : karet

Jumlah : 1 buah

6. TANGKI DEMINERALISASI (F-140)

Fungsi : Merendam tulang dengan HCl 5 % untuk mendapatkan kolagen

Tipe : silinder tegak dengan tutup atas dished head dan tutup bawah berbentuk konis yang dilengkapi dengan pengaduk dan coil pendingin.

Dasar pemilihan : cocok digunakan untuk menampung bahan yang berbentuk slurry

Kondisi operasi : T = 15^{0}C

Berat hancuran tulang = 13500 kg/hari x 2,2046 = 29762,1 lbm/hari

ρ_{tulang} = 1,9 gr/cm^3 x 62,43 = 118,617 lbm/cuft

Rate volume tulang= $\dfrac{29762{,}1 lbm/hari}{118{,}617 lbm/cuft}$ = 250,9092 cuft/hari

berat HCl 5% =127746,67 kg/hari = 281630,3087 lbm/hari

ρHCl 5% = 1,023 gr/cm^3 x 62,43 = 63,8659 lbm/cuft = 1023 kg/m^3

rate volume HCl 5% = $\dfrac{281630{,}3087 lbm/hari}{63{,}8659 lbm/cuft}$ = 4409,7133cuft/hari

Total rate volume = 4409,7133 + 2780,0577 = 7189,771 cuft/hari

$$\frac{1}{\rho_{campuran}} = \sum \frac{x_i}{\rho_i} = \frac{29762{,}1}{311392{,}4087.118{,}617} + \frac{281630{,}3087}{311392{,}4087.63{,}8659} = 0{,}015$$

$\rho_{campuran}$ = 66,6667 lbm/cuft = 1067,9005 kg/m^3

$\mu_{larutan\ HCl\ 5\%}$ = 1,035 cp = 1,035.10^{-3} kg/m.s

Cp $_{tulang}$ = 0,3368 kkal/kg.°C

$$\text{Jumlah impeller} = \frac{sg.H}{Dt} = \frac{\left(66{,}6667/62{,}43\right).27{,}9}{18{,}6}$$

$= 1{,}6 \approx 2$ impeller

Dari perhitungan neraca panas didapatkan data sebagai berikut :

- Q = 241811,2206 kkal/hari = 11709,7084 W = 39955,3294 btu/h
- Suhu tulang masuk tangki pada 30^{0}C (86^{o}F) dan HCl 5% masuk pada suhu 50^{o}C (122^{o}F)
- Suhu kolagen dan impurities keluar 15^{0}C (59^{o}F)

- Pendingin berupa air dengan suhu masuk 6^0C (42,8°F) dan suhu keluar 15^0C (59°F)
- Massa air pendingin = 26867,9134 kg/hari = 2468,08 lb/h

Dengan cara perhitungan yang sama pada tangki HCl ((F-110), maka didapat :

Spesifikasi :

Tangki

Kapasitas	: 8627,7252 cuft
Diameter	: 18,6 ft
Tinggi tutup atas (dished head)	: 4,8 ft
Tinggi tutup bawah (konis)	: 15,7 ft
Tinggi shell	: 27,9 ft
Tinggi tangki total	: 48,4 ft
Tebal shell	: 1 in
Tebal tutup atas (dished head)	: 1 in
Tebal tutup bawah (konis)	: 1 in
Bahan konstruksi	: High Alloy stell SA-240, grade M type 316
Jumlah tangki	: 7 buah

Pengaduk

Tipe	: flat six-blade turbine agitator with disk
Diameter	: 1,7008 m = 5,58 ft
Kecepatan pengaduk	: 50 rpm
Power motor	: 89,0981 Hp
Jumlah pengaduk	: 2 buah

Coil pendingin

Diameter	: 12,09 ft
Spasi coil	: 2 in
Tinggi coil	: 0,635 ft

7. Rotary Vacuum Filter (H-144)

Fungsi : Memisahkan kolagen dari impurities

Tipe : Rotary vacuum drum filter

Dasar pemilihan : cocok digunakan untuk pemisahan dalam kondisi kontinyu

Kondisi operasi : T = 15^{0}C

Rate Bahan masuk = 140822,3652 kg/hari

Fraksi masa bahan masuk rotary vacuum filter :

$$X_{Kolagen} = \frac{4495,5}{140822,3652} = 0,0319 \qquad X_{MgCl2} = \frac{300,7299}{140822,3652} = 0,0021$$

$$X_{Air} = \frac{121531,2956}{140822,3652} = 0,8631 \qquad X_{NaCl} = \frac{513,6644}{140822,3652} = 0,0036$$

$$X_{CaCl2} = \frac{8882,8165}{140822,3652} = 0,0631 \qquad X_{H3PO4} = \frac{5098,3588}{140822,3652} = 0,0362$$

ρkolagen = 59 lb/cuft = 945,1 kg/m^3 (Ward,1977)

ρair = 994,7 kg/m^3

$\rho CaCl_2$ = 1012 kg/m^3

$\rho MgCl_2$ = 1011,5 kg/m^3

ρH_3PO_4 = 1006,5 kg/m^3

ρNaCl = 1012,85 kg/m^3

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0,0319}{945,1} + \frac{0,8631}{994,7} + \frac{0,0631}{1012} + \frac{0,0021}{1011,5} + \frac{0,0036}{1012,85} + \frac{0,0362}{1006,5}$$

$\rho_{campuran}$ = 994,6287kg/m^3

$$\mu_{campuran} = \frac{\mu}{\varphi_p}$$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1.82(1-\varepsilon)}}$$

$$\varepsilon = \frac{\dfrac{121531,2956}{994,7}}{\dfrac{121531,2956}{994,7} + \dfrac{4495,5}{945,1} + \dfrac{8882,8165}{1012} + \dfrac{5098,3588}{1006,5} + \dfrac{300,7299}{1011,5} + \dfrac{513,6644}{1012,85}}$$

ε = 0,8629

$$\varphi_p = \frac{1}{10^{1,82(1-0,8629)}}$$

$= 0,563$

$\mu_{air} = 0,7679.10^{-3}$ kg/m.s

$$\mu_{campuran} = \frac{0,7679.10^{-3}}{0,563}$$

$= 1,3639.10^{-3}$ kg/m.s

padatan = 4495,5 kg/hari

liquida = 136326,8652 kg/hari

$$\text{rate volume padatan} = \frac{4495,5 kg/hari}{945,1 kg/m^3} = 4,7566 m^3/hari$$

$$\text{Vol liquida} = \frac{121531,2956}{994,7} + \frac{8882,8165}{1012} + \frac{5098,3588}{1006,5} + \frac{300,7299}{1011,5} + \frac{513,6644}{1012,85}$$

$= 136,8262$ m^3/hari

rate volume slurry = (136,8262 + 4,7566) m^3/hari = 141,5828 m^3/hari

$$Cx = \text{konsentrasi padatan} = \frac{4,5766}{141,5828} = 0,0323$$

$$\text{Massa slurry} = \frac{wetcake}{drycake} = \frac{5619,375 kg/hari}{4495,5 kg/hari} = 1,25$$

$$Cs = \frac{\rho_{air}.Cx}{1-m.Cx} = \frac{994,7.0,0323}{1-1,25.0,0323} = 33,4806 \frac{kgsolid}{m^3 filtrat}$$

Filter cycle time (tc) = 250 s

Filter rate = 140822,3652 $kg/hari$ = 1,6299 kg/s

$$\frac{V}{tc} = 1,6299.\frac{Cx}{Cs}$$

$$\frac{V}{tc} = 1,6299.\frac{0,0323}{33,4806} = 1,5724.10^{-3} \text{m}^3\text{filtrate/s}$$

fraksi drum yang tercelup dalam slurry : 33%

Δp dianggap = 90 kPa = 90.10^3 Pa

$\alpha = (4,37.10^9).(90.10^3)^{0,3} = 1,3389.10^{11}$ m/kg

mensubstitusikan persamaan 14.2-24 (Geankoplis,1993), dimana B=0 ;

$$\frac{V}{A.tc} = \left(\frac{2.f.(\Delta p)}{tc.\mu.\alpha.Cs} \right)^{1/2}$$

$$\frac{1{,}5724.10^{-3}}{A.} = \left(\frac{2.0{,}33.(90.10^{3})}{250.1{,}3639.10^{-3}.1{,}3389.10^{11}.33{,}4806} \right)^{1/2}$$

A= 7,9763 m^2 = 85,8541 ft^2

L = 2.D

A = π.D.L

A = π.2.D^2

7,9763 = 2. π.D^2

D = 1,1267 m

Power yang dibutuhkan = 0,005 hp /ft^2 area filter

= 0,005 . 85,8541

= 0,4293 hp ≈ 0,5 hp

Spesifikasi :

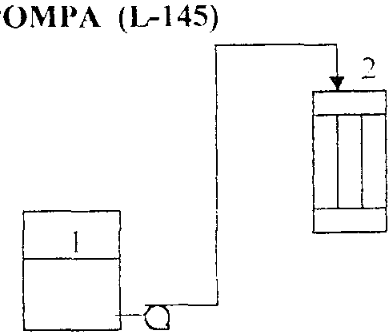
Tipe : Rotary vacuum drum filter

Filter rate : 1,6299 kg/s

Diameter : 1,1276 m = 3,6994 ft

Jumlah : 1 buah

8. POMPA (L-145)



Fungsi : Memompa slurry ke tangki liming

Tipe : centrifugal pump

Dasar pemilihan : dapat menangani sampai tekanan 350 bar (Ulrich table 4-20, p.206)

Jumlah : 1 buah

Rate kolagen masuk = 5619,375 kg/hari

Fraksi masa bahan masuk pompa :

$X_{Kolagen} = \dfrac{4495,5}{5619,375} = 0,8$ $\qquad X_{MgCl2} = \dfrac{2,4725}{5619,375} = 0,0004$

$X_{Air} = \dfrac{1001,9346}{5619,375} = 0,1783$ $\qquad X_{NaCl} = \dfrac{4,2707}{5619,375} = 0,0008$

$X_{CaCl2} = \dfrac{73,1643}{5619,375} = 0,013$ $\qquad X_{H3PO4} = \dfrac{42,0329}{5619,375} = 0,0075$

ρkolagen = 59 lb/cuft = 945,1 kg/m^3 (Ward,1977)

ρair = 994,7 kg/m^3

ρ$CaCl_2$ = 1012 kg/m^3

ρ$MgCl_2$ = 1011,5 kg/m^3

ρH_3PO_4 = 1006,5 kg/m^3

ρNaCl = 1012,85 kg/m^3

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0,8}{945,1} + \frac{0,1783}{994,7} + \frac{0,013}{1012} + \frac{0,0004}{1011,5} + \frac{0,0008}{1012,85} + \frac{0,0075}{1006,5}$$

$\rho_{campuran}$ = 994,6287 kg/m^3 = 62,0947 lbm/ft^3

Rate volumetric kolagen = $\dfrac{5619,375 \text{ kg/hari}}{994,6287 \text{kg/m}^3}$

= 5,6497 m^3/hari = 6,539.10^{-5} m^3/s

q_F = 2,3092.10^{-3} cuft/s

$$\mu_{campuran} = \frac{\mu}{\varphi_p}$$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1.82(1-\varepsilon)}}$$

$$\varepsilon = \frac{\frac{1001,9346}{994,7}}{\frac{1001,9346}{994,7} + \frac{4495,5}{945,1} + \frac{73,1643}{1012} + \frac{42,0329}{1006,5} + \frac{2,4725}{1011,5} + \frac{4,2707}{1012,85}}$$

$\varepsilon = 0,1712$

$$\varphi_p = \frac{1}{10^{1,82(1-0,1712)}}$$

$= 0,031$

$\mu_{air} = 0,7679.10^{-3}$ kg/m.s

$$\mu_{campuran} = \frac{0,7679.10^{-3}}{0,031}$$

$= 0,0248$ kg/m.s $= 0,0167$ lbm/ft.s

Diasumsikan aliran laminer, sehingga :

$Di_{opt} = 3,0.q_F^{0,36}.\mu^{0,18}$ (Peters & Timmerhaus 4[ed], p.496)

$= 3,0.(\ 2,3092.10^{-3}\text{cuft/s})^{0,45}.(\ 0,0167\ \text{lbm/ft.s})^{0,13}$

$= 0,1147$ in

Dipilih steel-pipe (IPS) berukuran 1/8 in sch.80 :

ID $= 0,215$ in $= 0,0179$ ft

OD $= 0,405$ in $= 0,0338$ft

A $= 0,036\ \text{in}^2 = 0,25.10^{-3}\ \text{ft}^2$ (Peters & Timmerhaus 4[ed],tabel 13, p.496)

Kecepatan linear (v) $= (2,3092.10^{-3}$ cuft/s) / $(0,25.10^{-3}\ \text{ft}^2) = 9,2368$ ft/s

$$N_{Re} = \frac{\rho.v.ID}{\mu} = \frac{(62,0947)lbm/ft^3.(9,2368)ft/s.(0,0179)ft}{0,0167 lbm/ft.s} = 614,77$$

(aliran laminer : asumsi benar)

Dengan menggunakan persamaan Bernoulli :

$$\frac{1}{2.\alpha.gc}.(v_2^2 - v_1^2) + \frac{g}{gc}(z_2 - z_1) + \frac{P_2 - P_1}{\rho} + \sum F + Ws = 0$$

(Geankoplis 3[rd] ed., pers. 2.7-28, p.64)

dimana $\sum F$ merupakan total *friksional losses*, meliputi :

1. Losses karena konstraksi pada outlet rotary vacuum filter, h_c.
2. Losses karena friksi pada pipa lurus, Ft.

3. Losses karena friksi pada elbow dan valve, h_f.
4. Losses karena ekspansi pada inlet tangki.

Perhitungan $\sum F$:

1. Losses karena konstraksi pada outlet rotary vacuum filter, h_c.

$K_c = 0{,}55.\left(1 - \frac{A_2}{A_1}\right)$ (Geankoplis 3rd ed., pers.2.10-16, p.93)

Dimana : A_1 = luas penampang tangki

A_2 = luas penampang pipa

Karena $A_1 >> A_2$, maka (A_2/A_1) diabaikan.

$K_c = 0{,}55.(1\text{-}0) = 0{,}55$

Untuk aliran laminer, $\alpha = 0{,}5$

$h_c = K_c.\left(\frac{v^2}{2.\alpha.gc}\right)$ (Geankoplis 3rd rd., pers. 2.10-16, p.93)

$= 0{,}55.\left(\frac{(9{,}2368\,ft/s)^2}{2.0{,}5.32{,}174\,lbm.ft/lbf.s^2}\right)$

= 1,4585 ft.lbf/lbm

2. Losses karena friksi pada pipa lurus, Ft.

Digunakan pipa commercial steel, ε =0,00015 ft (Peters & Timmerhaus 4th ed., fig.14-1,p.482).

Dari Peters & Timmerhaus 4th ed., fig.14-1, p.482 diperoleh f = 0,027

$Ft = 4.f.\frac{\Delta L}{D}\frac{v^2}{2.gc}$ (Geankoplis 3rd ed.,pers.2.10-6,p.89)

$= 4.0{,}027.\frac{10\,ft}{0{,}0179\,ft}.\frac{9{,}2368^2}{2.(32{,}174\,lbm.ft/lbf.s^2)}$

= 79,9979 ft.lbf/lbm

3. Losses karena friksi pada elbow dan valve, h_f.

Terdapat 3 elbow 90°, 1 gate valve, dan 1 globe valve.

Dari Geankoplis table 2.10-1, p.93 :

$K_f = (3.0{,}75) + 0{,}17 + 6 = 8{,}42$

$$h_f = K_f.\frac{v^2}{2.\alpha.gc}$$ (Geankoplis 3[rd] ed.,per.2.10-17,p.94)

$$= 8,42.\frac{(9,2368\,ft/s)^2}{2.0,5.(32,174 lbm.ft/lbf.s^2)}$$

$= 22,328$ ft.lbf/lbm

4. Losses karena ekspansi pada inlet tangki

$$K_{ex} = \left(1-\frac{A_1}{A_2}\right)^2$$ (Geankoplis 3[rd] ed.,per.2.10-15,p.93)

Dimana : A_1 = luas penampang pipa

A_2 = luas penampang tangki

Karena $A_1 << A_2$, maka (A_1/A_2) diabaikan.

$K_{ex} = (1-0)^2 = 1$

$$h_{ex} = K_{ex}.\frac{v^2}{2.\alpha.gc}$$ (Geankoplis 3[rd] ed.,per.2.10-15,p.93)

$$= 1.\frac{9,2368^2}{2.0,5.(32,174 lbm.ft/lbf.s^2)}$$

$= 2,6518$ ft.lbf/lbm

$\sum F = (2,6518 + 22,328 + 79,9979 + 1,4585)$ ft.lbf/lbm

$= 106,4362$ ft.lbf/lbm

$$-Ws = \frac{1}{2.\alpha.gc}.(v_2^2 - v_1^2) + \frac{g}{gc}(z_2 - z_1) + \frac{P_2 - P_1}{\rho} + \sum F$$

$$= \frac{1}{2.0,5.(32,174 lbm.ft/lbf.s^2)}.(9,2368^2 - 0) +$$

$$\frac{32,174\,ft/s^2}{32,174\,ft.lbm/lbf.s^2}(1) + 0 + 106,4362$$

$= 109,088$ ft.lbf/lbm

Efisiensi pompa (η) = 5% (Peters & Timmerhaus 4[th] ed., fig 14.36, p.520)

$$\text{Brake hp} = \frac{-Ws.m}{\eta.550}$$ (Geankoplis 3[rd] ed., pers.3.3-2, p.134)

$$= \frac{(109{,}088\, ft.lbf / lbm).(0{,}1434 lbm/s)}{0{,}05.(550\, ft.lbf/s)}$$

$= 0{,}5688$ hp

Efisiensi motor = 80 % (Peters & Timmerhaus 4[th]ed.,fig.14,38,p.521)

Power motor pompa yang dipakai = 0,5688 / 0,80

= 0,711 hp ≈ 0,75 hp

Spesifikasi :

Tipe : centrifugal pump.

Rate volumetric : $2{,}3092.10^{-3}$ cuft/s

Dipilih steel-pipe (IPS) berukuran 1/8 in sch.80 :

ID = 0,215 in = 0,0179 ft

OD = 0,405 in = 0,0338ft

A = 0,036 in^2 = $0{,}25.10^{-3}$ ft^2

Power motor : 0,75 hp

Jumlah : 7 buah

9. TANGKI LIMING (F-150)

Fungsi : Merendam kolagen dengan air kapur 10%

Tipe : silinder tegak dengan tutup atas berbentuk dished head dan tutup bawah berbentuk konis yang dilengkapi dengan pengaduk dan coil pemanas.

Dasar pemilihan : cocok digumakan untuk menampung bahan yang berbentuk slurry

Kondisi operasi : $T = 20^0C$

Rate kolagen masuk = 5619,375 kg/hari

Rate $Ca(OH)_2$ masuk = 17982 kg/hari

Fraksi masa bahan masuk tangki liming :

$X_{Kolagen} = \frac{4495{,}5}{23601{,}375} = 0{,}1905$ $X_{MgCl2} = \frac{2{,}4725}{23601{,}375} = 0{,}0001$

$X_{Air} = \frac{1001{,}9346}{23601{,}375} = 0{,}0424$ $X_{NaCl} = \frac{4{,}2707}{23601{,}375} = 0{,}0002$

$X_{CaCl2} = \dfrac{73,1643}{23601,375} = 0,0031$ $\qquad X_{H3PO4} = \dfrac{42,0329}{23601,375} = 0,0018$

$X_{Ca(OH)2} = \dfrac{17982}{23601,375} = 0,7619$

ρkolagen = 59 lb/cuft = 945,1 kg/m^3 (Ward,1977)

ρair = 994,7 kg/m^3

ρ$CaCl_2$ = 1012 kg/m^3

ρ$MgCl_2$ = 1011,5 kg/m^3

ρH_3PO_4 = 1006,5 kg/m^3

ρNaCl = 1012,85 kg/m^3

ρ$Ca(OH)_2$ = 998,38 kg/m^3

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}} + \frac{X_{Ca(OH)_2}}{\rho_{Ca(OH)_2}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0,1905}{945,1} + \frac{0,0424}{994,7} + \frac{0,031}{1012} + \frac{0,0001}{1011,5} + \frac{0,0002}{1012,85} + \frac{0,0018}{1006,5} + \frac{0,7619}{998,38}$$

$\rho_{campuran}$ = 961,4966 kg/m^3 = 60,0262 lbm/ft^3

Rate volume kolagen dan $Ca(OH)_2$ = $\dfrac{23601,375 \text{ kg/hari}}{961,4966 \text{kg/m}^3}$

= 24,5464 m^3/hari = 866,8432 cuft/hari

$\mu_{campuran} = \dfrac{\mu}{\varphi_p}$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1,82(1-\varepsilon)}}$$

$$\varepsilon = \frac{\dfrac{1001,9346}{994,7}}{\dfrac{1001,9346}{994,7} + \dfrac{4495,5}{945,1} + \dfrac{73,1643}{1012} + \dfrac{42,0329}{1006,5} + \dfrac{2,4725}{1011,5} + \dfrac{4,2707}{1012,85} + \dfrac{17982}{998,38}}$$

ε = 0,0422

$$\varphi_p = \frac{1}{10^{1,82(1-0,0422)}}$$

$= 0,0181$

$\mu_{air} = 0{,}7679.10^{-3}$ kg/m.s

$$\mu_{campuran} = \frac{0{,}7679.10^{-3}}{0{,}0181}$$

$$= 0{,}04243 \text{ kg/m.s} = 0{,}0285 \text{ lbm/ft.s}$$

Diambil : tinggi shell (Hs) = 1,5 . Diameter shell(D)

Volume shell = $(\pi/4).D^2.Hs = (\pi/4).D^2.1{,}5.D = 1{,}5.(\pi/4).D^3$

Volume torispherical dished head (cuft) = 0,000049 x D^3 (inch)

(Brownell & Young, pers.5.11,p.88)

Volume larutan dalam konis = volume konis

$$= \left(\frac{1}{3}.\frac{\pi}{4}.D^2.Ht\right) - \left(\frac{1}{3}.\frac{\pi}{4}.Dn^2.Hn\right)$$

$$= \left(\frac{1}{3}.\frac{\pi}{4}.D^2.\frac{D}{2.tg\alpha}\right) - \left(\frac{1}{3}.\frac{\pi}{4}.Dn^2.\frac{Dn}{2.tg\alpha}\right)$$

$$= \left(\frac{\pi.D^3}{24.tg\alpha}\right) - \left(\frac{\pi.Dn^3}{24.tg\alpha}\right)$$

$$= \frac{\pi}{24.tg\alpha}\left(D^3 - Dn^3\right)$$

dimana :

Dn = diameter lubang pengeluaran liquida = 0,5 ft (=6 in)

D = diamete konis bagian atas = diameter shell

Ht = tinggi konis

Hn = tinggi konis terpancung

Volume tangki penampung = vol.shell + vol.dished head + vol.konis

Diambil : volume tangki penampung = 1,2.volume larutan total

$$1{,}2.\ 866{,}8432 \text{ cuft} = \frac{\pi}{4}.1{,}5.D^3.\left(\frac{1ft}{12in}\right)^3 + (0{,}000049.D^3)$$

$$1040{,}2118 \text{ cuft} = 6{,}8177.10^{-4}.D^3 + 4{,}9.10^{-5}.D^3 + \frac{\pi}{24.tg\alpha}\left(D^3 - Dn^3\right)$$

$$D = 110{,}0825 \text{ in} = 9{,}1735 \text{ ft} \approx 9{,}2 \text{ ft}$$

$$Hs = 1,5.D = 1,5.(\ 9,2\ ft) = 13,8\ ft$$

Volume larutan dalam konis $= \dfrac{\pi}{24.tg\alpha}\left(D^3 - (0,5\,ft)^3\right)$

$$= \frac{\pi}{24.tg30^o}\left((9,2\,ft)^3 - (0,5\,ft)^3\right)$$

$$= 176,5196\ cuft$$

Volume larutan dalam shell = vol. larutan total – vol. larutan dalam konis

$$= (866,8432 - 176,5196)\ cuft$$

$$= 690,3236\ cuft$$

Tinggi larutan dalam shell (H) $= \dfrac{\text{volume larutan dalam shell}}{\dfrac{\pi}{4}.D^2}$

$$= \frac{690,3236\ cuft}{\dfrac{\pi}{4}.(9,2\,ft)^2}$$

$$= 10,3845\ ft$$

Tinggi larutan dalam konis = tinggi konis (Hc)

$$Hc = \frac{D}{2.tg\alpha} - \frac{Dn}{2.tg\alpha}$$

$$= \frac{9,2\,ft}{2.tg30^o} - \frac{0,5\,ft}{2.tg30^o}$$

$$= 7,5344\ ft$$

Tinggi larutan dalam tangki = H + Hc

$$= (10,3845 + 7,5344)\ ft$$

$$= 17,9189\ ft$$

$$P_{operasi} = P_{hidrostatis} = \left(\frac{\rho.H}{144}\right) psi$$

$$= \left(\frac{60,0262\,lbm/cuft.17,9189\,ft}{144}\right) psi$$

$$= 7,4695\ psi$$

$$P_{desain} = 1,5.P_{operasi} = 1,5.(\ 7,4695\ psi) = 11,2043\ psi$$

Tebal shell

$t_s = \dfrac{P.ID}{2(f.E - 0{,}6.P)} + c$ (Brownell & Young, pers. 13.1)

dimana :

$P = P_{desain} = 11{,}2043$ psi

ID = 9,2 ft = 110,0825 in

Konstruksi : bahan konstruksi = carbon stell SA-283, grade D, dengan

f = stress maksimum yang diijinkan = 12650 psi

tipe sambungan = *double-welded butt joint*, dengan

E = *welded-joint efficiency* = 0,8

(Brownell & Young, table 13.2)

c = *corrosion allowance* = $\dfrac{1}{8}$ in

$t_s = \dfrac{(11{,}2043\,psi).(110{,}0825\,in)}{2.(12650.0{,}8 - 0{,}6.11{,}2043)\,psi} + \dfrac{1}{8}\,in$

$t_s = 0{,}186$ in $\approx \dfrac{3}{8}$ in

Tebal dished head

$t_s = \dfrac{3}{8}\ in$

$OD = ID + 2.t_s$

= 110,0825 in + (2.(3/8)) in

= 110,8325 in

Dari table 5.7 Brownell & Young diperoleh :

OD standar = 114 in dengan t_s = 3/8 in

r (crown radius / radius of dish) = 108 in

icr (inside corner radius / knuckle radius) = $6\frac{7}{8}$ in

$W = \dfrac{1}{4}.\left(3 + \sqrt{\dfrac{r}{icr}}\right)$ (Brownell & Young, pers. 7.76, p.138)

$$= \frac{1}{4}\left(3 + \sqrt{\frac{108}{6\frac{7}{8}}}\right)$$

$= 1{,}7409$

a = ID/2 = 110,0825 in / 2 = 55,0413 in

AB = ID/2 – icr =(55,0413 – 6,875) in = 48,1663 in

BC = r – icr = (108 – 6,875) in = 101,125 in

b = r - $\sqrt{BC^2 - AB^2}$ = 108 - $\sqrt{101{,}125^2 - 48{,}1663^2}$ = 19,0828 in

$$t_d = \frac{P.rc.W}{2.f.E - 0{,}2.P} + c$$ (Brownell & Young, pers. 7.77, p.138)

dimana :

$P = P_{desain}$ = 11,2043 psi

Konstruksi : bahan konstruksi = carbon stell SA-283, grade D, dengan

f = stress maksimum yang diijinkan = 12650 psi

tipe sambungan = *double-welded butt joint*, dengan

E = *welded-joint efficiency* = 0,8

(Brownell & Young, table 13.2)

c = *corrosion allowance* = $\frac{1}{8}$ in

$$t_d = \frac{(11{,}2043\ \text{psi}).(108in).1{,}7409}{2.(12650psi).(0{,}8) - 0{,}2.(11{,}2043\ \text{psi})} + \frac{1}{8}in$$

$= 0{,}2291$ in $\approx \frac{3}{8}$ in

Dipilih panjang straight-flange (sf) = 4,5 in

(Brownell & Young, table 5.8, p.93)

OA = t + b +sf

= (3/8 + 19,0828 + 4,5) in

= 23,9578 in = 1,9965 ft ≈ 2 ft

Tinggi tangki keseluruhan = tinggi shell + tinggi dish + tinggi konis

= 13,8 ft + 2 ft + 7,6 ft

= 23,4 ft

Perhitungan Pengaduk

Dipilih tipe pengaduk : flat six-blade turbine agitator with disk.

Kecepatan agitator antara 20 – 200 rpm (Geankoplis),diambil 50 rpm.

N = 50 rpm = 0,8333 rps.

$\mu_{campuran}$ = 0,04243 kg/m.s = 0,0285 lbm/ft.s

$\rho_{campuran}$ = 961,4966 kg/m^3 = 60,0262 lbm/ft^3

Dari table 3.4, p.144 Geankoplis diperoleh :

Da/Dt = 0,3 W/Da = 1/5 L/Da = ¼ C/Dt = 1/3 J/Dt = 1/12

dimana :

Dt = diameter tangki = 9,2 ft = 2,8042 m

Da = diameter pengaduk = 0,3 x 2,8042 m = 0,8413 m

W = lebar blade = (0,8413 m)/5 = 0,1683 m

L = panjang blade = (0,8413 m)/4 = 0,2103 m

C = jarak dari dasar tangki ke pusat pengaduk = (2,8042 m)/3 = 0,9347 m

J = lebar baffle = $\frac{1}{12}$ x 2,8042 m = 0,2337 m

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

$$= \frac{(0,8413)^2.0,8333.961,4966}{0,04243}$$

$$= 13365,2744 \text{ (turbulen)}$$

Dari fig. 3.4-4, p.155 Geankoplis 2nd ed., dengan memotong kurva 1 dengan N_{Re}, diperoleh Np = 5.

$$Np = \frac{P}{\rho.N^3.Da^5}$$ (Geankoplis, pers. 3.4-2, p.145)

Dimana :

Np = power number

P = power pengaduk

N = kecepatan pengaduk

P = $Np.\rho.N^3.Da^5$

= 5. 961,4966 kg/m^3. (0,8333 rps)^3. (0,8413 m)^5

= 1172,4015 W = 1,1724015 kW = 1,5722 Hp

Power input = 110% x 1,5722 Hp = 1,7294 Hp

Transmission system losses = 20% dari total Hp

1,7294 Hp + 0,2.total Hp = total Hp

total Hp = 2,1618 Hp

Efisiensi motor = 82% (Peter & Timmerhaus, fig.14-38, p.521)

Power yang dibutuhkan = (2,1618 hp)/82% = 2,6363 hp ≈ 3 hp

Perhitungan Coil Pemanas

Dari perhitungan neraca panas didapatkan data sebagai berikut :

- Q = 15441,2065 kkal/hari = 747,7404 W = 2551,4055 btu/h
- Suhu bahan masuk tangki pada 15^{0}C (59^{o}F) yaitu kolagen, impurities dan $Ca(OH)_2$ masuk pada suhu 20^{o}C (68^{o}F)
- Suhu kolagen, impurities, $Ca(OH)_2$ keluar 20^{0}C (68^{o}F)
- Pemanas berupa air dengan suhu masuk 30^{0}C (=86^{o}F) dan suhu keluar 20^{0}C (68^{o}F)
- Massa air = 1544,1207 kg/hari = 141,8426 lb/h

$\mu_{campuran}$ = 0,04243 kg/m.s = 0,0285 lbm/ft.s

$\rho_{campuran}$ = 961,4966 kg/m^3 = 60,0262 lbm/ft^3

$Cp_{air\ kapur\ 10\%}$ = 0,2860 kkal/kg^{o}C Cp_{CaCl2} = 0,2162 kkal/kg^{o}C

$Cp_{kolagen}$ = 0,3369 kkal/kg^{o}C Cp_{MgCl2} = 0,2520 kkal/kg^{o}C

Cp_{H3PO4} = 0,452 kkal/kg^{o}C Cp_{NaCl} = 0,2737 kkal/kg^{o}C

$$X_{Kolagen} = \frac{4495,5}{23601,375} = 0,1905 \qquad X_{MgCl2} = \frac{2,4725}{23601,375} = 0,0001$$

$$X_{Air} = \frac{1001,9346}{23601,375} = 0,0424 \qquad X_{NaCl} = \frac{4,2707}{23601,375} = 0,0002$$

$$X_{CaCl2} = \frac{73,1643}{23601,375} = 0,0031 \qquad X_{H3PO4} = \frac{42,0329}{23601,375} = 0,0018$$

$$X_{air\ kapur\ 10\%} = \frac{17982}{23601,375} = 0,7619$$

$$Cp_{campuran} = \sum x_i . Cp_i$$

$= (0,1905 \times 0,3369) + (0,0424 \times 1) + (0,0031 \times 0,2162) + (0,7619 \times 0,2860) + (0,0001 \times 0,252) + (0,0002 \times 0,2737) + (0,0018 \times 0,452)$

$Cp_{campuran} = 0,326$ kkal/kg.°C = 0,326 kal/g.°C x 4,1868

= 1,3649 kJ/kg.K = 0,326 btu/lb°F

$t_f = (T + t)/2 = (86 + 63,5)$°F / 2 = 74,75°F

$\Delta t = (T - t) = (86 - 63,5)$°F = 22,5°F

Berdasarkan kern tabel 11, p.844, trial ukuran pipa coil = 1/8 in IPS, sch 40

Do = 0,405 in

Di = 0,269 in

a ' = 0,058 in^2

a " = 0,106 ft^2/ft

Evaluasi Perpindahan Panas

Sisi bejana : fluida panas	Sisi pipa : air, fluida dingin
ρcamp = 60,0262 lbm/cuft $\mu_{campuran}$ = 102,6424 lb/ft.h Da = 2,7601 ft N = 50 rpm = 3000 rph $Nre = \frac{\rho.Da^2.N}{\mu}$ $= \frac{60{,}0262.(2{,}7601)^2.3000}{102{,}6424}$ = 13365,4917 Jc = 340 (kern fig 20-2, p-718) $ho = Jc.\frac{k}{Divessel}.\left(\frac{Cp.\mu}{k}\right)^{1/3}.\left(\frac{\mu}{\mu w}\right)^{0.14}$ Dimana : Di = 9,2 ft k = 0,45 W/m.K = 0,26 Btu/hr.ft.°F Cp rata-rata = 0,326 Btu/lbm.°F $ho = 340.\frac{0{,}26}{9{,}2}\left(\frac{0{,}326.102{,}6424}{0{,}26}\right)^{1/3}$ = 48,5126 Btu/hr.ft².°F	Ap = 0,058 in² = 0,0004 ft² $Gp = \frac{W}{ap} = \frac{141{,}8426\ lb/h}{0{,}0004} = 354606{,}5 lb/h.ft^2$ $Nre = \frac{Dp.Gp}{\mu}$ Dimana : Dp = 2,469 in = 0,2058 ft μ = 1,937 lb/ft.h $Nre = \frac{354606{,}5.0{,}2058}{1{,}937}$ = 37675,7433 J_H = 115 (Kern, fig.24, p.834) $hi = J_H.\frac{k}{Di}.\left(\frac{Cp.\mu}{k}\right)^{1/3}.\left(\frac{\mu}{\mu w}\right)^{0.14}$ dimana : Cp = 0,9986 btu/lb.°F k = 0,6158W/m.K = 0,3558 btu/h.ft.°F (Geankoplis, App.A.2-11, p.862) $hi = 115.\frac{0{,}6158}{0{,}2058}\left(\frac{0{,}9986.1{,}937}{0{,}6158}\right)^{1/3}$ = 503,9483 btu/fr.ft².°F $hio = hi.\frac{di}{do}$ $= 503{,}9483.\frac{0{,}269}{0{,}405} = 334{,}7212$ btu/fr.ft².°F

$$Uc = \frac{hioxho}{hio + ho} = \frac{334{,}7212x48{,}5126}{334{,}7212 + 48{,}5126} = 42{,}3715 \text{ Btu/hr ft}^2.\ ^\circ F$$

$$Rd = \frac{Uc - Ud}{UcxUd}$$ Diambil Rd = 0,004

$$0{,}004 = \frac{42{,}3715 - Ud}{42{,}3715 x Ud}\ ; \ \text{Ud} = 36{,}2309\ \text{Btu/hr.ft}^2.°\text{F}$$

$$\text{Acoil} = \frac{Q}{Ud.\Delta T_{LMTD}} = \frac{2551{,}4055\ \text{btu/h}}{(36{,}2309 btu/hr.ft^2.°F).22{,}5°F} = 3{,}1298\ \text{ft}^2$$

$$L = \frac{Acoil}{a''} = \frac{3{,}1298 ft^2}{0{,}106 ft^2/ft} = 29{,}5264\ \text{ft}$$

dc = diameter coil = 0,65 . di vessel

= 0,65 . (9,2 ft)

= 5,98 ft

$$nc = \frac{L}{\pi.dc} = \frac{29{,}5264 ft}{\pi.5{,}98 ft} = 1{,}5717\ \text{buah} \approx 2\ \text{buah}$$

sc = Spasi coil, diambil 2 in

hc = ((nc-1).(do+sc)) + do

= ((2-1).(0,405+2)) + 0,405

= 2,81 in = 0,2342 ft

Pengecekan :

Tinggi liquida dibagian silinder (Hs) = 10,3845 ft

hc < Hs (memenuhi)

Spesifikasi :

Tangki

Kapasitas	: 1040,2118 cuft
Diameter	: 9,2 ft
Tinggi tutup atas (dished head)	: 2 ft
Tinggi tutup bawah (konis)	: 7,6 ft
Tinggi shell	: 13,8 ft
Tinggi tangki total	: 23,4 ft
Tebal shell	: 3/8 in
Tebal tutup atas (dished head)	: 3/8 in
Tebal tutup bawah (konis)	: 3/8 in

Bahan konstruksi	: Carbon steel SA-283, grade D
Jumlah tangki	: 7 buah
Pengaduk	
Tipe	: flat six-blade turbine agitator with disk
Diameter	: 0,8413 m = 2,7601 ft
Kecepatan pengaduk	: 50 rpm
Power motor	: 3 Hp
Jumlah pengaduk	: 1 buah
Coil pemanas	
Diameter	: 5,98 ft
Spasi coil	: 2 in
Tinggi coil	: 0,2342 ft

10. Rotary Vacuum Filter (H-151)

Fungsi : Memisahkan kolagen dari impurities

Tipe : Rotary vacuum drum filter

Dasar pemilihan : cocok digunakan untuk pemisahan dalam kondisi kontinyu

Kondisi operasi : T = 20^{0}C

Rate kolagen masuk = 23601,375 kg/hari

Fraksi masa bahan masuk tangki liming :

$X_{Kolagen} = \dfrac{4495,5}{23601,375} = 0,1905$ $\qquad X_{MgCl2} = \dfrac{2,4725}{23601,375} = 0,0001$

$X_{Air} = \dfrac{1001,9346}{23601,375} = 0,0424$ $\qquad X_{NaCl} = \dfrac{4,2707}{23601,375} = 0,0002$

$X_{CaCl2} = \dfrac{73,1643}{23601,375} = 0,0031$ $\qquad X_{H3PO4} = \dfrac{42,0329}{23601,375} = 0,0018$

$X_{Ca(OH)2} = \dfrac{17982}{23601,375} = 0,7619$

ρkolagen = 59 lb/cuft = 945,1 kg/m^3 (Ward,1977)

ρair = 994,7 kg/m^3

ρ$CaCl_2$ = 1012 kg/m^3

$\rho MgCl_2$ = 1011,5 kg/m^3

ρH_3PO_4 = 1006,5 kg/m^3

$\rho NaCl$ = 1012,85 kg/m^3

$\rho Ca(OH)_2$ = 998,38 kg/m^3

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}} + \frac{X_{Ca(OH)_2}}{\rho_{Ca(OH)_2}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0{,}1905}{945{,}1} + \frac{0{,}0424}{994{,}7} + \frac{0{,}031}{1012} + \frac{0{,}0001}{1011{,}5} + \frac{0{,}0002}{1012{,}85} + \frac{0{,}0018}{1006{,}5} + \frac{0{,}7619}{998{,}38}$$

$\rho_{campuran}$ = 961,4966 kg/m^3 = 60,0262 lbm/ft^3

Rate volume kolagen $= \dfrac{23601{,}375 \text{ kg/hari}}{961{,}4966 \text{kg/m}^3}$

= 24,5464 m^3/hari = 866,8432 cuft/hari

$\mu_{campuran} = \dfrac{\mu}{\varphi_p}$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1{,}82(1-\varepsilon)}}$$

$$\varepsilon = \frac{\dfrac{1001{,}9346}{994{,}7}}{\dfrac{1001{,}9346}{994{,}7} + \dfrac{4495{,}5}{945{,}1} + \dfrac{73{,}1643}{1012} + \dfrac{42{,}0329}{1006{,}5} + \dfrac{2{,}4725}{1011{,}5} + \dfrac{4{,}2707}{1012{,}85} + \dfrac{17982}{998{,}38}}$$

ε = 0,0422

$$\varphi_p = \frac{1}{10^{1{,}82(1-0{,}0422)}}$$

= 0,0181

μ_{air} = 0,7679.10^{-3} kg/m.s

$\mu_{campuran} = \dfrac{0{,}7679.10^{-3}}{0{,}0181}$

= 0,04243 kg/m.s = 0,0285 lbm/ft.s

padatan = 4495,5 kg/hari

liquida = 19105,875 kg/hari

rate volume padatan $= \dfrac{4495{,}5 kg / hari}{945{,}1 kg / m^3} = 4{,}7566 m^3 / hari$

$$\text{Vol liquida} = \frac{1001{,}9346}{994{,}7} + \frac{73{,}1643}{1012} + \frac{42{,}0329}{1006{,}5} + \frac{2{,}4725}{1011{,}5} + \frac{4{,}2707}{1012{,}85} + \frac{17982}{998{,}38}$$

$= 19{,}1392$ m^3/hari

rate volume slurry = (19,1392 + 4,7566) m^3/hari = 23,8958 m^3/hari

Dengan cara perhitungan yang sama pada Rotary vaccum filter (H-144), maka didapat :

Spesifikasi :

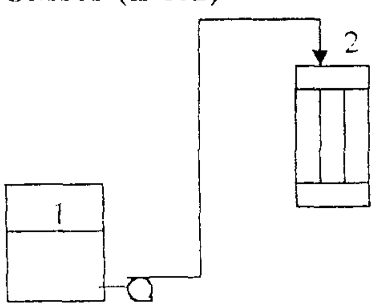
Tipe : Rotary vacuum drum filter

Filter rate : 0,2732 kg/s

Diameter : 1,604 m = 5,2624 ft

Jumlah : 1 buah

11. POMPA (L-152)



Fungsi : Memompa slurry ke tangki netralisasi

Tipe : centrifugal pump

Dasar pemilihan : dapat menangani sampai tekanan 350 bar (Ulrich table 4-20, p.206)

Jumlah : 1 buah

Rate kolagen masuk = 5619,375 kg/hari

Fraksi masa bahan masuk pompa :

$X_{Kolagen} = \dfrac{4495{,}5}{5619{,}375} = 0{,}8$ $X_{MgCl2} = \dfrac{0{,}1124}{5619{,}375} = 0{,}00002$

$X_{Air} = \dfrac{59,0034}{5619,375} = 0,0105$ $X_{NaCl} = \dfrac{0,2248}{5619,375} = 0,00004$

$X_{CaCl2} = \dfrac{4,2707}{5619,375} = 0,00076$ $X_{H3PO4} = \dfrac{2,4725}{5619,375} = 0,00044$

$X_{Ca(OH)2} = \dfrac{1057,7912}{5619,375} = 0,18824$

ρkolagen = 59 lb/cuft = 945,1 kg/m^3 (Ward,1977)

ρair = 994,7 kg/m^3

$\rho CaCl_2$ = 1012 kg/m^3

$\rho MgCl_2$ = 1011,5 kg/m^3

ρH_3PO_4 = 1006,5 kg/m^3

ρNaCl = 1012,85 kg/m^3

$\rho Ca(OH)_2$ = 998,38 kg/m^3

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}} + \frac{X_{Ca(OH)_2}}{\rho_{Ca(OH)_2}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0,8}{945,1} + \frac{0,0105}{994,7} + \frac{0,00076}{1012} + \frac{0,00002}{1011,5} + \frac{0,00004}{1012,85} + \frac{0,00044}{1006,5} + \frac{0,18824}{998,38}$$

$\rho_{campuran}$ = 955,274 kg/m^3 = 62,1328 lbm/ft^3

Rate volume kolagen $= \dfrac{5619,375 \text{ kg/hari}}{955,274 \text{kg/m}^3}$

= 5,8825 m^3/hari = 207,7374 cuft/hari

= 2,4044.10^{-3} cuft/s

$\mu_{campuran} = \dfrac{\mu}{\varphi_p}$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1,82(1-\varepsilon)}}$$

$$\varepsilon = \frac{\dfrac{59,0034}{994,7}}{\dfrac{59,0034}{994,7} + \dfrac{4495,5}{945,1} + \dfrac{4,2707}{1012} + \dfrac{2,4725}{1006,5} + \dfrac{0,1124}{1011,5} + \dfrac{0,2248}{1012,85} + \dfrac{1057,7912}{998,38}}$$

$\varepsilon = 0{,}01$

$$\varphi_p = \frac{1}{10^{1,82(1-0,01)}}$$

$= 0{,}0158$

$\mu_{air} = 0{,}7679.10^{-3}$ kg/m.s

$$\mu_{campuran} = \frac{0{,}7679.10^{-3}}{0{,}0158}$$

$= 0{,}0486$ kg/m.s $= 0{,}0327$ lbm/ft.s

Dengan cara yang sama pada perhitungan pompa (L-145), maka didapat :

Spesifikasi :

Tipe : centrifugal pump.

Rate volumetric : $2{,}4044.10^{-3}$ cuft/s

Dipilih steel-pipe (IPS) berukuran 1/8 in sch.80 :

ID $= 0{,}215$ in $= 0{,}0179$ ft

OD $= 0{,}405$ in $= 0{,}0338$ ft

A $= 0{,}036$ in^2 $= 0{,}25.10^{-3}$ ft^2

Power motor : 1,5 hp

Jumlah : 1 buah

12. TANGKI NETRALISASI (F-160)

Fungsi : Menetralkan kolagen setelah masuk dari tangki liming

Tipe : silinder tegak dengan tutup atas berbentuk dished head dan tutup bawah berbentuk konis yang dilengkapi dengan pengaduk dan coil pendingin.

Dasar pemilihan : cocok digunakan untuk menampung bahan yang berbentuk slurry.

Kondisi operasi : T = 18^{0}C

Rate kolagen masuk = 5619,375 kg/hari

Rate HCl 5% masuk = 20822,974 kg/hari

Rate kolagen + HCl 5% masuk = 26442,349 kg/hari

Fraksi massa :

$X_{Kolagen} = \dfrac{4495,5}{5619,375} = 0,170011$ $X_{MgCl2} = \dfrac{0,1124}{26442,349} = 0,000004$

$X_{Air} = \dfrac{59,0034}{5619,375} = 0,002231$ $X_{NaCl} = \dfrac{0,2248}{26442,349} = 0,000008$

$X_{CaCl2} = \dfrac{4,2707}{5619,375} = 0,000162$ $X_{H3PO4} = \dfrac{2,4725}{26442,349} = 0,000094$

$X_{Ca(OH)2} = \dfrac{1057,7912}{26442,349} = 0,040004$ $X_{HCl5\%} = \dfrac{20822,974}{26442,349} = 0,787486$

ρkolagen = 59 lb/cuft = 945,1 kg/m^3 (Ward,1977)

ρair = 994,7 kg/m^3

ρ$CaCl_2$ = 1012 kg/m^3

ρ$MgCl_2$ = 1011,5 kg/m^3

ρH_3PO_4 = 1006,5 kg/m^3

ρNaCl = 1012,85 kg/m^3

ρ$Ca(OH)_2$ = 998,38 kg/m^3

ρHCl 5% = 1023 kg/m^3

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}} + \frac{X_{Ca(OH)_2}}{\rho_{Ca(OH)_2}} + \frac{X_{HCl5\%}}{\rho_{HCl5\%}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0,170011}{945,1} + \frac{0,002231}{994,7} + \frac{0,000162}{1012} + \frac{0,000004}{1011,5} + \frac{0,000008}{1012,85} + \frac{0,000094}{1006,5} + \frac{0,040004}{998,38} + \frac{0,787486}{1023}$$

$\rho_{campuran}$ = 1007,8157 kg/m^3 = 62,9157 lbm/ft^3

Rate volume kolagen $= \dfrac{26442,349 \text{ kg/hari}}{1007,8157 \text{kg/m}^3}$

= 26,2373 m^3/hari = 926,5565 cuft/hari

= 0,0107 cuft/s

$$\mu_{campuran} = \frac{\mu}{\varphi_p}$$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1,82(1-\varepsilon)}}$$

$$\varepsilon = \frac{59,0034}{994,7} / (\frac{59,0034}{994,7} + \frac{4495,5}{945,1} + \frac{4,2707}{1012} + \frac{2,4725}{1006,5} + \frac{0,1124}{1011,5} + \frac{0,2248}{1012,85}$$

$$\frac{1057,7912}{998,38} + \frac{20822,974}{1023})$$

$\varepsilon = 0,0023$

$$\varphi_p = \frac{1}{10^{1,82(1-0,0023)}}$$

$= 0,0153$

$\mu_{air} = 0,7679.10^{-3}$ kg/m.s

$$\mu_{campuran} = \frac{0,7679.10^{-3}}{0,0153}$$

$= 0,0502$ kg/m.s $= 0,0337$ lbm/ft.s

$Cp_{HCl\ 5\%}$	$= 0,966865$ kkal/kg°C	Cp_{CaCl2}	$= 0,2162$ kkal/kg°C
$Cp_{Kolagen}$	$= 0,3369$ kkal/kg°C	Cp_{MgCl2}	$= 0,2520$ kkal/kg°C
Cp_{H3PO4}	$= 0,452$ kkal/kg°C	Cp_{NaCl}	$= 0,2737$ kkal/kg°C
$Cp_{Ca(OH)2}$	$= 0,286$ kkal/kg°C		

Dari perhitungan neraca panas didapatkan data sebagai berikut :

- Q = 2566003,764 kkal/hari = 124258,7323 W = 423989,942 btu/h
- Suhu bahan masuk tangki pada 20°C (68°F) yaitu kolagen, impurities dan HCl 5% masuk pada suhu 50°C (122°F)
- Suhu kolagen, impurities dan HCl keluar 18°C (64,4°F)
- Pendingin berupa air dengan suhu masuk 6°C (42,8°F) dan suhu keluar 18°C (64,4°F)
- Massa air pendingin = 213833,647 kg/hari = 19642,4024 lb/h

Dengan cara yang sama pada perhitungan tangki HCl (F-110), maka didapat :

Spesifikasi :

Tangki

Kapasitas	: 1111,8678 cuft
Diameter	: 9,4 ft
Tinggi tutup atas (dished head)	: 2,1 ft
Tinggi tutup bawah (konis)	: 7,8 ft
Tinggi shell	: 14,1 ft
Tinggi tangki total	: 24 ft
Tebal shell	: 3/8 in
Tebal tutup atas (dished head)	: 3/8 in
Tebal tutup bawah (konis)	: 3/8 in
Bahan konstruksi	: High Alloy stell SA-240, grade M type 316
Jumlah tangki	: 1 buah

Pengaduk

Tipe	: flat six-blade turbine agitator with disk
Diameter	: 0,8596 m = 2,8202 ft
Kecepatan pengaduk	: 50 rpm
Power motor	: 3,1 Hp
Jumlah pengaduk	: 1 buah

Coil pendingin

Diameter	: 6,11 ft
Spasi coil	: 2 in
Tinggi coil	: 10,0833 ft

13. Rotary Vacuum Filter (H-161)

Fungsi : Memisahkan kolagen dari impurities

Tipe : Rotary vacuum drum filter

Dasar pemilihan : cocok digunakan untuk pemisahan dalam kondisi kontinyu

Kondisi operasi : T = 18^{0}C

Rate Bahan masuk = 26442,3522 kg/hari

Fraksi masa bahan masuk rotary vacuum filter :

$X_{Kolagen} = \dfrac{4495,5}{26442,3522} = 0,170011$ $X_{MgCl2} = \dfrac{0,1124}{26442,3522} = 0,000004$

$X_{Air} = \dfrac{20355,2215}{26442,3522} = 0,769796$ $X_{NaCl} = \dfrac{0,2248}{26442,3522} = 0,000009$

$X_{CaCl2} = \dfrac{1588,821}{26442,3522} = 0,060086$ $X_{H3PO4} = \dfrac{2,4725}{26442,3522} = 0,000094$

ρkolagen = 59 lb/cuft = 945,1 kg/m^3 (Ward,1977)

ρair = 994,7 kg/m^3

ρ$CaCl_2$ = 1012 kg/m^3

ρ$MgCl_2$ = 1011,5 kg/m^3

ρH_3PO_4 = 1006,5 kg/m^3

ρNaCl = 1012,85 kg/m^3

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0,170011}{945,1} + \frac{0,769796}{994,7} + \frac{0,060086}{1012} + \frac{0,000004}{1011,5} + \frac{0,000009}{1012,85} + \frac{0,000094}{1006,5}$$

$\rho_{campuran}$ = 986,9094 kg/m^3 = 61,6128 lbm/cuft

$\mu_{campuran} = \dfrac{\mu}{\varphi_p}$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1,82(1-\varepsilon)}}$$

$$\varepsilon = \frac{\dfrac{20355,2215}{994,7}}{\dfrac{20355,2215}{994,7} + \dfrac{4495,5}{945,1} + \dfrac{1588,821}{1012} + \dfrac{2,4725}{1006,5} + \dfrac{0,1124}{1011,5} + \dfrac{0,2248}{1012,85}}$$

$\varepsilon = 0,7638$

$$\varphi_p = \frac{1}{10^{1,82(1-0,7638)}}$$

$= 0,3716$

μ_{air} pada 30°C = 0,8007.10^{-3} kg/m.s

$$\mu_{campuran} = \frac{0{,}8007.10^{-3}}{0{,}3716}$$

$= 2{,}1547.10^{-3}$ kg/m.s = $1{,}4479.10^{-3}$ lbm/ft.s

padatan = 4495,5 kg/hari

liquida = 21946,8522 kg/hari

rate volume slurry = $\frac{26442{,}3522 \text{kg/hari}}{986{,}9094 \text{kg/m}^3}$ = 26,7931 m^3/hari

Dengan cara yang sama pada perhitungan Rotary vaccum filter (H-144), maka didapat :

Spesifikasi :

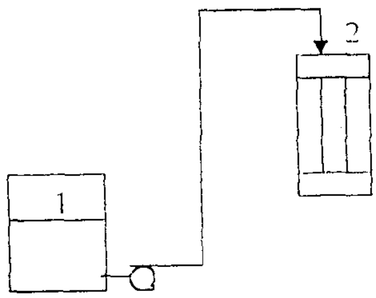
Tipe : Rotary vacuum drum filter

Filter rate : 0,306 kg/s

Diameter : 0,7897 m = 2,5908 ft

Jumlah : 1 buah

14. POMPA (L-162)



Fungsi : Memompa slurry dari tangki netralisasi

Tipe : centrifugal pump

Dasar pemilihan : dapat menangani sampai tekanan 350 bar (Ulrich table 4-20, p.206)

Jumlah : 1 buah

Rate kolagen masuk = 5619,375 kg/hari

Fraksi masa bahan masuk pompa :

$X_{Kolagen} = \dfrac{4495,5}{5619,375} = 0,800000$ $X_{MgCl2} = \dfrac{0,0056}{5619,375} = 0,000001$

$X_{Air} = \dfrac{1042,3694}{5619,375} = 0,185495$ $X_{NaCl} = \dfrac{0,0112}{5619,375} = 0,000002$

$X_{CaCl2} = \dfrac{81,3618}{5619,375} = 0,014479$ $X_{H3PO4} = \dfrac{0,127}{5619,375} = 0,000023$

ρkolagen = 59 lb/cuft = 945,1 kg/m³ (Ward,1977)

ρair = 994,7 kg/m³

$\rho CaCl_2$ = 1012 kg/m³

$\rho MgCl_2$ = 1011,5 kg/m³

ρH_3PO_4 = 1006,5 kg/m³

ρNaCl = 1012,85 kg/m³

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0,8}{945,1} + \frac{0,185495}{994,7} + \frac{0,014479}{1012} + \frac{0,000001}{1011,5} + \frac{0,000002}{1012,85} + \frac{0,000023}{1006,5}$$

$\rho_{campuran}$ = 954,8474 kg/m³ = 59,6111 lbm/ft³

$$\text{Rate volumetric kolagen} = \frac{5619,375 \text{ kg/hari}}{954,8474 \text{kg/m}^3}$$

$= 5,8851$ m³/hari = $6,811.10^{-5}$ m³/s

q_F = $2,4052.10^{-3}$ cuft/s

$$\mu_{campuran} = \frac{\mu}{\varphi_p}$$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1,82(1-\varepsilon)}}$$

$$\varepsilon = \frac{\dfrac{1042,3694}{994,7}}{\dfrac{1042,3694}{994,7} + \dfrac{4495,5}{945,1} + \dfrac{81,3618}{1012} + \dfrac{0,127}{1006,5} + \dfrac{0,0056}{1011,5} + \dfrac{0,0112}{1012,85}}$$

ε = 0,1781

$$\varphi_p = \frac{1}{10^{1,82(1-0,1781)}}$$

$= 0,0319$

$\mu_{air} = 0,8007.10^{-3}$ kg/m.s

$$\mu_{campuran} = \frac{0,8007.10^{-3}}{0,0319}$$

$= 0,0251$ kg/m.s $= 0,0169$ lbm/ft.s

Dengan cara yang sama pada perhitungan pompa (L-145), maka didapat :

Spesifikasi :

Tipe : centrifugal pump.

Rate volumetric : $2,4052.10^{-3}$ cuft/s

Dipilih steel-pipe (IPS) berukuran 1/8 in sch.80 :

ID = 0,215 in = 0,0179 ft

OD = 0,405 in = 0,0338 ft

A = 0,036 in^2 = $0,25.10^{-3}$ ft^2

Power motor : 0,8 hp

Jumlah : 1 buah

15. STORAGE BIN (F-163)

Fungsi : tempat penyimpanan sementara kolagen yang akan di ekstraksi

Tipe : silinder tegak dengan tutup atas berbentuk dished head dan tutup bawah berbentuk konis

Dasar pemilihan : cocok digunakan untuk menampung slurry

Kondisi operasi : T = 30^0C

Rate kolagen masuk = 5619,375 kg/hari

Fraksi masa bahan masuk :

$$X_{Kolagen} = \frac{4495,5}{5619,375} = 0,800000 \qquad X_{MgCl2} = \frac{0,0056}{5619,375} = 0,000001$$

$$X_{Air} = \frac{1042,3694}{5619,375} = 0,185495 \qquad X_{NaCl} = \frac{0,0112}{5619,375} = 0,000002$$

$X_{CaCl2} = \dfrac{81{,}3618}{5619{,}375} = 0{,}014479$ $X_{H3PO4} = \dfrac{0{,}127}{5619{,}375} = 0{,}000023$

ρkolagen = 59 lb/cuft = 945,1 kg/m^3 (Ward,1977)

ρair = 994,7 kg/m^3

$\rho CaCl_2$ = 1012 kg/m^3

$\rho MgCl_2$ = 1011,5 kg/m^3

ρH_3PO_4 = 1006,5 kg/m^3

ρNaCl = 1012,85 kg/m^3

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0{,}8}{945{,}1} + \frac{0{,}185495}{994{,}7} + \frac{0{,}014479}{1012} + \frac{0{,}000001}{1011{,}5} + \frac{0{,}000002}{1012{,}85} + \frac{0{,}000023}{1006{,}5}$$

$\rho_{campuran}$ = 954,8474 kg/m^3 = 59,6111 lbm/ft^3

Rate volumetric kolagen = $\dfrac{5619{,}375 \text{ kg/hari}}{954{,}8474 \text{kg/m}^3}$

= 5,8851 m^3/hari = 6,811.10^{-5} m^3/s

q_F = 2,4052.10^{-3} cuft/s

$\mu_{campuran} = \dfrac{\mu}{\varphi_p}$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1.82(1-\varepsilon)}}$$

$$\varepsilon = \frac{\dfrac{1042{,}3694}{994{,}7}}{\dfrac{1042{,}3694}{994{,}7} + \dfrac{4495{,}5}{945{,}1} + \dfrac{81{,}3618}{1012} + \dfrac{0{,}127}{1006{,}5} + \dfrac{0{,}0056}{1011{,}5} + \dfrac{0{,}0112}{1012{,}85}}$$

ε = 0,1781

$$\varphi_p = \frac{1}{10^{1.82(1-0.1781)}}$$

= 0,0319

μ_{air} pada 30°C = 0,8007.10^{-3} kg/m.s

$$\mu_{campuran} = \frac{0,8007.10^{-3}}{0,0319}$$

$= 0,0251$ kg/m.s $= 0,0169$ lbm/ft.s

$$\text{Volume larutan kolagen} = \frac{5619,375 \text{ kg/hari}}{954,8474 \text{kg/m}^3}$$

$= 5,8851$ m^3/hari $= 207,8205$ cuft/hari

Diambil : tinggi shell (Hs) = 1,5 . Diameter shell(D)

Volume shell = $(\pi/4).D^2.Hs = (\pi/4).D^2.1,5.D = 1,5.(\pi/4).D^3$

Volume torispherical dished head (cuft) = 0,000049 x D^3 (inch)

(Brownell & Young, pers.5.11,p.88)

Volume larutan dalam konis = volume konis

$$= \left(\frac{1}{3}.\frac{\pi}{4}.D^2.Ht\right) - \left(\frac{1}{3}.\frac{\pi}{4}.Dn^2.Hn\right)$$

$$= \left(\frac{1}{3}.\frac{\pi}{4}.D^2.\frac{D}{2.tg\alpha}\right) - \left(\frac{1}{3}.\frac{\pi}{4}.Dn^2.\frac{Dn}{2.tg\alpha}\right)$$

$$= \left(\frac{\pi.D^3}{24.tg\alpha}\right) - \left(\frac{\pi.Dn^3}{24.tg\alpha}\right)$$

$$= \frac{\pi}{24.tg\alpha}\left(D^3 - Dn^3\right)$$

dimana :

Dn = diameter lubang pengeluaran liquida = 0,5 ft (=6 in)

D = diamete konis bagian atas = diameter shell

Ht = tinggi konis

Hn = tinggi konis terpancung

Volume tangki penampung = vol.shell + vol.dished head + vol.konis

Diambil : volume tangki penampung = 1,2.volume larutan total

$$1,2.\ 207,8205 \text{ cuft} = \frac{\pi}{4}.1,5.D^3.\left(\frac{1 ft}{12 in}\right)^3 + (0,000049.D^3)$$

$$+\ \frac{\pi}{24.tg\alpha}\left(D^3\left(\frac{1ft}{12in}\right)^3 - Dn^3\right)$$

$$249{,}3846\ \text{cuft} = \frac{\pi}{4}.1{,}5.D^3.\left(\frac{1ft}{12in}\right)^3 + (0{,}000049.D^3)$$

$$+\ \frac{\pi}{24.tg\alpha}\left(D^3\left(\frac{1ft}{12in}\right)^3 - (0{,}5ft)^3\right)$$

$$249{,}3846\ \text{cuft} = 6{,}8177.10^{-4}.D^3 + 0{,}000049.D^3 + 1{,}3121.10^{-4}.D^3 - 0{,}0283$$

$$249{,}3846\ \text{cuft} = 8{,}6198.10^{-4}.D^3$$

$$D = 66{,}139\ \text{in} = 5{,}5226\ \text{ft} \approx 5{,}6\ \text{ft}$$

$$Hs = 1{,}5.D = 1{,}5.(\ 5{,}6\ \text{ft}) = 8{,}4\ \text{ft}$$

Volume larutan dalam konis $= \dfrac{\pi}{24.tg\alpha}\left(D^3 - (0{,}5ft)^3\right)$

$$= \frac{\pi}{24.tg30^o}\left((5{,}6ft)^3 - (0{,}5ft)^3\right)$$

$$= 39{,}7882\ \text{cuft}$$

Volume larutan dalam shell = vol. larutan total – vol. larutan dalam konis

= (249,3846 – 39,7882) cuft

= 209,5964 cuft

Tinggi larutan dalam shell (H) $= \dfrac{\text{volume larutan dalam shell}}{\frac{\pi}{4}.D^2}$

$$= \frac{209{,}5964}{\frac{\pi}{4}.(5{,}6ft)^2}$$

$$= 8{,}5098\ \text{ft} \approx 8{,}6\ \text{ft}$$

Tinggi larutan dalam konis = tinggi konis (Hc)

$$Hc = \frac{D}{2.tg\alpha} - \frac{Dn}{2.tg\alpha}$$

$$= \frac{5{,}6ft}{2.tg30^o} - \frac{0{,}5ft}{2.tg30^o}$$

$= 4,4167 \text{ ft} \approx 4,5 \text{ ft}$

Tinggi larutan dalam tangki = H + Hc

$= (8,6 + 4,5) \text{ ft}$

$= 13,1 \text{ ft}$

$$P \text{ operasi} = P \text{ hidrostatis} = \left(\frac{\rho.H}{144}\right) psi$$

$$P_{operasi} \quad P_{hidrostatis} \quad \left(\frac{\rho.H}{144}\right) \text{psi}$$

$$= \left(\frac{59,6111 lbm/cuft.13,1 ft}{144}\right) \text{psi}$$

$= 5,423$ psi

$P_{desain} = 1,3.P_{operasi} = 1,3.(5,423 \text{ psi}) = 7,0499 \text{ psi}$

Tebal shell

$$t_s = \frac{P.ID}{2(f.E - 0,6.P)} + c$$ (Brownell & Young, pers. 13.1)

dimana :

$P = P_{desain} = 7,0499$ psi

ID = 5,6 ft = 66,139 in

Konstruksi : bahan konstruksi = carbon stell SA-283, grade D, dengan

f = stress maksimum yang diijinkan = 12650 psi

tipe sambungan = *double-welded butt joint*, dengan

E = *welded-joint efficiency* = 0,8

(Brownell & Young, table 13.2)

c = *corrosion allowance* = $\frac{1}{8}$ in

$$t_s = \frac{(7,0499 psi).(66,139 in)}{2.(12650.0,8 - 0,6.7,0499) psi} + \frac{1}{8} in$$

$t_s = 0,148 \text{ in} \approx \frac{1}{4} \text{ in}$

Tebal dished head

t_s = ¼ in

OD = ID + 2.t_s

= 66,139 in + (2.(1/4)) in

= 66,639 in

Dari table 5.7 Brownell & Young diperoleh :

OD standar = 72 in dengan t_s = ¼ in

r (crown radius / radius of dish) = 72 in

icr (inside corner radius / knuckle radius) = 4 ⅜ in

$$W = \frac{1}{4}.\left(3+\sqrt{\frac{r}{icr}}\right)$$ (Brownell & Young, pers. 7.76, p.138)

$$= \frac{1}{4}.\left(3+\sqrt{\frac{72}{4\frac{3}{8}}}\right)$$

= 1,7642

a = ID/2 = 66,139 in / 2 = 33,0695 in

AB = ID/2 – icr =(33,0695 – 4,375) in = 28,6945 in

BC = r – icr = (72 – 4,375) in = 67,625 in

$b = r - \sqrt{BC^2 - AB^2} = 72 - \sqrt{67{,}625^2 - 28{,}6945^2} = 10{,}7647$ in

$$t_d = \frac{P.rc.W}{2.f.E - 0{,}2.P} + c$$ (Brownell & Young, pers. 7.77, p.138)

dimana :

$P = P_{desain}$ = 7,0499 psi

Konstruksi : bahan konstruksi = carbon stell SA-283, grade D, dengan

f = stress maksimum yang diijinkan = 12650 psi

tipe sambungan = *double-welded butt joint*, dengan

E = *welded-joint efficiency* = 0,8

(Brownell & Young, table 13.2)

c = *corrosion allowance* = $\frac{1}{8}$ in

$$t_d = \frac{(7{,}0499\,psi).(72\,in).1{,}7642}{2.(12650\,psi).(0{,}8) - 0{,}2.(7{,}0499\,psi)} + \frac{1}{8}in$$

$= 0{,}1692$ in $\approx$ ¼ in

Dipilih panjang straight-flange (sf) = 2 in

(Brownell & Young, table 5.8, p.93)

OA = t + b + sf

= (3/16 + 10,7647 + 2) in

= 12,9522 in = 1,0794 ft $\approx$ 1,1 ft

Tinggi tangki keseluruhan = tinggi shell + tinggi dish + tinggi konis

= 8,4 ft + 4,5 ft + 1,1 ft

= 14 ft

Tebal konis

$$t_c = \frac{P.ID}{2.\cos\alpha.(f.E - 0{,}6.P)} + c$$ (Brownell & Young, pers.6.154, p.118)

$$= \frac{(7{,}0499\,psi).(66{,}139\,in)}{2.\cos 30^o.(12650.0{,}8 - 0{,}6.7{,}0499)\,psi} + \frac{1}{8}in$$

$= 0{,}1516$ in $\approx$ 3/16 in

Spesifikasi :

Tangki

Kapasitas	: 249,3846 cuft
Diameter	: 5,6 ft
Tinggi tutup atas (dished head)	: 1,1 ft
Tinggi tutup bawah (konical)	: 1,1 ft
Tinggi shell	: 8,4 ft
Tinggi tangki total	: 14 ft
Tebal shell	: ¼ in
Tebal tutup atas (dished head)	: ¼ in
Tebal tutup bawah (konical)	: ¼ in

Bahan konstruksi : Carbon steel SA-283, grade D

Jumlah tangki : 1 buah

16. TANGKI EKSTRAKSI I (F-210)

Fungsi : Mengekstrak gelatin dari larutan kolagen

Tipe : silinder tegak dengan tutup atas berbentuk dished head, tutup bawah berbentuk konis dan dilengkapi dengan pengaduk dan coil pemanas.

Dasar pemilihan : cocok digumakan untuk menampung bahan yang berbentuk slurry

Kondisi operasi : T = 50^{0}C

Perhitungan :

Rate kolagen masuk = 5619,375 kg/hari

Rate air masuk = 9297,2806 kg/hari

Rate HCl 5% masuk = 75,4071 kg/hari

Rate total bahan masuk tangki ekstraksi = (5619,375 + 9297,2806 + 75,4071)

= 15292,0627 kg/hari

Fraksi masa bahan masuk :

$$X_{Kolagen} = \frac{4495,5}{15292,0627} = 0,294 \qquad X_{MgCl2} = \frac{0,0056}{15292,0627} = 3,6620.10^{-7}$$

$$X_{Air} = \frac{10339,65}{15292,0627} = 0,6761 \qquad X_{NaCl} = \frac{0,0112}{15292,0627} = 7,3241.10^{-7}$$

$$X_{CaCl2} = \frac{81,3618}{15292,0627} = 5,3205.10^{-3} \qquad X_{H3PO4} = \frac{0,127}{15292,0627} = 8,305.10^{-6}$$

$$X_{HCl5\%} = \frac{75,4071}{15292,0627} = 4,9311.10^{-3}$$

ρkolagen = 945,1 kg/m^3 (Ward,1977)

ρgelatin = 988,4 kg/m^3

ρair = 994,7 kg/m^3

ρHCl5% = 1007,1 kg/m^3

ρ$CaCl_2$ = 1003,4 kg/m^3

ρ$MgCl_2$ = 1003,95 kg/m^3

ρH_3PO_4 = 999,3 kg/m^3

$\rho NaCl$ = 994,94 kg/m^3

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0,2948}{945,1} + \frac{0,6761}{988,07} + \frac{5,3205.10^{-3}}{1003,4} + \frac{3,662.10^{-7}}{1003,95} + \frac{7,3241.10^{-7}}{994,94}$$

$$+ \frac{8,305.10^{-6}}{999,3} + \frac{4,9311.10^{-3}}{1007,1}$$

$\rho_{campuran}$ = 993,6445 kg/m^3 = 62,0311 lbm/ft^3

$\mu_{campuran} = \dfrac{\mu}{\varphi_p}$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1,82(1-\varepsilon)}}$$

ε=(10339,65/988,07)/((10339,65/988,07) + (4495,5/945,1) + (81,3618/1003,4) + (0,0056/1003,95) + (0,0112/994,94) + (0,127/999,3) + (75,4071/1007,1)

ε = 0,6805

$$\varphi_p = \frac{1}{10^{1,82(1-0,6805)}}$$

$$= 0,2621$$

μ_{air} pada 50°C = 0,5494.10^{-3} kg/m.s

$$\mu_{campuran} = \frac{0,5494.10^{-3}}{0,2621}$$

= 2,09615.10^{-3} kg/m.s = 1,4054.10^{-3} lbm/ft.s

$$\text{Volume larutan kolagen} = \frac{15292,0627 \text{ kg/hari}}{993,6445 \text{kg/m}^3}$$

= 15,3899 m^3/hari = 543,4635 cuft/hari

waktu tinggal = 1 jam maka :

$$\text{Volume larutan kolagen} = \frac{543,4635 cuft/hari}{24 jam/hari} x 1 jam$$

= 22,6443 cuft

Diambil : tinggi shell (Hs) = 1,5 . Diameter shell(D)

Volume shell = $(\pi/4).D^2.Hs = (\pi/4).D^2.1,5.D = 1,5.(\pi/4).D^3$

Volume torispherical dished head (cuft) = 0,000049 x D^3 (inch)

(Brownell & Young, pers.5.11,p.88)

Volume larutan dalam konis = volume konis

$$= \left(\frac{1}{3}.\frac{\pi}{4}.D^2.Ht\right) - \left(\frac{1}{3}.\frac{\pi}{4}.Dn^2.Hn\right)$$

$$= \left(\frac{1}{3}.\frac{\pi}{4}.D^2.\frac{D}{2.tg\alpha}\right) - \left(\frac{1}{3}.\frac{\pi}{4}.Dn^2.\frac{Dn}{2.tg\alpha}\right)$$

$$= \left(\frac{\pi.D^3}{24.tg\alpha}\right) - \left(\frac{\pi.Dn^3}{24.tg\alpha}\right)$$

$$= \frac{\pi}{24.tg\alpha}\left(D^3 - Dn^3\right)$$

dimana :

Dn = diameter lubang pengeluaran liquida = 0,5 ft (=6 in)

D = diamete konis bagian atas = diameter shell

Ht = tinggi konis

Hn = tinggi konis terpancung

Volume tangki penampung = vol.shell + vol.dished head + vol.konis

Diambil : volume tangki penampung = 1,2.volume larutan total

$$1,2.\ 22,6443 \text{ cuft} = \frac{\pi}{4}.1,5.D^3\left(\frac{1 ft}{12 in}\right)^3 + (0,000049.D^3) + \frac{\pi}{24.tg\alpha}\left(D^3 - Dn^3\right)$$

$$27,1732 \text{ cuft} = 6,8177.10^{-4}.D^3 + 4,9.10^{-5}.D^3 + \frac{\pi}{24.tg\alpha}\left(D^3 - Dn^3\right)$$

$$D = 32,6632 \text{ in} = 2,7219 \text{ ft} \approx 2,8 \text{ ft}$$

$$Hs = 1,5.D = 1,5.(2,8 \text{ ft}) = 4,2 \text{ ft}$$

$$\text{Volume larutan dalam konis} = \frac{\pi}{24.tg\alpha}\left(D^3 - (0,5 ft)^3\right)$$

$$= \frac{\pi}{24.tg30^o}\left((2,8 ft)^3 - (0,5 ft)^3\right)$$

$$= 4,9487 \text{ cuft}$$

Volume larutan dalam shell = vol. larutan total – vol. larutan dalam konis

$= (27{,}1732 - 4{,}9487)$ cuft

$= 22{,}2245$ cuft

$$\text{Tinggi larutan dalam shell (H)} = \frac{\text{volume larutan dalam shell}}{\frac{\pi}{4}.D^2}$$

$$= \frac{22{,}2245}{\frac{\pi}{4}.(2{,}8\,ft)^2}$$

$= 3{,}6093$ ft

Tinggi larutan dalam konis = tinggi konis (Hc)

$$Hc = \frac{D}{2.tg\alpha} - \frac{Dn}{2.tg\alpha}$$

$$= \frac{2{,}8\,ft}{2.tg30^o} - \frac{0{,}5\,ft}{2.tg30^o}$$

$= 1{,}9919$ ft

Tinggi larutan dalam tangki = H + Hc

$= (3{,}6093 + 1{,}9919)$ ft

$= 5{,}6012$ ft

$$P_{operasi} = P_{hidrostatis} = \left(\frac{\rho.H}{144}\right) \text{psi}$$

$$= \left(\frac{62{,}0311\,lbm/cuft..5{,}6012\,ft}{144}\right) \text{psi}$$

$= 2{,}4128$ psi

$P_{desain} = 1{,}5.P_{operasi} = 1{,}5.(2{,}4128 \text{ psi}) = 3{,}6193$ psi

Tebal shell

$$t_s = \frac{P.ID}{2(f.E - 0{,}6.P)} + c \qquad \text{(Brownell \& Young, pers. 13.1)}$$

dimana :

$P = P_{desain} = 3{,}6193$ psi

ID = 32,6632 in = 2,7219 ft ≈ 2,8 ft

Konstruksi : bahan konstruksi = High Alloy steel SA-240, grade M type 316

f = stress maksimum yang diijinkan = 18750 psi

tipe sambungan = *double-welded butt joint*, dengan

E = *welded-joint efficiency* = 0,8

(Brownell & Young, table 13.2)

c = *corrosion allowance* = $\frac{1}{8}$ in

$$t_s = \frac{(3{,}6193\,psi).(32{,}6632\,in)}{2.(18750.0{,}8 - 0{,}6.3{,}6193)\,psi} + \frac{1}{8}\,in$$

t_s = 0,1289 ≈ 3/16 in

Tebal dished head

t_s = 3/16 in

OD = ID + 2.t_s

= 32,6632 in + (2.(3/16)) in

= 33,0382 in

Dari table 5.7 Brownell & Young diperoleh :

OD standar = 34 in dengan t_s = 3/16 in

r (crown radius / radius of dish) = 34 in

icr (inside corner radius / knuckle radius) = 2 ⅛ in

$$W = \frac{1}{4}.\left(3 + \sqrt{\frac{r}{icr}}\right)$$ (Brownell & Young, pers. 7.76, p.138)

$$= \frac{1}{4}.\left(3 + \sqrt{\frac{34}{2\frac{1}{8}}}\right) = 1{,}75$$

a = ID/2 = 32,6632 in / 2 = 16,3316 in

AB = ID/2 – icr =(16,3316 – 2,125) in = 14,2066 in

BC = r – icr = (34 – 2,125) in = 31,875 in

$b = r - \sqrt{BC^2 - AB^2} = 34 - \sqrt{31{,}875^2 - 14{,}2066^2} = 5{,}466$ in

$t_d = \dfrac{P.rc.W}{2.f.E - 0,2.P} + c$ (Brownell & Young, pers. 7.77, p.138)

dimana :

$P = P_{desain} = 3,6193$ psi

Konstruksi : bahan konstruksi = High Alloy steel SA-240, grade M type 316

f = stress maksimum yang diijinkan = 18750 psi

tipe sambungan = *double-welded butt joint*, dengan

E = *welded-joint efficiency* = 0,8

(Brownell & Young, table 13.2)

c = *corrosion allowance* = $\dfrac{1}{8}$ in

$$t_d = \frac{(3,6193\ \text{psi}).(34\,in).1,75}{2.(18750\,psi).(0,8) - 0,2.(3,6193\,psi)} + \frac{1}{8}in$$

$= 0,1322$ in $\approx 3/16$ in

Dipilih panjang straight-flange (sf) = 2 in

(Brownell & Young, table 5.8, p.93)

OA = t + b + sf

= (3/16 + 5,466 + 2) in

= 7,6535 in = 0,6378 ft ≈ 0,7 ft

Tinggi tangki keseluruhan = tinggi shell + tinggi dish + tinggi konis

= 4,2 ft + 0,7 ft + 2 ft

= 6,9 ft

Perhitungan Pengaduk

Dipilih tipe pengaduk : flat six-blade turbine agitator with disk.

Kecepatan agitator antara 20 – 200 rpm (Geankoplis),diambil 50 rpm.

N = 50 rpm = 0,8333 rps.

$\rho_{campuran} = 993,6445\ kg/m^3 = 62,0311\ lbm/ft^3$

$\mu_{campuran} = 2,09615.10^{-3}\ kg/m.s = 1,4054.10^{-3}\ lbm/ft.s$

Dari table 3.4, p.144 Geankoplis diperoleh :

Da/Dt = 0,3 W/Da = 1/5 L/Da = ¼ C/Dt = 1/3 J/Dt = 1/12 dimana :

Dt = diameter tangki = 2,8 ft = 0,8535 m

Da = diameter pengaduk = 0,3 x 0,8535 m = 0,2561 m

W = lebar blade = (0,2561 m)/5 = 0,0512 m

L = panjang blade = (0,2561 m)/4 = 0,064 m

C = jarak dari dasar tangki ke pusat pengaduk = (0,8535 m)/3 = 0,2845 m

J = lebar baffle = $\frac{1}{12}$ x 0,8535 m = 0,0711 m

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

$$= \frac{(0,2561)^2.0,8333.993,6445}{2,09615.10^{-3}}$$

$$= 25907,7212 \text{ (turbulen)}$$

Dari fig. 3.4-4, p.145 Geankoplis, dengan memotong kurva 1 dengan N_{Re}, diperoleh Np = 5.

$$Np = \frac{P}{\rho.N^3.Da^5}$$ (Geankoplis, pers. 3.4-2, p.145)

Dimana :

Np = power number

P = power pengaduk

N = kecepatan pengaduk

P = $Np.\rho.N^3.Da^5$

= 5. 993,6445kg/m^3. (0,8333 rps)^3. (0,2561 m)^5

= 3,167 W = 0,0042 hp

Power input = 110% x 0,0042 hp = 0,0047 hp

Transmission system losses = 20% dari total hp

0,0047 Hp + 0,2.total hp = total hp

total hp = 0,0058 hp

Efisiensi motor = 80% (Peter & Timmerhaus, fig.14-38, p.521)

Power yang dibutuhkan = (0,0058hp)/80% = 0,0073 hp ≈ 0,25 hp

Perhitungan Coil Pemanas

Dari perhitungan neraca panas didapatkan data sebagai berikut :

- Q = 250882,4896 kkal/hari = 12148,9846 W = 41454,2075 btu/h
- Suhu bahan masuk tangki pada 30^{0}C (=86^{o}F) yaitu kolagen, impurities dan HCl 5% masuk pada suhu 50^{o}C (=122^{o}F)
- Suhu kolagen, impurities, gelatin dan HCl keluar 50^{0}C (=122^{o}F)
- Pemanas berupa steam dengan suhu masuk 120^{0}C(=248^{o}F) dan suhu keluar 120^{0}C
- Massa steam = 476,5811 kg/hari = 5,516.10^{-3} kg/s

$\rho_{campuran}$ = 993,6445 kg/m^3 = 62,0311 lbm/ft^3

$\mu_{campuran}$ = 2,09615.10^{-3} kg/m.s = 5,0708 lbm/ft.h

$Cp_{HCl\ 5\%}$ = 0,966865 kkal/kg°C Cp_{CaCl2} = 0,2162 kkal/kg^{0}C

$Cp_{kolagen}$ = 0,3369 kkal/kg^{0}C Cp_{MgCl2} = 0,2520 kkal/kg^{0}C

Cp_{H3PO4} = 0,452 kkal/kg^{o}C Cp_{NaCl} = 0,2737 kkal/kg^{0}C

$X_{Kolagen}$ = 0,294 X_{MgCl2} = 3,6620.10^{-7}

X_{Air} = 0,6761 X_{NaCl} = 7,3241.10^{-7}

X_{CaCl2} = 5,3205.10^{-3} X_{H3PO4} = 8,305.10^{-6}

$X_{HCl5\%}$ = 4,9311.10^{-3}

$Cp_{campuran}$ = $\sum x_i . Cp_i$

= (0,294 x 0,3369) + (0,6761 x 1) + (5,3205.10^{-3} x 0,2162) + (4,9311.10^{-3} x 0,966865) + (3,6620.10^{-7} x 0,252) + (7,3241.10^{-7} x 0,2737) + (8,305.10^{-6} x 0,452)

$Cp_{campuran}$ = 0,7811 kkal/kg.°C = 0,7811 kal/g.°C x 4,1868

= 3,2703 kJ/kg.K

$$\Delta T_{LMTD} = \frac{(T1-t2)-(T2-t1)}{\ln\frac{(T1-t2)}{(T2-t1)}} = \frac{(248-122)-(248-104)}{\ln\frac{(248-122)}{(248-104)}} = 134,7998^oF$$

Tc = ½ . (T1+T2) = ½ . (248+248) = 248^{o}F

tc = ½ .(t1+t2) = ½. (122+104) = 113°F

Berdasarkan kern tabel 11, p.844, trial ukuran pipa coil = 1/8 in IPS, sch 40

Do = 0,405 in

Di = 0,269 in

a ' = 0,058 in

a " = 0,106 ft²/ft

Evaluasi Perpindahan Panas

<table>
<tr><th>Sisi bejana : fluida dingin</th><th>Sisi pipa : Steam, fluida panas</th></tr>
<tr><td>

$\rho_{campuran}$ = 62,0311 lbm/ft³

Da = 0,8402 ft

N = 50 rpm = 3000 rph

μcamp = 5,0708 lbm/ft.h

$Nre = \frac{\rho.Da^2.N}{\mu}$

$= \frac{62{,}0311.(0{,}8402)^2.3000}{5{,}0708\ lbm/ft.h}$

= 25907,1482

Jc = 520 (kern fig 20-2, p-718)

$ho = Jc.\frac{k}{Divessel}.\left(\frac{Cp.\mu}{k}\right)^{1/3}.\left(\frac{\mu}{\mu w}\right)^{0,14}$

Dimana :

Di = 2,8 ft

k = 0,45 W/m.K = 0,26 Btu/hr.ft.°F

Cp rata-rata = 3,2703 kJ/kg.K

= 0,7811 Btu/lbm.°F

$ho = 520.\frac{0{,}26}{2{,}8}.\left(\frac{0{,}7811.5{,}0708}{0{,}26}\right)^{1/3}$

= 119,6985 Btu/hr.ft².°F

</td><td>hio = 1500 Btu/hr.ft.°F (untuk steam)</td></tr>
</table>

$$Uc = \frac{hioxho}{hio + ho} = \frac{1500x119{,}6985}{1500 + 119{,}6985} = 110{,}8526\ Btu/hr\ ft^2.\ °F$$

$$Rd = \frac{Uc - Ud}{UcxUd}$$ Diambil Rd = 0,004

$$0{,}004 = \frac{110{,}8526 - Ud}{110{,}8526 x Ud} \text{ ; } Ud = 76{,}7991 \text{ Btu/hr.ft}^2.{}^\circ F$$

$$Acoil = \frac{Q}{Ud.\Delta T_{LMTD}} = \frac{41454{,}2075 \text{ btu/h}}{76{,}7991.134{,}7998} = 4{,}0043 \text{ ft}^2$$

$$L = \frac{Acoil}{a''} = \frac{4{,}0043 ft^2}{0{,}106 ft^2 / ft} = 37{,}7764 \text{ ft}$$

Dc = diameter coil = 0,65 . di vessel

= 0,65 . (2,8)

= 1,82 ft

$$nc = \frac{L}{\pi.dc} = \frac{37{,}7764}{\pi.1{,}82} = 6{,}6069 \text{ buah} \approx 7 \text{ buah}$$

sc = Spasi coil, diambil 2 in

hc = ((nc-1).(do+sc)) + do

= ((7-1).(0,405+2)) + 0,405

= 14,835 in = 1,2363 ft

Pengecekan :

Tinggi liquida dibagian silinder (Hs) = 3,6093 ft

hc < Hs (memenuhi)

Spesifikasi :

Tangki

Kapasitas	: 27,1732 cuft
Diameter	: 2,8 ft
Tinggi tutup atas (dished head)	: 0,7 ft
Tinggi tutup bawah (konical)	: 2 ft
Tinggi shell	: 4,2 ft
Tinggi tangki total	: 6,9 ft
Tebal shell	: 3/16 in
Tebal tutup atas (dished head)	: 3/16 in
Tebal tutup bawah (konical)	: 3/16 in

Bahan konstruksi	: High Alloy stell SA-240, grade M type 316
Jumlah tangki	: 1 buah
Pengaduk	
Tipe	: flat six-blade turbine agitator with disk
Diameter	: 0,8402 ft
Kecepatan pengaduk	: 50 rpm
Power motor	: 0,25 Hp
Jumlah pengaduk	: 1 buah
Coil pemanas	
Diameter	: 1,82 ft
Spasi coil	: 2 in
Tinggi coil	: 1,2363 ft

17. TANGKI EKSTRAKSI II (F-220)

Fungsi : Mengekstrak gelatin dari larutan kolagen

Tipe : silinder tegak dengan tutup atas berbentuk dished head, tutup bawah berbentuk konis dan dilengkapi dengan pengaduk dan jaket pemanas.

Dasar pemilihan : cocok digumakan untuk menampung bahan yang berbentuk liquida

Kondisi operasi : $T = 50^0C$

Perhitungan :

Rate total bahan masuk tangki ekstraksi =15292,0627 kg/hari

Fraksi masa bahan masuk :

$$X_{Kolagen} = \frac{3416,58}{15292,0627} = 0,2234 \qquad X_{MgCl2} = \frac{0,0056}{15292,0627} = 3,6620.10^{-7}$$

$$X_{Air} = \frac{10339,65}{15292,0627} = 0,6761 \qquad X_{NaCl} = \frac{0,0112}{15292,0627} = 7,3241.10^{-7}$$

$$X_{CaCl2} = \frac{81,3618}{15292,0627} = 5,3205.10^{-3} \qquad X_{H3PO4} = \frac{0,127}{15292,0627} = 8,305.10^{-6}$$

$$X_{HCl5\%} = \frac{75,4071}{15292,0627} = 4,9311.10^{-3} \qquad X_{gelatin} = \frac{1078,92}{15292,0627} = 0,0706$$

ρkolagen = 945,1 kg/m³ (Ward,1977)

$\rho gelatin = 988,4 \ kg/m^3$

$\rho air = 994,7 \ kg/m^3$

$\rho HCl5\% = 1007,1 \ kg/m^3$

$\rho CaCl_2 = 1003,4 \ kg/m^3$

$\rho MgCl_2 = 1003,95 \ kg/m^3$

$\rho H_3PO_4 = 999,3 \ kg/m^3$

$\rho NaCl = 994,94 \ kg/m^3$

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0,2234}{945,1} + \frac{0,6761}{988,07} + \frac{5,3205.10^{-3}}{1003,4} + \frac{3,662.10^{-7}}{1003,95} + \frac{7,3241.10^{-7}}{994,94}$$

$$+ \frac{8,305.10^{-6}}{999,3} + \frac{4,9311.10^{-3}}{1007,1} + \frac{0,0706}{988,4}$$

$\rho_{campuran} = 997,728 \ kg/m^3 = 62,286 \ lbm/ft^3$

$$\mu_{campuran} = \frac{\mu}{\varphi_p}$$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1.82(1-\varepsilon)}}$$

ε = (10339,65/988,07) / ((10339,65/988,07) + (3416,58/945,1) + (81,3618/1003,4)+ (0,0056/1003,95) + (0,0112/994,94) + (0,127/999,3) + (75,4071/1007,1) + (1078,92/988,4))

ε = 0,6827

$$\varphi_p = \frac{1}{10^{1.82(1-0.6827)}}$$

$= 0,2646$

μ_{air} pada 50°C = $0,5494.10^{-3}$ kg/m.s

$$\mu_{campuran} = \frac{0,5494.10^{-3}}{0,2646}$$

$= 2,0763.10^{-3}$ kg/m.s = $1,3952.10^{-3}$ lbm/ft.s

$$\text{Volume larutan kolagen} = \frac{14992,0627 \text{ kg/hari}}{997,728 \text{kg/m}^3}$$

= 15,3269 m^3/hari = 541,2614 cuft/hari

waktu tinggal = 1 jam maka :

$$\text{Volume larutan kolagen} = \frac{541,2614 cuft / hari}{24 jam / hari} \times 1 \text{ jam}$$

= 22,5526 cuft

$Cp_{HCl\ 5\%}$ = 0,966865 kkal/kg°C Cp_{CaCl2} = 0,2162 kkal/kg°C

$Cp_{Kolagen}$ = 0,3369 kkal/kg°C Cp_{MgCl2} = 0,2520 kkal/kg°C

Cp_{H3PO4} = 0,452 kkal/kg°C Cp_{NaCl} = 0,2737 kkal/kg°C

Cpgelatin = 0,3613 kkal/kg°C

Dari perhitungan neraca panas didapatkan data sebagai berikut :

- Q = 63422,3877 kkal/hari = 44043,3248 W = 150282,611 btu/h
- Suhu bahan masuk tangki pada 45°C (113°F) yaitu kolagen, gelatin, impurities dan HCl 5%
- Suhu kolagen, impurities, gelatin dan HCl keluar 50°C (122°F)
- Pemanas berupa steam dengan suhu masuk 120°C (248°F) dan suhu keluar 120°C
- Massa steam = 120,4948 kg/hari = 11,0685 btu/h

Dengan cara yang sama pada perhitungan tangki ekstraksi I (F-210),maka didapat:

Spesifikasi :

Tangki

Kapasitas	: 27,0631 cuft
Diameter	: 2,8 ft
Tinggi tutup atas (dished head)	: 0,7 ft
Tinggi tutup bawah (konical)	: 2 ft
Tinggi shell	: 4,2 ft
Tinggi tangki total	: 6,9 ft

Tebal shell	: 3/16 in
Tebal tutup atas (dished head)	: 3/16 in
Tebal tutup bawah (konical)	: 3/16 in
Bahan konstruksi	: High Alloy stell SA-240, grade M type 316
Jumlah tangki	: 1 buah
Pengaduk	
Tipe	: flat six-blade turbine agitator with disk
Diameter	: 0,8402 ft
Kecepatan pengaduk	: 50 rpm
Power motor	: 0,25 Hp
Jumlah pengaduk	: 1 buah
Coil pemanas	
Diameter	: 1,82 ft
Spasi coil	: 2 in
Tinggi coil	: 2,375 ft

18. Rotary Vacuum Filter (H-221)

Fungsi : Memisahkan kolagen dari larutan gelatin

Tipe : Rotary vacuum drum filter

Dasar pemilihan : cocok digunakan untuk pemisahan dalam kondisi kontinyu

Kondisi operasi : T = 50^{0}C

Rate total bahan masuk rotary filter =15292,0627 kg/hari

Fraksi masa bahan masuk :

$$X_{Kolagen} = \frac{3416,58}{15292,0627} = 0,2234 \qquad X_{MgCl2} = \frac{0,0056}{15292,0627} = 3,6620.10^{-7}$$

$$X_{Air} = \frac{10339,65}{15292,0627} = 0,6761 \qquad X_{NaCl} = \frac{0,0112}{15292,0627} = 7,3241.10^{-7}$$

$$X_{CaCl2} = \frac{81,3618}{15292,0627} = 5,3205.10^{-3} \qquad X_{H3PO4} = \frac{0,127}{15292,0627} = 8,305.10^{-6}$$

$$X_{HCl5\%} = \frac{75,4071}{15292,0627} = 4,9311.10^{-3} \qquad X_{gelatin} = \frac{1078,92}{15292,0627} = 0,0706$$

ρkolagen = 945,1 kg/m^3 (Ward,1977)

ρgelatin = 988,4 kg/m^3

ρair = 994,7 kg/m^3

ρHCl5% 1007,1 kg/m^3

ρ$CaCl_2$ = 1003,4 kg/m^3

ρ$MgCl_2$ = 1003,95 kg/m^3

ρH_3PO_4 = 999,3 kg/m^3

ρNaCl = 994,94 kg/m^3

$$\frac{1}{\rho_{campuran}} = \frac{X_{kolagen}}{\rho_{kolagen}} + \frac{X_{Air}}{\rho_{air}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{NaCl}}{\rho_{NaCl}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}}$$

$$\frac{1}{\rho_{campuran}} = \frac{0,2234}{945,1} + \frac{0,6761}{988,07} + \frac{5,3205.10^{-3}}{1003,4} + \frac{3,662.10^{-7}}{1003,95} + \frac{7,3241.10^{-7}}{994,94}$$

$$+ \frac{8,305.10^{-6}}{999,3} + \frac{4,9311.10^{-3}}{1007,1} + \frac{0,0706}{988,4}$$

$\rho_{campuran}$ = 997,728 kg/m^3 = 62,286 lbm/ft^3

$$\mu_{campuran} = \frac{\mu}{\varphi_p}$$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1,82(1-\varepsilon)}}$$

ε = (10339,65/988,07) / ((10339,65/988,07) + (3416,58/945,1) + (81,3618/1003,4)+ (0,0056/1003,95) + (0,0112/994,94) + (0,127/999,3) + (75,4071/1007,1) + (1078,92/988,4))

ε = 0,6827

$$\varphi_p = \frac{1}{10^{1,82(1-0,6827)}}$$

$$= 0,2646$$

μ_{air} pada 50°C = 0,5494.10^{-3} kg/m.s

$$\mu_{campuran} = \frac{0,5494.10^{-3}}{0,2646}$$

$$= 2,0763.10^{-3} \text{ kg/m.s} = 1,3952.10^{-3} \text{ lbm/ft.s}$$

$$\text{Volume larutan slurry} = \frac{15292{,}0627 \text{ kg/hari}}{997{,}728 \text{kg/m}^3}$$

$= 15{,}3269 \text{ m}^3\text{/hari} = 541{,}2614 \text{ cuft/hari}$

Dengan cara yand sama pada perhitungan Rotary vaccum filter (H-144), maka didapat :

Spesifikasi :

Tipe : Rotary vacuum drum filter

Filter rate : 0,177 kg/s

Diameter : 0,5852 m = 1,9199 ft

Jumlah : 1 buah

19. TANGKI EKSTRAKSI III (F-230)

Fungsi : Mengekstrak gelatin dari larutan kolagen.

Tipe : silinder tegak dengan tutup atas berbentuk dished head dan tutup bawah berbentuk konis serta dilengkapi dengan pengaduk dan coil pemanas.

Dasar pemilihan : cocok digumakan untuk menampung bahan yang berbentuk liquida

Kondisi operasi : $T = 50^0C$

Kapasitas = 9249,6098 kg/hari x 2,2046 = 20391,68977 lbm/hari

Perhitungan :

Waktu tinggal = 120 menit = 2 jam

Rate larutan masuk = 849,6436 lbm/jam

Rate larutan masuk = 849,6436 lbm/jam x 2 jam

= 1699,2872 lbm

ρ HCl 5% = 1,0071 gr/cm^3

ρ H2O = 0,98807 gr/cm^3

ρ H_3PO_4 = 0,9993 gr/cm^3

ρ gelatin = 0,9884 gr/cm^3

ρ $CaCl_2$ = 1,0034 gr/cm^3

ρ $MgCl_2$ = 1,00395 gr/cm^3

ρ NaCl = 0,99494 gr/cm^3

(Ward, A.G)

Xkolagen = 0,2992

X_{H2O} = 0,6881

$X_{HCl\ 5\%}$ = 0,00159

X_{CaCl2} = $4{,}978.10^{-4}$

$X_{H3PO4} = 7,784.10^{-7}$ $X_{MgCl2} = 3,243.10^{-8}$

$X_{NaCl} = 6,487.10^{-8}$ Xgelatin = 0,0106

$$\frac{1}{\rho_{campuran}} = \sum \frac{x_i}{\rho_i}$$

$$\frac{1}{\rho_{\cdot campuran}} =$$

$$\frac{0,00159}{1,0071} + \frac{0,6881}{0,98807} + \frac{0,0106}{0,9884} + \frac{4,978.10^{-4}}{1,0034} + \frac{3,243.10^{-8}}{1,00395} + \frac{6,487.10^{-8}}{0,99494}$$

$$+ \frac{7,784.10^{-7}}{0,9993} + \frac{0,2992}{0,9451}$$

$\rho_{campuran} = 0,9749\ gr/cm^3 = 60,863\ lbm/ft^3$

Volume larutan total per hari = $\dfrac{1699,2872}{60,863} = 27,9199\ ft^3$

$Cp_{HCl\ 5\%} = 0,966865$ kkal/kg °C $Cp_{CaCl2} = 0,2162$ kkal/kg °C

$Cp_{Kolagen} = 0,3369$ kkal/kg °C $Cp_{MgCl2} = 0,2520$ kkal/kg °C

$Cp_{gelatin} = 0,3613$ kkal/kg°C $Cp_{NaCl} = 0,2737$ kkal/kg °C

$Cp_{H3PO4} = 0,4520$ kkal/kg °C

Dari perhitungan neraca panas didapatkan data sebagai berikut :

- Q = panas yang disuplai = 130116,2179 kkal/hari = 6301,1496 W = 21500,4934 Btu/hr
- Suhu bahan masuk tangki pada 47,5^{0}C yaitu larutan kolagen, gelatin, HCl 5% yang ditambahkan dan H_2O yang ditambahkan.
- Suhu kolagen dan impurities keluar 50^{0}C
- Pemanas berupa steam dengan suhu masuk 120^{0}C dan suhu keluar 120^{0}C
- Massa steam = 247,1712 kg/hari = 2,86.10^{-3} kg/s = 22,7047 lbm/jam

Dengan cara yang sama pada perhitungan <u>tangki ekstraksi I (F-210)</u>, maka didapat:

Spesifikasi :

Tangki :

Kapasitas	: 27,9199 cuft
Diameter	: 2,9 ft
Tinggi tutup atas (dished head)	: 0,7 ft
Tinggi tutup bawah (konis)	: 2,1 ft
Tinggi shell	: 4,35 ft
Tinggi tangki total	: 7,15 ft
Tebal shell	: 3/16 in
Tebal tutup atas (dished head)	: 3/16 in
Tebal tutup bawah (dished head)	: 3/16 in
Bahan konstruksi	: High alloy stell SA-240 grade M, type316
Jumlah tangki	: 2 buah

Pengaduk

Tipe	: flat six-blade turbine agitator with disk
Diameter	: 0,264 m = 0,866 ft
Kecepatan pengaduk	: 50 rpm
Power motor	: 0,5 Hp
Jumlah pengaduk	: 1 buah

Coil pemanas

Diameter dalam pipa	: 0,269 in
Spasi coil	: 2 in
Tinggi coil	: 0,635 ft
Diameter luar pipa	: 0,405 in

20. TANGKI EKSTRAKSI IV (F-240)

Fungsi : Mengekstrak gelatin dari larutan kolagen.

Tipe : silinder tegak dengan tutup atas berbentuk dished head dan tutup bawah berbentuk konis serta dilengkapi dengan pengaduk dan coil pemanas.

Dasar pemilihan : cocok digumakan untuk menampung bahan yang berbentuk liquida

Kondisi operasi : T = 50^0C

Kapasitas = 9249,6098 kg/hari x 2,2046 = 20391,68977 lbm/hari

Perhitungan :

Waktu tinggal = 120 menit = 2 jam

Rate larutan masuk = 849,6436 lbm/jam x 2 jam

= 1699,2872 lbm

ρ HCl 5% = 1,0071 gr/cm^3

ρ H2O = 0,98807 gr/cm^3

ρ H_3PO_4 = 0,9993 gr/cm^3

ρ gelatin = 0,9884 gr/cm^3

ρ $CaCl_2$ = 1,0034 gr/cm^3

ρ $MgCl_2$ = 1,00395 gr/cm^3

ρ NaCl = 0,99494 gr/cm^3

(Ward, A.G)

Xkolagen = 0,2633

X_{H2O} = 0,6881

X_{H3PO4} = 7,784.10^{-7}

X_{NaCl} = 6,487.10^{-8}

$X_{HCl\ 5\%}$ = 0,00159

X_{CaCl2} = 4,978.10^{-4}

X_{MgCl2} = 3,243.10^{-8}

Xgelatin = 0,0465

$$\frac{1}{\rho_{campuran}} = \sum \frac{x_i}{\rho_i}$$

$$\frac{1}{\rho_{campuran}} =$$

$$\frac{0,00159}{1,0071} + \frac{0,6881}{0,98807} + \frac{0,0465}{0,9884} + \frac{4,978.10^{-4}}{1,0034} + \frac{3,243.10^{-8}}{1,00395} + \frac{6,487.10^{-8}}{0,99494}$$

$$+ \frac{7,784.10^{-7}}{0,9993} + \frac{0,2633}{0,9451}$$

$\rho_{campuran}$ = 0,9764 gr/cm^3 = 60,96 lbm/ft^3

Volume larutan total per hari = $\frac{1699,2872}{60,96}$ = 27,8754 ft^3

$Cp_{HCl\ 5\%}$ = 0,966865 kkal/kg °C

$Cp_{Kolagen}$ = 0,3369 kkal/kg °C

$Cp_{gelatin}$ = 0,3613 kkal/kg°C

Cp_{H3PO4} = 0,4520 kkal/kg °C

Cp_{CaCl2} = 0,2162 kkal/kg °C

Cp_{MgCl2} = 0,2520 kkal/kg °C

Cp_{NaCl} = 0,2737 kkal/kg °C

Dari perhitungan neraca panas didapatkan data sebagai berikut :

- Q = panas yang disuplai = 42105,86345 kkal/hari = 2039,064 W = 6957,6 Btu/hr
- Suhu bahan masuk tangki pada 45^{0}C yaitu larutan kolagen, impuritis dan gelatin
- Suhu kolagen, gelatin dan impurities keluar 50^{0}C
- Pemanas berupa steam dengan suhu masuk 120^{0}C dan suhu keluar 120^{0}C
- Massa steam = 79,9960 kg/hari = 9,3.10^{-4} kg/s = 7,35 lbm/jam

Dengan cara yang sama pada perhitungan tangki ekstraksi I (F-210), maka didapat:

Spesifikasi :

Tangki :

Kapasitas	: 27,8754 cuft
Diameter	: 2,9 ft
Tinggi tutup atas (dished head)	: 0,7 ft
Tinggi tutup bawah (konis)	: 2,1 ft
Tinggi shell	: 4,35 ft
Tinggi tangki total	: 7,15 ft
Tebal shell	: 3/16 in
Tebal tutup atas (dished head)	: 3/16 in
Tebal tutup bawah (dished head)	: 3/16 in
Bahan konstruksi	: High alloy stell SA-240 grade M type 316
Jumlah tangki	: 2 buah

Pengaduk

Tipe	: flat six-blade turbine agitator with disk
Diameter	: 0,264 m = 0,866 ft
Kecepatan pengaduk	: 50 rpm
Power motor	: 0,5 Hp
Jumlah pengaduk	: 1 buah

Coil pemanas

Diameter dalam pipa : 0,269 in

Diameter luar pipa : 0,405 in

Spasi coil : 2 in

Tinggi coil : 0,2342 ft

21. Tangki Ekstraksi V (F-250)

Fungsi : Mengekstrak gelatin dari larutan kolagen.

Tipe : silinder tegak dengan tutup atas berbentuk dished head dan tutup bawah berbentuk konis serta dilengkapi dengan pengaduk dan coil pemanas.

Dasar pemilihan : cocok digumakan untuk menampung bahan yang berbentuk liquida

Kondisi operasi : $T = 50^0C$

Kapasitas = 7449,975 kg/hari x 2,2046 = 16424,215 lbm/hari

Perhitungan :

Waktu tinggal = 240 menit = 4 jam

Rate larutan masuk = 684,3423 lbm/jam x 4 jam

=2737,3692 lbm

ρ HCl 5% = 1,0071 gr/cm^3

ρ $H2O$ = 0,98807 gr/cm^3

ρ H_3PO_4 = 0,9993 gr/cm^3

ρ gelatin = 0,9884 gr/cm^3

ρ $CaCl_2$ = 1,0034 gr/cm^3

ρ $MgCl_2$ = 1,00395 gr/cm^3

ρ NaCl = 0,99494 gr/cm^3

(Ward, A.G)

Xkolagen = 0,30

X_{H2O} = 0,6917

X_{H3PO4} = $7,79.10^{-8}$

X_{NaCl} = $6,711.10^{-9}$

$X_{HCl\ 5\%}$ = $8,05,10^{-4}$

X_{CaCl2} = $4,94.10^{-5}$

X_{MgCl2} = $2,68.10^{-9}$

Xgelatin = $6,7.10^{-3}$

$$\frac{1}{\rho_{campuran}} = \sum \frac{x_i}{\rho_i}$$

$$\frac{1}{\rho_{campuran}} =$$

$$\frac{8{,}05.10^{-4}}{1{,}0071} + \frac{0{,}6917}{0{,}98807} + \frac{6{,}7.10^{-3}}{0{,}9884} + \frac{4{,}94.10^{-5}}{1{,}0034} + \frac{2{,}68.10^{-9}}{1{,}00395} + \frac{6{,}711.10^{-9}}{0{,}99494}$$

$$+ \frac{7{,}79.10^{-8}}{0{,}9993} + \frac{0{,}3}{0{,}9451}$$

$\rho_{campuran} = 0{,}9755\ gr/cm^3 = 60{,}90\ lbm/ft^3$

$$\text{Volume larutan total} = \frac{2737{,}3692}{60{,}90} = 44{,}95\ ft^3$$

$Cp_{HCl\ 5\%} = 0{,}966865$ kkal/kg °C

$Cp_{Kolagen} = 0{,}3369$ kkal/kg °C

$Cp_{gelatin} = 0{,}3613$ kkal/kg°C

$Cp_{H3PO4} = 0{,}4520$ kkal/kg °C

$Cp_{CaCl2} = 0{,}2162$ kkal/kg °C

$Cp_{MgCl2} = 0{,}2520$ kkal/kg °C

$Cp_{NaCl} = 0{,}2737$ kkal/kg °C

Dari perhitungan neraca panas didapatkan data sebagai berikut :

- Q = panas yang disuplai = 104960,4867 kkal/hari = 5082,931 W = 17343,744 Btu/jam
- Suhu bahan masuk tangki pada 47,5^{0}C yaitu larutan kolagen, impuritis, gelatin, HCl 5% yang ditambahkan dan H_2O yang ditambahkan.
- Suhu kolagen, gelatin dan impurities keluar 50^{0}C
- Pemanas berupa steam dengan suhu masuk 120^{0}C dan suhu keluar 120^{0}C
- Massa steam = 199,3849 kg/hari = $2{,}31.10^{-3}$ kg/s = 18,3152 lbm/jam

Dengan cara yang sama pada perhitungan tangki ekstraksi I (F-210), maka didapat:

Spesifikasi :

Tangki :

Kapasitas	: 44,95 cuft
Diameter	: 3,4 ft
Tinggi tutup atas (dished head)	: 0,8 ft
Tinggi tutup bawah (konis)	: 2,6 ft
Tinggi shell	: 5,1 ft

Tinggi tangki total	: 8,5 ft
Tebal shell	: 3/16 in
Tebal tutup atas (dished head)	: 3/16 in
Tebal tutup bawah (dished head)	: 3/16 in
Bahan konstruksi	: High alloy stell SA-240 grade M, type 316
Jumlah tangki	: 4 buah
Pengaduk	
Tipe	: flat six-blade turbine agitator with disk
Diameter	: 0,311 m = 1,02 ft
Kecepatan pengaduk	: 50 rpm
Power motor	: 0,5 Hp
Jumlah pengaduk	: 1 buah
Coil Pemanas	
Diameter dalam pipa	: 0,269 in
Spasi coil	: 2 in
Diameter luar pipa	: 0,405 in
Tinggi coil	: 0,4346 ft

22. Rotary Vacuum Filter V (H-241)

Fungsi : Memisahkan kolagen dari larutan gelatin hasil ekatraksi pada tangki IV

Tipe : Rotary vacuum drum filter

Dasar pemilihan : cocok digunakan untuk pemisahan dalam kondisi kontinyu

Kondisi operasi : $T = 45^0C$

Rate Bahan masuk = 9249,6098 kg/hari

Fraksi masa bahan masuk rotary vacuum filter :

$$X_{Kolagen} = \frac{2240{,}5111}{9249{,}6098} = 0{,}2422 \qquad X_{MgCl2} = \frac{0{,}0003}{9249{,}6098} = 3{,}24.10^{-8}$$

$$X_{Air} = \frac{6365{,}0885}{9249{,}6098} = 0{,}6881 \qquad X_{NaCl} = \frac{0{,}0006}{9249{,}6098} = 6{,}5.10^{-8}$$

$X_{CaCl2} = \dfrac{4{,}0647}{9249{,}6098} = 4{,}39.10^{-4}$ $X_{H3PO4} = \dfrac{0{,}0072}{9249{,}6098} = 7{,}78.10^{-7}$

$X_{gelatin} = \dfrac{624{,}7195}{9249{,}6098} = 0{,}0675$ $X_{HCl\ 5\%} = \dfrac{14{,}6779}{9249{,}6098} = 1{,}59.10^{-3}$

ρkolagen = 59 lb/cuft = 945,1 kg/m^3 (Ward,1977)

ρ HCl 5% = 1,0071 gr/cm^3 ρ $CaCl_2$ = 1,0034 gr/cm^3

ρ H2O = 0,98807 gr/cm^3 ρ $MgCl_2$ = 1,00395 gr/cm^3

ρ H_3PO_4 = 0,9993 gr/cm^3 ρ NaCl = 0,99494 gr/cm^3

ρ gelatin = 0,9884 gr/cm^3 (Ward, A.G)

$$\frac{1}{\rho_{campuran}} = \sum \frac{x_i}{\rho_i}$$

$$\frac{1}{\rho_{campuran}} = \frac{0{,}00159}{1{,}0071} + \frac{0{,}6881}{0{,}98807} + \frac{0{,}0675}{0{,}9884} + \frac{4{,}39.10^{-4}}{1{,}0034} + \frac{3{,}24.10^{-8}}{1{,}00395} + \frac{6{,}5.10^{-8}}{0{,}99494}$$

$$+ \frac{7{,}78.10^{-7}}{0{,}9993} + \frac{0{,}2422}{0{,}9451}$$

$\rho_{campuran}$ = 0,9881 gr/cm^3 = 61,69 lbm/ft^3

$\mu_{campuran} = \dfrac{\mu}{\varphi_p}$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1.82(1-\varepsilon)}}$$

$$\varepsilon = \frac{\dfrac{6365{,}0885}{988{,}07}}{\dfrac{6365{,}0885}{988{,}07} + \dfrac{2240{,}5111}{945{,}1} + \dfrac{624{,}7195}{988{,}4} + \dfrac{4{,}067}{1003{,}4} + \dfrac{0{,}0003}{1003{,}95} + \dfrac{0{,}0006}{994{,}94} + \dfrac{0{,}0072}{999{,}3} + \dfrac{14{,}6779}{1007{,}1}}$$

ε = 0,804

$$\varphi_p = \frac{1}{10^{1.82(1-0.804)}}$$

$= 0{,}4398$

μ_{air} pada 50°C = 0,5494.10^{-3} kg/m.s

$$\mu_{campuran} = \frac{0,5494.10^{-3}}{0,4398}$$

$$= 1,25.10^{-3}\ kg/m.s$$

padatan = 2240,5111 kg/hari

liquida = 7009,0987 kg/hari

$$\text{rate volume padatan} = \frac{2240,5111 kg/hari}{945,1 kg/m^3} = 2,3707 m^3/hari$$

$$\text{Vol liquida} = \frac{6365,0885}{998,07} + \frac{624,7195}{988,4} + \frac{4,067}{1003,4} + \frac{0,0003}{1003,95} + \frac{0,0006}{994,94} + \frac{0,0072}{999,3} + \frac{14,7669}{1007,1}$$

$$= 7,0282\ m^3/hari$$

rate volume slurry = (7,0282 +2,3707) m^3/hari = 9,3989 m^3/hari

Dengan cara yang sama pada perhitungan Rotary vaccum filter (H-144), maka didapat :

Spesifikasi :

Tipe : Rotary vacuum drum filter

Filter rate : 0,1071 kg/s

Diameter : 0,1882 m

Jumlah : 1 buah

23. Rotary Vacuum Filter VI (H-251)

Fungsi : Memisahkan kolagen dari larutan gelatin hasil ekstraksi pada tangki V.

Tipe : Rotary vacuum drum filter

Dasar pemilihan : cocok digunakan untuk pemisahan dalam kondisi kontinyu

Kondisi operasi : T = 45^{0}C

Rate Bahan masuk = 7449,97500 kg/hari

Fraksi masa bahan masuk rotary vacuum filter :

$$X_{Kolagen} = \frac{1926{,}8395}{7449{,}975} = 0{,}2586 \qquad X_{MgCl2} = \frac{0{,}00002}{7449{,}975} = 2{,}68.10^{-9}$$

$$X_{Air} = \frac{5153{,}1755}{7449{,}975} = 0{,}6917 \qquad X_{NaCl} = \frac{0{,}00005}{7449{,}975} = 6{,}71.10^{-9}$$

$$X_{CaCl2} = \frac{0{,}36798}{7449{,}975} = 4{,}94.10^{-5} \qquad X_{H3PO4} = \frac{0{,}00058}{7449{,}975} = 7{,}78.10^{-8}$$

$$X_{gelatin} = \frac{363{,}59567}{7449{,}975} = 0{,}0488 \qquad X_{HCl\,5\%} = \frac{5{,}99570}{7449{,}975} = 8{,}048.10^{-4}$$

ρkolagen = 59 lb/cuft = 945,1 kg/m^3 (Ward,1977)

ρ HCl 5% = 1,0071 gr/cm^3

ρ H2O = 0,98807 gr/cm^3

ρ H_3PO_4 = 0,9993 gr/cm^3

ρ gelatin = 0,9884 gr/cm^3

ρ $CaCl_2$ = 1,0034 gr/cm^3

ρ $MgCl_2$ = 1,00395 gr/cm^3

ρ NaCl = 0,99494 gr/cm^3

(Ward, A.G)

$$\frac{1}{\rho_{campuran}} = \sum \frac{x_i}{\rho_i}$$

$$\frac{1}{\rho_{\cdot campuran}} =$$

$$\frac{8{,}048.10^{-4}}{1{,}0071} + \frac{0{,}6917}{0{,}98807} + \frac{0{,}0488}{0{,}9884} + \frac{4{,}94.10^{-5}}{1{,}0034} + \frac{2{,}68.10^{-9}}{1{,}00395} + \frac{6{,}71.10^{-9}}{0{,}99494}$$

$$+ \frac{7{,}78.10^{-8}}{0{,}9993} + \frac{0{,}2586}{0{,}9451}$$

$\rho_{campuran}$ = 0,9901 gr/cm^3 = 61,81 lbm/ft^3

$$\mu_{campuran} = \frac{\mu}{\varphi_p}$$ (Geankoplis 2 ed., 1985)

$$\varphi_p = \frac{1}{10^{1.82(1-\varepsilon)}}$$

ε=

$$\frac{\dfrac{5153{,}1755}{988{,}07}}{\dfrac{5153{,}1755}{988{,}07} + \dfrac{1926{,}8395}{945{,}1} + \dfrac{363{,}59567}{988{,}4} + \dfrac{0{,}36798}{1003{,}4} + \dfrac{0{,}00002}{1003{,}95} + \dfrac{0{,}00005}{994{,}94} + \dfrac{0{,}00058}{999{,}3} + \dfrac{5{,}9957}{1007{,}1}}$$

ε = 0,756

$$\varphi_p = \frac{1}{10^{1,82(1-0,756)}}$$

$= 0,4441$

μ_{air} pada 50°C = $0,5494.10^{-3}$ kg/m.s

$$\mu_{campuran} = \frac{0,5494.10^{-3}}{0,4441}$$

$= 1,24.10^{-3}$ kg/m.s

padatan = 1926,8395 kg/hari

liquida = 5523,1355 kg/hari

rate volume padatan $= \frac{1926,8395 kg/hari}{945,1 kg/m^3} = 2,039 m^3/hari$

Vol liquida =

$$\frac{5153,1755}{998,07} + \frac{363,59567}{988,4} + \frac{0,36798}{1003,4} + \frac{0,00002}{1003,95} + \frac{0,00005}{994,94} + \frac{0,00058}{999,3} + \frac{5,9957}{1007,1}$$

$= 6,8564$ m³/hari

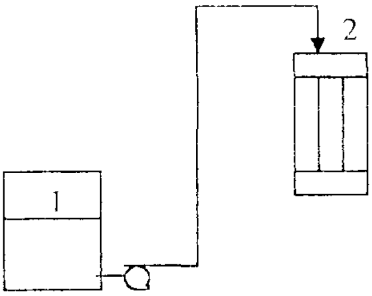
rate volume slurry = (6,8564 +2,039) m³/hari = 8,8954 m³/hari

Dengan cara yang sama pada perhitungan Rotary vaccum filter (H-144), maka didapat :

Spesifikasi :

Tipe	: Rotary vacuum drum filter
Filter rate	: 0,086 kg/s
Diameter	: 0,3828 m
Jumlah	: 1 buah

24. POMPA (L-254)



Fungsi : untuk mengalirkan larutan gelatin 11,02% menuju evaporator

Kebutuhan total larutan gelatin = 23023,1719 kg/ hari = 2114,903 lb/jam

Pada P = 1 atm dan pada suhu 44°C :

ρ HCl 5% = 1,0071 gr/cm^3 | ρ $CaCl_2$ = 1,0034 gr/cm^3

ρ H2O = 0,98807 gr/cm^3 | ρ $MgCl_2$ = 1,00395 gr/cm^3

ρ H_3PO_4 = 0,9993 gr/cm^3 | ρ NaCl = 0,99494 gr/cm^3

ρ gelatin = 0,9884 gr/cm^3 (Ward, A.G)

$$\frac{1}{\rho_{\cdot campuran}} = \frac{0{,}0039}{1{,}0071} + \frac{0{,}8824}{0{,}98807} + \frac{0{,}1102}{0{,}9884} + \frac{0{,}0035}{1{,}0034} + \frac{0{,}0056}{1{,}00395} + \frac{4{,}86.10^{-7}}{0{,}99494}$$

$$+ \frac{5{,}51.10^{-6}}{0{,}9993}$$

$$= 1{,}0176$$

ρ campuran = 0,9827 gr/cm^3 = 61,35 lb/ft^3

$$\text{volume} = \frac{2114{,}903}{61{,}35} = 34{,}4727 \text{ ft}^3/\text{jam} = 9{,}576.10^{-3} \text{ ft}^3/\text{s} = 4{,}3 \text{ gpm}$$

μ gelatin pada 44°C = 0,1 poises = 6,7197.10^{-3} lb/ft . s (Ward,A.G)

Dengan cara yang sama pada perhitungan <u>pompa (L-145)</u>, maka didapat :

Spesifikasi :

Tipe	: centrifugal pump
Rate aliran pompa	: 9,576.10^{-3} ft^3/s
Power motor	: 0,1 Hp
Bahan konstruksi	: stainless steel
Jumlah	: 1 buah

25. TANKI PENAMPUNG HASIL EKSTRAKSI (F-253)

Fungsi : untuk menyimpan larutan gelatin hasil ekstraksi

Bentuk : tanki silinder vertikal dengan tutup atas dished head dan tutup bawah berbentuk konis.

Dasar pemilihan : cocok digunakan untuk menampung bahan yang berbentuk liquida

Kondisi operasi : T = 50° C

P = 14,7 psia = 1 atm (Perry 7[ed], hal 2-88)

Kebutuhan larutan gelatin = 23023,1719 kg/ hari = 2114,903 lb/jam

Pada P = 1 atm :

ρ HCl 5% = 1,0071 gr/cm^3

ρ H2O = 0,98807 gr/cm^3

ρ H_3PO_4 = 0,9993 gr/cm^3

ρ gelatin = 0,9884 gr/cm^3

ρ $CaCl_2$ = 1,0034 gr/cm^3

ρ $MgCl_2$ = 1,00395 gr/cm^3

ρ NaCl = 0,99494 gr/cm^3

(Ward, A.G)

$$\frac{1}{\rho_{campuran}} = \frac{0,0039}{1,0071} + \frac{0,8824}{0,98807} + \frac{0,1102}{0,9884} + \frac{0,0035}{1,0034} + \frac{0,0056}{1,00395} + \frac{4,86.10^{-7}}{0,99494} + \frac{5,51.10^{-6}}{0,9993}$$

$$= 1,0176$$

ρ campuran = 0,9827 gr/cm^3 = 61,35 lb/ft^3

$$\text{Rate volumetrik} = \frac{2114,903}{61,35} = 34,4727\ ft^3/jam$$

Dirancang waktu tinggal = 6 jam

Volume larutan gelatin = 34,4727 cuft/jam × 6 jam = 206,8362 cuft

Diambil : tinggi shell (Hs) = 1,5 . Diameter shell(D)

Volume shell = $(\pi/4).D^2.Hs = (\pi/4).D^2.1,5.D = 1,5.(\pi/4).D^3$

Volume torispherical dished head (cuft) = 0,000049 x D^3 (inch)

(Brownell & Young, pers.5.11,p.88)

Volume larutan dalam konis = volume konis

$$= \left(\frac{1}{3}.\frac{\pi}{4}.D^2.Ht\right) - \left(\frac{1}{3}.\frac{\pi}{4}.Dn^2.Hn\right)$$

$$= \left(\frac{1}{3}.\frac{\pi}{4}.D^2.\frac{D}{2.tg\alpha}\right) - \left(\frac{1}{3}.\frac{\pi}{4}.Dn^2.\frac{Dn}{2.tg\alpha}\right)$$

$$= \left(\frac{\pi.D^3}{24.tg\alpha}\right) - \left(\frac{\pi.Dn^3}{24.tg\alpha}\right)$$

$$= \frac{\pi}{24.tg\alpha}\left(D^3 - Dn^3\right)$$

dimana :

Dn = diameter lubang pengeluaran liquida = 0,5 ft (=6 in)

D = diamete konis bagian atas = diameter shell

Ht = tinggi konis

Hn = tinggi konis terpancung

Volume tangki penampung = vol.shell + vol.dished head + vol.konis

Diambil : volume tangki penampung = 1,2.volume larutan total

$$1{,}2.\ 206{,}8362\ \text{cuft} = \frac{\pi}{4}.1{,}5.D^3.\left(\frac{1ft}{12in}\right)^3 + (0{,}000049.D^3)$$

$$+ \frac{\pi}{24.tg\alpha}\left(D^3\left(\frac{1ft}{12in}\right)^3 - Dn^3\right)$$

$$248{,}2034\ \text{cuft} = \frac{\pi}{4}.1{,}5.D^3.\left(\frac{1ft}{12in}\right)^3 + (0{,}000049.D^3)$$

$$+ \frac{\pi}{24.tg\alpha}\left(D^3\left(\frac{1ft}{12in}\right)^3 - (0{,}5ft)^3\right)$$

248,2034 cuft $= 6{,}8177.10^{-4}.D^3 + 0{,}000049.D^3 + 1{,}3121.10^{-4}.D^3 - 0{,}0283$

248,2034 cuft $- 8{,}6198.10^{-4}.D^3$

D = 66,03 in = 5,5 ft

Hs = 1,5.D = 1,5.(5,5 ft) = 8,25 ft

Volume larutan dalam konis $= \frac{\pi}{24.tg\alpha}\left(D^3 - (0{,}5ft)^3\right)$

$$= \frac{\pi}{24.tg30^o}\left((5{,}5\,ft)^3 - (0{,}5\,ft)^3\right)$$

$= 37{,}69$ cuft

Volume larutan dalam shell = vol. larutan total – vol. larutan dalam konis

= (206,8362 – 37,69) cuft

= 169,1462 cuft

$$\text{Tinggi larutan dalam shell (H)} = \frac{\text{volume larutan dalam shell}}{\frac{\pi}{4}.D^2}$$

$$= \frac{169{,}1462}{\frac{\pi}{4}.(5{,}5\,ft)^2}$$

$= 7{,}12$ ft ≈ 7,2 ft

Tinggi larutan dalam konis = tinggi konis (Hc)

$$Hc = \frac{D}{2.tg\alpha} - \frac{Dn}{2.tg\alpha}$$

$$= \frac{5{,}5\,ft}{2.tg30^o} - \frac{0{,}5\,ft}{2.tg30^o}$$

$= 4{,}33$ ft ≈ 4,34 ft

Tinggi larutan dalam tangki = H + Hc

= (7,2 + 4,34) ft

= 11,54 ft

$$P_{operasi} = P_{hidrostatis} = \left(\frac{\rho.H}{144}\right)\text{psi}$$

$$= \left(\frac{61{,}35\,lbm/cuft..11{,}54\,ft}{144}\right)\text{psi}$$

= 4,92 psi

$P_{desain} = 1{,}5.P_{operasi} = 1{,}5.(4{,}92\text{ psi}) = 7{,}38\text{ psi}$

Tebal shell

$$t_s = \frac{P.ID}{2(f.E - 0{,}6.P)} + c$$ (Brownell & Young, pers. 13.1)

dimana :

$P = P_{desain} = 7{,}38$ psi

ID = 5,5 ft = 66 in

Konstruksi : bahan konstruksi High Alloy stell SA-240 grade M, type 316

f = stress maksimum yang diijinkan = 18750 psi

tipe sambungan = *double-welded butt joint*, dengan

E = *welded-joint efficiency* = 0,8

(Brownell & Young, hal 343)

$c = corrosion\ allowance = \frac{1}{8}$ in

$$t_s = \frac{(7{,}38\,psi).(66\,in)}{2.(18750.0{,}8 - 0{,}6.7{,}38)\,psi} + \frac{1}{8}\,in$$

$t_s = 0{,}1412$ in ≈ ¼ in

Tebal dished head

t_s = ¼ in

$OD = ID + 2.t_s$

$= 66 \text{ in} + (2.\frac{1}{4}) \text{ in}$

$= 66{,}5$ in

Dari table 5.7 Brownell & Young diperoleh :

OD standar = 72 in

r (crown radius / radius of dish) = 72 in

icr (inside corner radius / knuckle radius) = 4⅜ in

$$W = \frac{1}{4}.\left(3 + \sqrt{\frac{r}{icr}}\right)$$ (Brownell & Young, pers. 7.76, p.138)

$$= \frac{1}{4}.\left(3 + \sqrt{\frac{72}{4\frac{3}{8}}}\right)$$

$= 1,76$

$a = ID/2 = 66 \text{ in} / 2 = 33 \text{ in}$

$AB = ID/2 - icr = (33 - 4\tfrac{3}{8}) \text{ in} = 28,625 \text{ in}$

$BC = r - icr = (72 - 4\tfrac{3}{8}) \text{ in} = 67,625 \text{ in}$

$b = r - \sqrt{BC^2 - AB^2} = 72 - \sqrt{67,625^2 - 28,625^2} = 10,73 \text{ in}$

$$t_d = \frac{P.rc.W}{2.f.E - 0,2.P} + c$$ (Brownell & Young, pers. 7.77, p.138)

dimana :

$P = P_{desain} = 7,38$ psi

Konstruksi : bahan konstruksi High alloy stell SA-240 grade M, type 316

f = stress maksimum yang diijinkan = 18750 psi

tipe sambungan = *double-welded butt joint*, dengan

E = *welded-joint efficiency* = 0,8

(Brownell & Young, hal 343)

$c = \textit{corrosion allowance} = \frac{1}{8}$ in

$$t_d = \frac{(7,38\,psi).(72\,in).1,76}{2.(12650\,psi).(0,8) - 0,2.(7,38\,psi)} + \frac{1}{8}\,in$$

$= 0,171 \text{ in} \approx \tfrac{1}{4} \text{ in}$

Dipilih panjang straight-flange (sf) = 2 in

(Brownell & Young, table 5.8, p.93)

$OA = t + b + sf$

$= (1/4 + 10,73 + 2) \text{ in}$

$= 12,98 \text{ in} = 1,08 \text{ ft} \cong 1,1 \text{ ft}$

Tinggi tangki keseluruhan = tinggi shell + tinggi dish + tinggi konis

= 7,2 ft + 1,1 ft + 4,34 ft

= 12,64 ft

Tebal konis

$$t_c = \frac{P.ID}{2.\cos\alpha.(f.E - 0,6.P)} + c$$ (Brownell & Young, pers.6.154, p.118)

$$= \frac{(7{,}38\,psi).(66\,in)}{2.\cos 30^{o}.(18750.0{,}8 - 0{,}6.7{,}38)\,psi} + \frac{1}{8}\,in$$

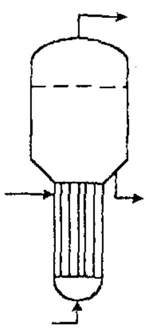
$= 0{,}1438$ in ≈ ¼ in

Spesifikasi :

Tangki :

Kapasitas	: 206,8362 cuft
Diameter	: 6,6 ft
Tinggi tutup atas (dished head)	: 1,1 ft
Tinggi tutup bawah (konis)	: 4,34 ft
Tinggi shell	: 7,2 ft
Tinggi tangki total	: 12,64 ft
Tebal shell	: ¼ in
Tebal tutup atas (dished head)	: ¼ in
Tebal tutup bawah (dished head)	: ¼ in
Bahan konstruksi	: High alloy steel SA-240 grade M,type 316
Jumlah tangki	: 1 buah

26. Evaporator (V-310)



Fungsi : untuk memekatkan konsentrasi larutan gelatin dari 11,02% hingga 35%.

Tipe : Single Effect Vertical Forced Circulation Evaporator.

Dasar pemilihan : - beroperasi secara kontinyu

- forced circulation supaya koefisien perpindahan panas besar

- single effect karena kapasitas kecil

Kondisi operasi :

- T larutan (fluida dingin) : t_1= 44°C=111,2°F; t_2 =53°C =127,4°F
- T steam (fluida panas) : T = 120°C = 248°F
- $T_{operasi}$ = 53°C = 127,4°F dan $P_{operasi}$ = 4 inHg = 13,5457 kPa = 0,13 atm

- Dari appendix B didapat : kebutuhan panas = 9373367,067 kkal/hari

  = 1548845,817 Btu/jam

  laju steam = 17085,8245 kg/hari

  = 1569,4754 lb/jam

  massa larutan = 7249,0101 kg/hari

  = 665,882 lb/jam

Perhitungan

ΔT = 248 – 127,4 = 120,6°F

Td larutan = 53°C = 127,4°F

Dari Badger fig.5-26 hal 209, diperoleh :

U_D = 510 Btu/ft^2.jam.°F

Q = U_D.A.ΔT → A = 1548845,817/(510.120,6) = 25,182 ft^2

Untuk evaporator jenis Vertical Forced Circulation, tube ditentukan :

OD < 2 in (Kern, hal 406)

L = 48 in = 4 ft (Badger, hal 208)

Ditentukan ukuran tube pipa diameter nominal (Kern, tabel 11) :

1½ in sch.40

OD = 1,9 in

ID = 1,610 in

at = 0,498 ft^2/ft

A = Nt.at.L → Nt = 25,182/(0,498.4) = 12,64 ≈ 13

ρ_l = 982,7 kg/m^3

ρ_v = 0,6381 kg/m^3

Dari steam table untuk superheated vapor pada T = 127,4°F dan P = 13,5457 kPa, diperoleh : specifik volum = v = 281,9542 ft^3/lb

Laju volumetrik uap = 1569,4754 lb/jam x 281,9542 ft^3/lb

= 450939,3614 ft^3/jam = 3,5471 m^3/s

Kecepatan uap maksimum = V_v =0,035.$(\rho_l/\rho_v)^{0,5}$= 0,035.$(982,7/0,6381)^{0,5}$

= 1,3735 m/s

Q =$V_v.A_s \rightarrow A_s$= 3,5471/1,3735 = 2,5825 m^2=π/4.$D_s^2 \rightarrow D_s$= 1,813 m= 5,9481 ft

Menentukan tinggi evaporator

Tinggi badan silinder = 1,5 – 2 dari panjang tube (Hugot, hal 500)

Ditentukan H_s = 2.L = 2.4 = 8 ft

Menghitung tebal shell

Asumsi : t_s = $\frac{1}{4}$ in

ID = 5,9481 ft = 71,3772 in

OD = ID + 2.t_s = 71,3772 + 2. $\frac{1}{4}$ = 71,8772 in

H_s/OD = (8x12)/71,8772 = 1,3356

OD/ts = 71,8772/($\frac{1}{4}$) = 287,5088

Dari fig. 8.8 dan fig 8.7 brownell & young pada suhu 127,4°F, diperoleh :

A = 0,00022

B = 3900 psi

$$P\ allowable = \frac{4.B}{3\left(\frac{OD}{t_s}\right)} = \frac{4.3900}{3.287,5088} = 18,0864\ psi > 14,7\ psi\ (memenuhi)$$

t_s' = t_s + c = $\frac{1}{4}$ + $\frac{1}{8}$ = 0,375 in

Digunakan tebal plate = $\frac{3}{8}$ in

Spesifikasi :

Fungsi : untuk memekatkan konsentrasi larutan gelatin hingga 35%

Tipe : Vertical Forced Circulation Evaporator

Kondisi operasi : - $T_{larutan}$ (fluida dingin)

t_1 = 44°C = 111,2°F

t2 = 53°C =127,4°F

- T_{steam} (fluida panas)

  T = 120°C = 248°F

Luas perpindahan panas = 24,6235 ft^2

Jumlah = 1 buah

27. Barometic Kondenser (E-311)

Fungsi : mengembunkan uap air dari evaporator

Tipe : Counter Current Condenser

Dasar Pemilihan : operasinya mudah

Perhitungan

Laju massa uap masuk = 15774,1618 kg/hari = 1449,0107 lb/jam

Suhu uap masuk = 53°C = 127,4°F

Suhu air pendingin = 30°C = 86°F

Catatan : (Ludwig, hal 211)

Non condensable gas tidak melebihi 1% dari total uap air yang akan dikondensasi.

Jadi laju uap yang akan dikondensasi = 0,99 x 1449,0107 = 1434,5206 lb/jam

Non condensable gas = 1449,0107 – 1434,5206 = 14,4901 lb/jam

Temperatur uap jenuh pada 13,5457 kPa (dari neraca panas) = 53°C = 127,4°F

Terminal difference = 5°F

Temperatur air keluar barometrik kondenser = 127,4 – 5 = 122,4°F

Temperatur air masuk = 86°F

Kenaikan suhu air = (122,4 – 86) = 36,4°F

Temperatur udara (non condensable gas) meninggalkan barometrik kondenser = 86 + 5 = 91°F

Dari Ludwig hal 211, pers. 6.8 :

Gpm air pendingin yang dibutuhkan :

$$Gpm = \frac{Ws.L}{Tw.500}$$

di mana : Ws = jumlah uap yang dikondensasi (lb)

L = panas laten penguapan pada T_{sat} = 127,4°F= 1021,3 Btu/lb

$$Gpm = \frac{1434{,}5206.1021{,}3}{36{,}4.500} = 80{,}4987\ gpm$$

Tinggi barometrik kondenser

Pa = tekanan pada permukaan liquid dalam kaki barometer

Pb = tekanan pada permukaan liquid

Ph = tekanan hidrostatik

$$P_A = P_B$$

$$Ph + Pa = Pb$$

$$\rho_{air}.h_{air}.g+0 = \rho_{liq}.h_{Hg}.g$$

$$h_{air} = (13{,}6.76)/1 = 1033{,}6\ cm = 10{,}34\ m$$

Pada keadaan ideal : Pa = 0

Spesifikasi :

Fungsi : mengembunkan uap air dari evaporator

Tipe : Counter Current Condenser

Kapasitas : 1449,0107 lb/jam

Laju air pendingin : 80,4987 gpm

Tinggi barometrik : 10,34 m

28. Hot Well (F-310)

Fungsi : untuk menampung kondensasi dari barometrik kondensor.

Perhitungan

Laju massa = 1434,5206 lb/jam = 650,6842 kg/jam

Waktu tinggal = 10 menit

Kapasitas = 650,6842.10/60 = 108,4474 kg

ρ_{air} = 1000 kg/m^3

Volume air = 108,4474/1000 = 0,1084 m^3

Volume air = 80% dari volume hot well

Volume hot well = 0,1084/0,8 = 0,1355 m^3

Bentuk = persegi

Ukuran = p : 0,52 m; l : 0,52 m; t : 0,5 m

Spesifikasi:

Fungsi : untuk menampung kondensasi dari barometrik kondensor.

Volume : 0,1355 m^3

Bentuk : persegi

Ukuran : p = 0,52 m; l = 0,52 m; t = 0,5 m

29. Ejektor (G-312)

Fungsi : untuk memvakumkan evaporator

Tipe : Single stage steam ejector

Dasar Pemilihan : kondisi vakum cukup besar

Perhitungan

Tekanan masuk ejektor = P operasi = 4 inHg abs

Uap yang masuk = non condensable gas = 14,4901 lb/jam

Dari Ludwig vol 1, hal 230, didapat :

$W_s = W_{s90}.f$ di mana : W_s = total steam (lb/jam)

W_{s90} = total steam untuk steam 90 psig

f = steam pressure factor

Dari Ludwig vol 1, hal 227, didapat :

Pada P suction 3 – 5 inHg, diambil udara leakage = 22,5 lb/jam

W'm = total campuran = uap + udara leakage

= 26,13 + 22,5 = 48,63 lb/jam

Dari Ludwig fig. 6-26A, hal 230, didapat :

P suction = 4 inHg abs

W'm = 48,63 lb/jam

Ukuran ejektor = 2 in L ejektor

W_{s90} = 360 lb/jam

Dari Ludwig fig. 6-26B, hal 230, didapat :

Pada tekanan steam = 125 psig (Ludwig, hal 230)

F = 0,88 Ws = 360 . 0,88 = 316,8 lb/jam

Evacuation : sistem volume = 300 ft^3 (Ludwig, hal 230)

E = 1,3 V = 300 W'm = 48,63 lb/jam

Dari Ludwig pers. 6-7, hal 230, didapat :

W'm = E.V/t

t = (1,3.300)/48,63 = 8,02 menit

Konsumsi air = $0,06.W_s$ = 0,06 x 316,8 = 19,008 gpm (Ludwig, hal 232)

Spesifikasi:

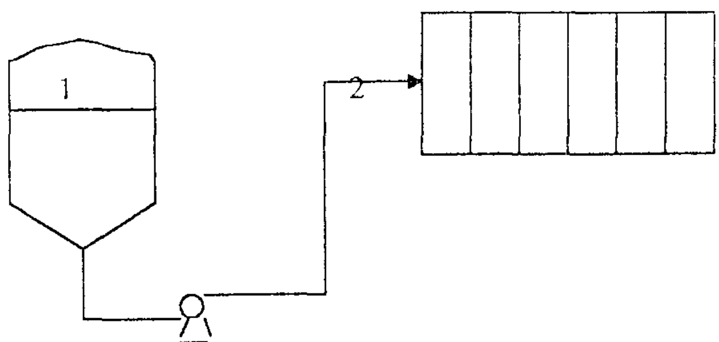
Fungsi : untuk memvakumkan evaporator

Tipe : Single stage steam ejector

Laju steam : 316,8 lb/jam

Air pendingin : 19,008 gpm

30. POMPA (L-314)



Fungsi : untuk mengalirkan larutan gelatin 35% menuju cooler

Kebutuhan total larutan gelatin = 7249,0101 kg/ hari = 665,882 lb/jam

Pada P = 1,96 psia (0,13 atm) dan suhu operasi 53°C (127,4°F) :

$\rho\ CaCl_2 = 1,0034\ gr/cm^3$

$\rho\ H2O = 0,98565\ gr/cm^3$ $\rho\ MgCl_2 = 1,00395\ gr/cm^3$

$\rho\ H_3PO_4 = 0,9993\ gr/cm^3$ $\rho\ NaCl = 0,99494\ gr/cm^3$

ρ gelatin = 0,9866 gr/cm^3 (Ward, A.G)

$$\frac{1}{\rho_{campuran}} = \frac{0,6409}{0,98565} + \frac{0,35}{0,9866} + \frac{0,0035}{1,0034} + \frac{0,0056}{1,00395} + \frac{4,86.10^{-7}}{0,99494}$$

$$+ \frac{5,51.10^{-6}}{0,9993}$$

$= 1,0141$

ρ campuran = 0,9861 gr/cm^3 = 61,55 lb/ft^3

$$\text{volume} = \frac{665,882}{61,55} = 10,8186 \text{ ft}^3/\text{jam} = 3.10^{-3} \text{ ft}^3/\text{s} = 1,35 \text{ gpm}$$

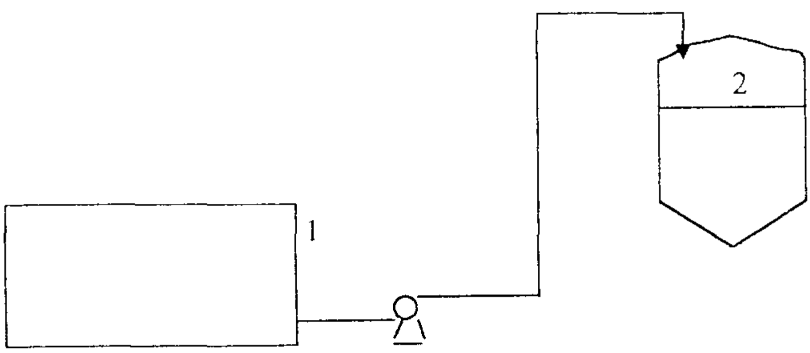
μ gelatin pada 53°C = 0,9 poises = 0,0605 lb/ft . s (Ward,A.G)

Dengan cara yang sama pada perhitungan pompa (L-145), maka didapat :

Spesifikasi :

Tipe	: centrifugal pump
Rate aliran pompa	: 3.10^{-3} ft^3/s
Power motor	: 0,1 Hp
Bahan konstruksi	: stainless steel
Jumlah	: 1 buah

31. POMPA (L-321)



Fungsi : untuk mengalirkan larutan gelatin 35% menuju spray dryer

Kebutuhan total larutan gelatin = 7249,0101 kg/ hari = 665,882 lb/jam

Suhu operasi 15°C (59°F) dan P = 1 atm :

ρ $CaCl_2$ = 1,0041 gr/cm^3

ρ H2O = 0,99930 gr/cm^3 ρ $MgCl_2$ = 1,0035 gr/cm^3

ρ H_3PO_4 = 0,9996 gr/cm^3 ρ NaCl = 0,9944 gr/cm^3

ρ gelatin = 0,9868 gr/cm^3 (Ward, A.G)

$$\frac{1}{\rho_{\cdot campuran}} = \frac{0,6409}{0,99930} + \frac{0,35}{0,9868} + \frac{0,0035}{1,0041} + \frac{0,0056}{1,0035} + \frac{4,86.10^{-7}}{0,9944}$$

$$+\frac{5{,}51.10^{-6}}{0{,}9996}$$

$= 1{,}013$

ρ campuran = 0,9872 gr/cm^3 = 61,63 lb/ft^3

volume = $\frac{665{,}882}{61{,}63}$. = 10,8045 ft^3/jam = 3.10^{-3} ft^3/s = 1,35 gpm

μ gelatin pada 15°C = 0,5 poises = 0,034 lb/ft . s(Ward,A.G)

Dengan cara yang sama pada perhitungan pompa (L-145), maka didapat :

Spesifikasi :

Tipe	: Displacement pump
Rate aliran pompa	: 3.10^{-3} ft^3/s
Power motor	: 0,1 Hp
Bahan konstruksi	: stainless steel
Jumlah	: 1 buah

32. Alat Pendingin (B-320)

Fungsi : untuk mendinginkan larutan gelatin

Tipe : Double pipe Heat Exchanger

Perhitungan :

Rd = 0,003

Dipilih ukuran pipa 2 ½ x 1 ¼ in IPS dengan 20 ft-hairpains

Suhu air masuk = 4°C = 39,2°F Suhu larutan masuk= 53°C= 127,4°F

Suhu air keluar = 15°C = 59°F Suhu larutan keluar= 15°C = 59°F

Neraca panas :

Massa air = 9212,173836 kg/hari = 846,215 lb/jam

Massa larutan gelatin = 7249,0101 kg/hari = 665,882 lb/jam

Q = 16744,3145 Btu/jam

$$\Delta T_{LMTD} = \frac{(127{,}4-59)-(59-39{,}2)}{\ln\dfrac{(127{,}4-59)}{(59-39{,}2)}} = 39{,}19°F$$

$$\text{Dalam °F : Tc} = \frac{127{,}4+59}{2} = 93{,}2°F \;; \quad tc = \frac{59+39{,}2}{2} = 49{,}1°F$$

$$\text{Dalam °C : Tc} = \frac{53+15}{2} = 34°C \;; \quad tc = \frac{15+4}{2} = 9{,}5°C$$

Hot fluid : annulus, larutan gelatin 35%	Cold fluid : inner pipe, air
- Dari table 11 : $D_2 = \frac{2{,}469}{12} = 0{,}20575$ ft $D_1 = \frac{1{,}66}{12} = 0{,}138$ ft $a_a = \frac{\pi.(D_2^2 - D_1^2)}{4}$ $a_a = \frac{\pi.(0{,}20575^2 - 0{,}138^2)}{4}$ $= 0{,}0183$ ft^2 $De = \frac{(D_2^2 - D_1^2)}{D_1}$ $= \frac{(0{,}20575^2 - 0{,}138^2)}{0{,}138}$ $De = 0{,}1688$ ft - $Ga = \frac{Wa}{a_a} = \frac{665{,}882}{0{,}0183} = 36386{,}995$ - pada 34°C , μ = 0,4015 lbm/ft.hr $Rea = \frac{De.Ga}{\mu} = \frac{36386{,}995.0{,}1688}{0{,}4015}$ $= 15297{,}9446$ - $J_H = 65$ didapat dari fig. 34 (Kern)	- D = 1,38/12 = 0,115 ft $a_p = \pi D^2/4 = \frac{\pi.(0{,}115)^2}{4} = 0{,}0104$ ft^2 - $Gp = \frac{W}{a_p} = \frac{846{,}215}{0{,}0104} = 81366{,}83$ - pada 9,5°C, μ = 3,2108 lbm/ft.hr $Rep = \frac{D.Gp}{\mu} = \frac{81366{,}83.0115}{3{,}2108}$ $Rep = 2914{,}285$ - $J_H = 15$ - pada 49,1°F, k = 0,3378°F $\left(\frac{Cp.\mu}{k}\right)^{1/3} = \left(\frac{1.3{,}2108}{0{,}3378}\right)^{1/3} = 2{,}118$ - $hi = J_H.\frac{k}{D}.\left(\frac{Cp.\mu}{k}\right)^{1/3}.\left(\frac{\mu}{\mu w}\right)^{0{,}14}$ $= \frac{15x0{,}3378x2{,}118}{0{,}115}$ $= 93{,}3209$ - $hio = hi \times \frac{ID}{OD}$

- Cp gelatin 35% = 0,777 kkal/kg.°C = 1,39768 Btu/lbm.°F - k = 0,359 pada 93,2°F $\left(\frac{Cp.\mu}{k}\right)^{1/3} = \left(\frac{1{,}39768.0{,}4015}{0{,}359}\right)^{1/3}$ = 1,1606 - ho = $J_H.\frac{k}{De}.\left(\frac{Cp.\mu}{k}\right)^{1/3}.\left(\frac{\mu}{\mu w}\right)^{0.14}$ $= \frac{65x0{,}359x1{,}1606}{0{,}1688}$ = 160,4419	$= 93{,}3209 \text{ x } \frac{1{,}38}{1{,}66}$ = 77,58

- Uc = $\frac{hio.ho}{hio+ho} = \frac{160{,}4419.77{,}58}{160{,}4419+77{,}58} = 52{,}2939$

- Design Overall coefficient

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

$$\frac{1}{U_D} = \frac{1}{52{,}2939} + 0{,}003$$

$U_D = 45{,}2025$

- Luas perpindahan panas

$Q = U_D.A.\Delta T$

$$A = \frac{Q}{U_D.\Delta T} = \frac{16744{,}3145}{45{,}2025.39{,}19} = 9{,}45 \text{ ft}^2$$

Dari table 11 kern untuk 1 ¼ in IPS didapat :

a" = 0,435 ft^2/ft

$$\text{panjang} = \frac{9{,}45}{0{,}435} = 21{,}72 \text{ ft}$$

$$20 \text{ ft-hairpain} : \frac{21{,}72}{20} = 1{,}086 \text{ pipa} \approx 2 \text{ pipa}$$

- Luas perpindahan actual = 40 x 0,435

$$= 17{,}4 \text{ ft}^2$$

$$U_D = \frac{16744{,}3145}{17{,}4.39{,}19} = 24{,}555$$

$$Rd = \frac{Uc - U_D}{Uc.U_D} = \frac{52{,}2939 - 24{,}555}{52{,}2939x24{,}555} = 0{,}007$$

ΔP

Hot fluid : annulus, larutan gelatin 35%	Cold fluid : inner pipe, air
- De' = $(D_2\text{-}D_1)$ $= (0{,}20575 - 0{,}138)$ $= 0{,}06775$ ft $Rea' = \frac{De'.Ga}{\mu} = \frac{0{,}06775.36386{,}995}{0{,}4015}$ $= 6140{,}02$ $f = 0{,}0035 + \frac{0{,}264}{(6140{,}02)^{0.42}} = 0{,}0103$ - pada 34°C , $\rho_{gelatin} = 62{,}1326$ lb/ft^3 $\Delta Fa = \frac{4.f.Ga^2.L}{2.g.\rho^2.De'}$ $=$ $\frac{4x0{,}0103x(36386{,}995)^2.40}{2x(62{,}1326)^2x4{,}18.10^8x0{,}06775}$ $\Delta Fa = 9{,}979.10^{-3}$ - $v = \frac{G}{3600.\rho} = \frac{36386{,}995}{3600.62{,}1326} = 0{,}1627$ $F_l = 3 \text{ x } \left(\frac{v^2}{2.g'}\right) = 3 \text{ x } \left(\frac{0{,}1627^2}{2x32{,}2}\right)$ $F_l = 1{,}23.10^{-3}$ $\Delta Pa = \frac{(9{,}979.10^{-3} + 1{,}23.10^{-3})x61{,}1326}{144}$	- Rep' = 2914,285 $f = 0{,}0035 + \frac{0{,}264}{(2914{,}285)^{0.42}}$ $= 0{,}0128$ - pada tc = 49,1°F sg = 1 ρair = 62,5 x 1 = 62,5 $\Delta Fp = \frac{4.f.Gp^2.L}{2.g.\rho^2.D}$ $= \frac{4.0{,}0128.81366{,}83^2.40}{2.4{,}18.10^8.62{,}5^2.0{,}115}$ $\Delta Fp = 0{,}1033$ ft $\Delta Pp = \frac{0{,}1033x62{,}5}{144} = 0{,}045$

$= 4{,}76.10^{-3}$	

33. Blower I (G-332)

Fungsi : Menghembuskan udara masuk ke pemanas udara (HE)

Data : Kapasitas udara = 91332,3161 kg/hari = 1,0571 kg/s

Tudara = 30°C = 546°R

P masuk = 1 atm

P keluar = 2 atm

$$-Ws = \frac{\gamma}{\gamma - 1} \times \frac{R.T_1}{M} \times \left[\left(\frac{P_2}{P_1} \right)^{(\gamma-1)/\gamma} - 1 \right]$$ Geankoplis 3rd.ed, p.139, eq(3.3-14)

di mana : R = 8314,3 j/kmol

γ = 1,4 (untuk udara, geankoplis, 3rd.ed, p.139)

T_1= 30 °C

M= 28,84 kg udara/mol

P_2= 2 atm

P_1= 1 atm

$$-Ws = \frac{1{,}4}{1{,}4 - 1} \times \frac{8314{,}3.30}{28{,}84} \times \left[\left(\frac{2}{1} \right)^{(1{,}4-1)/1{,}4} - 1 \right]$$

$= 6629{,}6549$ j/kg

$$\text{brake kw} = \frac{-Ws.m}{\eta.1000};$$

di mana : m = kapasitas = 1,0571 kg/s

η = 0,8

$$\text{brake kw} = \frac{6629{,}6549 \times 1{,}0571}{0{,}8 \times 1000} = 8{,}76 \text{ kw}$$

$$= 8{,}76 \text{ kw} \times \frac{1 \text{ Hp}}{0{,}7457 \text{ kw}} = 11{,}75 \text{ Hp}$$

bahan konstruksi = wrought iron

jumlah = 1 buah

Spesifikasi alat:

Fungsi: untuk menghembuskan udara ke dalam alat pemanas udara

Type: Centrifugal blower

Power : 11,75 Hp

Kapasitas udara: 3805,5131 kg/jam

Kondisi operasi: T udara masuk = 30 °C

P masuk = 1 atm

P keluar = 2 atm

Bahan konstruksi = wrought iron

Jumlah : 1 buah

34. Heat Exchanger (E-331)

Fungsi : Untuk memanaskan udara yang dipakai pada spray dryer

Type : Shell and Tube

Kondis operasi : T steam masuk, T_1 = 120°C

t udara masuk, t_1 = 30°C

t udara keluar, t_2 = 110°C

1. Neraca panas.

Dari geankoplis App. A-5, untuk steam pada suhu 120°C, didapatkan harga

λ = 526,4214 kkal/kg = 946,9511 btu/lbm

Q = m.λ

= 431,2454 . 946,9511 = 408368,2662 btu/jam

2. $\Delta T_{LMTD} = \dfrac{(120-30)-(120-110)}{\ln\dfrac{(120-30)}{(120-110)}} = 36{,}41°C$

3. $Tc = \dfrac{T_2+T_1}{2} = \dfrac{120+120}{2} = 120°C$

$tc = \dfrac{t_2+t_1}{2} = \dfrac{110+30}{2} = 70°C$

Trial Ud

Dari table 8 hal 840 kern, untuk proses heater, jika digunakan liquida panas berupa steam dan pada liquida dingin berupa gas (udara), maka Ud overall berkisar antara 5-50 btu/jam.ft^2.°F.

Dicoba trial Ud = 20 Btu/jam.ft^2.°F , maka :

$$A = \frac{Q}{Ud.\Delta T_{LMTD}} = \frac{408368,2662}{20.36,41} = 560,79 \text{ ft}^2$$

Asumsi dipakai pipa ¾ in OD, 16 BWG, panjang 16 ft

Dari Kern, p843 , table 10 diperoleh data :

a' = 0,302 in^2

a" = 0,19633 ft^2/ft

$$\text{Jumlah tube} = \frac{A}{a''.L} = \frac{560,79}{0,19633.16} = 178,55$$

Standarisasi, Nt = 184 (Kern, p.842, table 9, 1 in OD on 1¼ square pitch , 6 passes)

Bagian Shell

ID shell = 23,25 in

Ns = 1

Bagian Tube

OD = 1 in, 16 BWG

ID = 0,870 in = 0,072 ft

L = 16 ft, pt = 1,25 in

Nt = 184

N = 6 passes

Evaluasi Perpindahan Panas (Rd)

Shell, udara	Tube, Steam
4. ID shell = 23,25 in ; B = 12 in Pt = 1,25 in C' = 1,25 – 1 = 0,25 in $As = \frac{ID.C'.B}{144.Pt} = \frac{23,25.0,25.12}{144.1,25}$ $= 0,3875$ ft^2 5. $Gs = \frac{M}{as} = \frac{91332,3161x2,2046/24}{0,3875}$	4'. $at = \frac{Nts \tan dar.a't}{144.n}$ $= \frac{184x0,594}{144x6} = 0,1265$ ft^2 5'. $Gt = \frac{m}{at} = \frac{431,2454}{0,1265}$ = 3409,055 lb/ft^2.jam 6'. ID = 0,870 in = 0,072 ft

$= 21650,67$ lb/jam.ft^2 6. pada tc = 70°C (Kern, fig 15) didapatkan : $\mu = 0,02 \times 2,42 = 0,0484$ lb/j.ft dari fig 28 didapat : De = 0,95 in $= 0,079$ ft $\text{Res} = \dfrac{De.Gs}{\mu} = \dfrac{0,079.21650,67}{0,0484}$ $= 35338,90$ 7. jH = 130 8. $\left(\dfrac{Cp.\mu}{k}\right)^{1/3} = \left(\dfrac{0,25.0,0484}{0,01548}\right)^{1/3}$ $= 0,9212$ 9. $ho = jH.\dfrac{k}{De}.\left(\dfrac{Cp.\mu}{k}\right)^{1/3}$ $= 130.\dfrac{0,01548}{0,079}.0,9212$ $= 23,47$ btu/jam.ft^2.°F	$\text{Ret} = \dfrac{ID.Gt}{\mu} = \dfrac{0,072.3409,055}{0,013.2,42}$ $= 7792,1257$ 7'. hio = 1500 btu/jam.ft^2.°F

10. $\text{Uc} = \dfrac{hio.ho}{hio + ho} = \dfrac{1500x23,47}{1500 + 23,47} = 23,11$ Btu/j.ft^2.°F

A terkoreksi = Nt.L.a" = 184.16.0,2618 ft^2/ft = 770,7392 ft^2

U_D terkoreksi $= \dfrac{Q}{Aterkoreksi.\Delta T_{LMTD}} = 14,55$ Btu/j.ft^2.°F

14. $\text{Rd} = \dfrac{1}{Ud} - \dfrac{1}{Uc} = \dfrac{1}{14,55} - \dfrac{1}{23,11} = 0,025$ (memenuhi)

EVALUASI ΔP

Shell,udara	Tube
1. Res = 35338,90 fs = 0,0016 (Kern, p.839,fig 29)	1'. Ret = 7792,1257 ft = 0,00029

N+1 = $\frac{12.L}{B}$ (eq 7.43, Kern) $= \frac{12.16}{12} = 16$ 2. $\Delta Ps = \frac{f.Gs^2.Ds.(N+1)}{5{,}22.10^{10}.Des.\theta_S}$ = 5,761 psia < 10 psi (memenuhi)	2'. $\Delta Pt = \frac{f.Gt^2.Dt.L.n}{5{,}22.10^{10}.Dt.\theta_t}$ $= 6{,}198.10^{-6}$ 3'. Ret = 7792,1257 $V^2/2g'$ = 0,0008 (Kern,p.837,fig 27) $\Delta Pr = \frac{4.n}{s}.\frac{V^2}{2.g'} = 0{,}4973$ ΔPttotal = ΔPt + ΔPr = 0,4973
$\Delta P = 5{,}761 + 6{,}198.10^{-6} + 0{,}4973 = 6{,}2583$ psi (memenuhi)	

35. Spray Dryer (B-330)

Fungsi : sebagai alat pengering slurry gelatin sehingga diperoleh powder gelstin dalam bentuk granular

Tipe : Bejana silinder dengan bagian bawah berbentuk konis dan tutup atas berbentuk dished head.

Kapasitas : 7249,0101 kg/hari = 302,0421 kg/jam

Kondisi : Suhu udara masuk = 110°C

Suhu feed masuk = 15°C

Tekanan operasi = 1 atm

Suhu operasi = 50°C

Perhitungan :

Menghitung ukuran dryer :

Feed masuk terdiri dari :

Padatan : 2537,1535 kg/hari = 105,7147 kg/jam

Air : 4711,8566 kg/hari = 196,3274 kg/jam

Kadar air mula-mula = 65%

Dari perhitungan Appendix A :

H_2O yang menguap = 4398,5058 kg/hari = 183,2711 kg/jam

Gelatin keluar sebagai produk = 2850,5043 kg/hari = 118,771 kg/hari

Kadar air dalam produk = 11 %

Laju pengeringan = air yang menguap = 183,2711 kg/jam

Suhu udara masuk = 110 °C

Suhu udara keluar = 70 °C

Dari Perry ed 5.p. 20-63 :

Volume chamber = 6000 ft^3

Diameter = 22 ft = 6,705 m

Lubang pengeluaran = 12 in (Hesse p.85)

Tinggi shell = 0,4 D (fig 20.72 Perry ed 5) = 8,8 ft = 2,68 m

Volume silinder = $\pi/4 . D^2 . Hs = \pi/4 . 22^2 . 8,8$ = 3345,167 ft^3

Volume konis = Volume chamber – Volume silinder

= 6000 – 3345,167

= 2465,833 ft^3

Tinggi konis = $\dfrac{0,5.D}{tg\alpha} = \dfrac{0,5.22}{tg60}$ = 6,3502 ft = 1,9356 m

Tinggi total = Hs + hc = 4,6156 m

Waktu pengeringan total : T = 17.(L/S) (Foust,p.548)

L/S = Perbandingan massa dari air terhadap solid dalam feed

T = 17 x (196,3274/105,7147) = 31,5714 detik

Volume yang dibutuhkan untuk pengeringan tersebut :

Volume = waktu tinggal x total rate gas

ρ udara pada suhu 110°C = 0,901 kg/m^3 (geankoplis app. A3-3)

Rate volume udara = 91332,3161 kg/hari/0,901 = 101367,7204 m^3/hari

= 4223,6550 m^3/jam

Air yang diuapkan = 183,2711 kg/jam

ρ uap air pada suhu 110°C = 0,5507 kg/m^3 (Geankoplis A.2-12)

Rate volumetric air yang menguap = 183,2711/0,5507 = 332,7966 m^3/jam

Total aliran gas meninggalkan dryer = rate udara + rate uap air

= 4223,6550 + 332,7966

= 4556,4516 m^3/jam

= 0,053 m^3/s

Volume = 31,5714 x 0,053 m^3/s = 1,673 m^3

Pengecekan terhadap volume chamber:

Volume chamber = 6000 ft^3 = 169,9 m^3 > 1,673 m^3 kadar air yang diinginkan dapat tercapai

.**Spesifikasi dryer :**

Tinggi silinder	: 2,68 m
Tinggi konis	: 1,9356 m
Diameter	: 6,705 m

Menghitung tebal shell

Untuk shell tutup bagian bawah dan tutup bagian atas dipilih bahan konstruksi carbon steel SA-283 grade C (Brownell, App D item 4)

f = 12650 psia

E = 0,85 (single welded butt join)

C = 1/8 in = 0,125 in

Ri = 11 ft = 132 in

Pdesain = 1,1 . Poperasi

= 1,1 . 14,7

= 16,17 psi

Tebal shell

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

$$= \frac{16{,}17.132}{(12650.0{,}85) - (0{,}6.16{,}17)} + \frac{1}{8} in$$

$$= 0{,}3237 \text{ in} \approx \frac{7}{16} \text{ in}$$

Menghitung tebal konis

$$\text{Tebal konis} = \frac{P.L.W}{2.f.E - (0{,}2.P)} + C \qquad \text{(B \& Y pers 7.77)}$$

L = di/2cos α (B & Y pers 13.17)

di = D – 2.icr.(1-cos α) (B & Y p. 260)

D = 22 ft = 132 in

Dari table 5.6 B&Y untuk t = 7/16 in didapat icr = 8

$$di = 132 - 2.8.(1\text{-}\cos 30) = 129{,}856 \text{ in}$$

$$L = \frac{129{,}856}{2.\cos 30} = 74{,}9724 \text{ in}$$

$$W = \tfrac{1}{4}.\left\{3 + \sqrt{L/icr}\right\} = \tfrac{1}{4}.\left\{3 + \sqrt{\frac{74{,}9724}{8}}\right\} = 1{,}52 \text{ in}$$

$$t = \frac{16{,}17.74{,}9724.1{,}52}{(2.12650.0{,}85) - (0{,}2.16{,}17)} + \frac{1}{8} in$$

$$= 0{,}2107 \text{ in} \approx \frac{3}{8} \text{ in}$$

Menghitung tutup atas (dished head)

$$\text{Tebal dished} = \frac{0{,}885.P.rc}{f.E - 0{,}1.P} + C$$ (Brownell,pers 13-12)

Dimana : Rc = ID = 22 ft = 132 in

$$t = \frac{0{,}885.16{,}17.132}{(12650.0{,}85) - (0{,}1.16{,}17)} + \frac{1}{8} in$$

$$= 0{,}3 \text{ in} \approx \frac{3}{8} \text{ in}$$

Dari table 5.6 Brownell didapat, untuk tebal dished = $\frac{3}{8}$ in, sf = 1 ½ - 3 in, icr = 1 $\frac{1}{8}$ in, diambil sf = 2 in

BC = r – icr (B&Y,p.87)

= 132 – 1,125 in = 130,875 in = 10,90625 ft = 3,32 m

a = ID/2 = 132/2 = 66 in = 5,5 ft = 1,7 m

AB = a – icr = 1,7 – 1,125 = 0,575 m

$b = r - \sqrt{BC^2 - AC^2} = 132 - \sqrt{130{,}875^2 - 22{,}6375^2} = 3{,}1$ in = 0,079 m

OA = t + b + sf = $\frac{3}{8}$ + 3,1 + 2 = 5,475 in = 0,13291 m

OD = ID + 2.t = 132 + 2. $\frac{3}{8}$ = 132,75 in = 3,4 m

Atomizer

Menentukan kecepatan atomizer

$$D_{50} = \frac{k.M^{a}}{N^{b}.di^{c}.(n.h)^{d}}.10^{-4}\,\mu m$$ (Van't land, pers. 8-1)

D_{50} = median diameter, μm (=152 μm)

K = konstanta

M = atomizer wheel feed, kg/j = 7249,0101 kg/jam = 266,3528 lb/menit

N = kecepatan putaran, rpm

di = diameter roda atomizer, m (=0,25 m = 0,8202 ft (Van't land hal 163))

n = banyaknya vane dalam roda (=45)

h = tinggi vane roda atomizer (= 30 mm = 0,03 m)

Vane liquid loading = r = feed masuk / Lw

Dimana Lw = wetted dish peripheral

= π.Di = π . 0,25 = 0,7854 m

r = 7249,0101 kg/jam / 0,7854 m = 9229,705 kg/jam.m

Dari table 8.1 Van't Land didapat :

a = 0,12

b = 0,8

c = 0,6

d = 0,12

k = 1,2

$$152 = \frac{1,2.(7249,0101)^{0,12}}{N^{0,8}.(0,25)^{0,6}.(45.0,03)^{0,12}}.10^{-4}\ \mu m$$

N = 2456,0526 rpm ≈ 2500 rpm

Menghitung power yang dibutuhkan :

$P = 1,04.10^{-8}.(r.N)^{2}.W$

Dimana : P = Hp netto, Hp

r = jari-jari roda atomizer, ft

N = putara disk, rpm

W = rate feed, lbm/menit

$P = 1,04.10^{-8} . (0,4101.2500)^{2} . 266,3528$ lbm/menit

P = 2,9 Hp ≈ 3 Hp

36. Cyclone Spray Dryer (H-333)

Fungsi : Memisahkan debu yang terbawa oleh gas yang keluar dari Spray Dryer

Perhitungan :

Kapasitas : 4427,01082 kg/hari = 184,4588 kg/jam

Nozzle gas masuk ukuran 15" (fig 14-2 Peter and Timmerhaus)

Standar pipe ukuran nozzle : 15,25 in (Tabel 13,p.888 Peter and Timmerhaus)

Luas penampang nozzle : $\frac{1}{4}\ \mu Di^2 = \frac{1}{4}\ \pi.15{,}25^2 = 182{,}65\ in^2 = Ac$

Dari Perry edisi 6 hal 20-82, didapatkan penampang gas masuk :

$Ac = Bc \times Hc$

$Hc = 2 \times Bc$

$Ac = 2 \times Bc^2$

$$Bc = \sqrt{\frac{Ac}{2}} = \sqrt{\frac{182{,}654}{2}} = 9{,}55\ in$$

$Dc = Bc \times 4 = 9{,}55\ in \times 4 = 38{,}226\ in$

$De = Dc/2 = 38{,}226\ in / 2 \quad = 19{,}113\ in$

$Hc = Dc/2 = 38{,}226\ in / 2 \quad = 19{,}113\ in$

$Lc = 2 \times Dc = 2 \times 38{,}226\ in \quad = 76{,}45\ in$

$Sc = Dc/8 = 38{,}226\ in / 8 \quad = 4{,}778\ in$

$Zc = 2 \times Dc = 2 \times 38{,}226\ in \quad = 76{,}452\ in$

$Jc = Dc/4 = 38{,}226\ in / 4 \quad = 9{,}5565\ in$

Dimana :

Ac = luas penampang gas masuk, in^2

Dc = diameter cyclone, in

De = diameter lubang pengeluaran gas

Hc = diameter lubang masuk, in

Lc = tinggi cyclone bagian silinder, in

Zc = tinggi cyclone bagian kerucut, in

Jc = diameter lubang pengeluaran partikel, in

Spesifikasi :

1. Type : Effluent Dust Cyclone
2. Kapasitas : 1074,177 lb/menit

3. Ukuran : $Ac = 182,65\ in^2$

$Bc = 9,55$ in

$Dc = 38,226$ in

$De = 19,113$ in

$Hc = 19,113$ in

$Lc = 76,45$ in

$Sc = 4,778$ in

$Zc = 76,45$ in

$Jc = 5,9965$ in

37. CRUSHER (C-340)

Fungsi : menghancurkan gelatin dengan ukuran 6 mm

Tipe : Jaw crusher

Kondisi operasi : $T = 30^0C$

Tulang yang harus dihancurkan = 7249,0101 kg/hari = 0,302 ton/jam ≈ 1 ton/jam.

Dasar pemilihan :

- Kapasitas 1 ton/jam dapat digunakan Dodge jaw crusher

(Perry 6th ed., table 8-7)

Spesifikasi :

- Fungsi : menghancurkan gelatin dengan ukuran 6 mm
- Tipe : Dodge jaw crusher
- Kecepatan putaran jaw : 275 rpm
- Power : 3 Hp
- Setting : 1 in
- Crusher size : 4 x 6 in
- Jaw motion : ½ in
- Jumlah : 1 buah

APPENDIKS D.

PERHITUNGAN ANALISA EKONOMI

APPENDIX D
PERHITUNGAN ANALISA EKONOMI

Harga alat akan berubah setiap saat tergantung pada kondisi ekonomi dan politik, untuk itu dibutuhkan suatu metode yang dapat dipakai untuk mengkonversi harga alat pada beberapa tahun yang lalu agar dapat diperoleh harga alat yang ekivalen untuk waktu sekarang.

Ekivalensi itu dapat dihitung dengan menggunakan persamaan :

$$\text{Harga alat saat ini} = \frac{\text{Indeks harga saat ini}}{\text{Indeks harga tahun X}} \times \text{Harga alat tahun X}$$

Harga alat yang digunakan dalam pra rencana ini didasarkan pada harga alat yang terdapat pada pustaka:

a. Garret, D.E.,1989, " Chemichal Engineering Economics", Van Nostrand Reinhold, New York.
b. Peters,M.S., Timmerhouse,K.D., 1991, " Palant Design and Economics for Chemical Engineers", 4^{th} ed., McGraw Hill Co, Singapore
c. Ulrich, G.D.,1984, "A Guide To Chemical Engineering Process Design and Economic" John Willey and Sons, Singapore

Dalam perhitungan ini digunakan indeks harga sebagai berikut:

- Marshall & Swift equipment cost index
  Tahun X (Januari 1990) = 904 (Peters & Timmerhaus, tabel 3, p.163)
  Saat ini (Juni 2002) = 1073,5 (Chemical Engineering, Januari 2002)
- Chemical engineering plant cost index
  Tahun X (awal 1987) = 320 (Garret, p. 255)
  Saat ini (awal 2002) = 394,3 (Chemical Engineering, Januari 2002)

A. Perhitungan Harga Peralatan

Contoh perhitungan :

Nama alat : Bucket elevator (J-141)

Fungsi : memindahkan tulang dari gudang bahan baku (F-130) ke crusher (C-142)

Tipe : centrifugal discharge bucket.

Jumlah : 1 buah

Harga tahun 1990 : $6500 (Peters & Timmerhaus, fig. 14-90, p.569)

Harga alat saat ini : $\dfrac{1073{,}5}{904}$ x \$ 6500 = \$ 7718,75

Dengan cara yang sama didapatkan harga alat yang lain seperti pada tabel D.1.

Tabel D.1. Harga Peralatan Proses

Nama alat	Kode	Jumlah	Harga tahun 2002, @ $	Total $
Tangki HCl	F-110	1	123437,5	123437,5
Tangki Kapur	F-120	1	42323,121	42323,121
Tangki Demineralisasi	F-140	7	132661,7056	928631,9393
Bucket elevator	J-141	1	7718,75	7718,75
Crusher	C-142	1	14786,25	14786,25
Bucket elevator	J-143	1	7718,75	7718,75
Rotary vacuum filter	H-144	1	59375	59375
Pompa	L-145	7	111,11	777,77
Tangki Liming	F-150	7	71250	498750
Rotary vacuum filter	H-151	1	77187,5	77187,5
Pompa	L-152	1	200	200
Tangki Netralisasi	F-160	1	77187,5	77187,5
Rotary vacuum filter	H-161	1	45125	45125
Pompa	L-162	1	111,11	111,11
Storage bin	F-163	1	1500	1500
Tangki ekstraksi I	F-210	1	10093,75	10093,75
Tangki ekstraksi II	F-220	1	10006,25	10006,25
Rotary vacuum filter	H-221	1	34437,5	34437,5
Tangki ekstraksi III	F-230	1	11281,25	11281,25
Tangki ekstraksi IV	F-240	1	11340,625	11340,625
Rotary vacuum filter	H-241	1	27312,5	27312,5
Tangki ekstraksi V	F-250	1	14250	14250

Rotary vacuum filter	H-251	1	24937,5	24937,5
Tangki penampung hasil ekstraksi	F-252	1	1971,5	1971,5
Pompa	L-253	1	111,11	111,11
Evaporator	V-310	1	77187,5	77187,5
Barometric condensor	E-311	1	1306,25	1306,25
Steam ejector	G-312	1	593,75	593,75
Hot well	F-313	1	415,625	415,625
Pompa	L-314	1	111,11	111,11
Coller	B-320	1	21375	21375
Pompa	L-321	1	111,11	111,11
Spray dryer	B-330	1	110896,875	110896,875
Shell & tube	E-331	1	17218,75	17218,75
Blower	G-332	1	25875,9375	25875,9375
Cyclone	H-333	1	2800	2800
Crusher	C-340	1	14786,25	14786,25
Total				2.303.250,333

Tabel D.2. Harga Peralatan Utilitas

No	Nama alat	Kode	Jml	Total US $
1	Filter	H-413	1	1710
2	Tangki demineralisasi	H-418	1	52563,12
3	Tangki pengisi boiler	F-422	1	3176
4	Pompa air sumur	L-410	1	111,11
5	Pompa air ke filter	L-415	1	111,11
6	Pompa air sanitasi	L-412	1	111,11
7	Pompa tangki demineralisasi	L-417	1	111,11
8	Pompa air pendingin	L-420	1	111,11
9	Pompa air boiler	L-426	1	111,11
10	Pompa air refrigerant	L-425	1	111,11
11	Pompa air proses	L-424	1	111,11
11	Boiler	-	1	12842
12	Generator	-	1	21620
13	Tangki penampung IDO	-	1	14750
14	Refrigeration	-	1	27623,9733
	Total			135173,9733

Tabel D.3 Bak Utilitas

No	Nama Alat	Kode	Jml	Luas/m^2
1	Bak penampung air sumur	F-411	1	68,04
2	Bak penampung air bersih	F-414	1	68,2889
3	Bak penampung air demineralisasi	F-419	1	109,44
4	Bak air pendingin	F-423	1	27,3597
5	Bak air sanitasi	F-416	1	18,4157
6	Bak penampung air proses	F-421	1	46,0649
	Total			337,6092

Harga bak = Rp. 275.000,- /m^2

Total harga bak utilitas = 337,6092m^2.(Rp. 275.000,- /m^2)

= Rp. 92842530,-

Total harga peralatan = ((\$2303250,333 + \$135173,9733) x Rp.9000,-/\$)

+Rp.92842530,-

= Rp. 22.038.661.290,-

B. **Perhitungan Harga Tanah dan Bangunan**

Luas tanah = 10.000 m^2

Luas pabrik dan gudang = 1.875 m^2

Luas bangunan kantor = 400 m^2

Luas bangunan lain-lain = 2.091 m^2

Harga tanah = Rp. 150.000,- /m^2

Harga bangunan pabrik dan gudang = Rp. 1.000.000,-/m^2

Harga bangunan kantor = Rp. 1.250.000,-/m^2

Harga bangunan lain-lain = Rp. 750.000,-/m^2

Jadi :

Harga tanah = 10.000 m^2 x Rp.150.000,-/m^2 = Rp.1.500.000.000,-

Harga bangunan pabrik dan gudang = 1.875 m^2 x Rp. 1.000.000,-/m^2

= Rp.1.875.000.000,-/m^2

Harga bangunan kantor = 400 m^2 x Rp. 1.250.000,-/m^2

= Rp.500.000.000,-

Harga bangunan lain-lain = 2.091 m^2 x Rp. 750.000,-/m^2

= Rp.1.568.250.000,-

Total harga tanah dan bangunan = Rp.1.568.250.000,- + Rp.1.875.000.000,- + Rp.500.000.000,- + Rp.1.500.000.000,-

= Rp.5.443.250.000,-

C. Perhitungan Harga Bahan Baku dan Harga Jual Produk

➤ Harga Bahan Baku

1. Tulang

   Harga : Rp.1000,-/kg

   Kebutuhan : 13500 kg/hari

   Total : Rp. 4.455.000.000,- / tahun

2. HCl

   Harga : Rp.2500,-/liter

   Kebutuhan : 20647,2617 kg/hari

   Total : Rp. 14.449.054.900,- / tahun

3. CaO

   Harga : Rp. 1000,-/kg

   Kebutuhan : 1798,2 kg/hari

   Total : Rp. 593.406.000,- / tahun

Total harga bahan baku per tahun :

= Rp. 4.455.000.000,- + Rp. 14.449.054.900,- + Rp. 593.406.000,-

= Rp. 19.497.460.900,-

➤ Harga Jual Produk

Harga : Rp. 70000,- / kg

Produksi : 2849,079115 kg/hari

Total : Rp.65.813.727.500,-

D. Perhitungan Gaji Karyawan

Perincian gaji karyawan tiap bulan dapat dilihat pada tabel D.4 berikut ini.

Tabel D.4 Gaji Karyawan

No	Jabatan	Jumlah	Gaji/bulan (Rp)	Total (Rp)
1	Direktur Utama	1	7.000.000,00	7.000.000,00
2	Direktur Teknik & Produksi	1	5.000.000,00	5.000.000,00
3	Direktur Administrasi & Keuangan	1	5.000.000,00	5.000.000,00
4	Sekretaris	3	1.000.000,00	3.000.000,00
5	Kabag Produksi	1	2.500.000,00	2.500.000,00
6	Kabag Teknik	1	2.500.000,00	2.500.000,00
7	Kabag Keuangan	1	2.500.000,00	2.500.000,00
8	Kabag Pemasaran	1	2.500.000,00	2.500.000,00
9	Kabag Personalia & Umum	1	2.500.000,00	2.500.000,00
10	Kasie Proses	1	1.500.000,00	1.500.000,00
11	Kasie Penelitian & Pengembangan	1	1.500.000,00	1.500.000,00
12	Kasie Utilitas	1	1.500.000,00	1.500.000,00
13	Kasie Pemeliharaan & Perbaikan	1	1.500.000,00	1.500.000,00
14	Kasie Laboratorium & QC	1	1.500.000,00	1.500.000,00
15	Kasie Promosi & Penjualan	1	1.500.000,00	1.500.000,00
16	Kasie Keuangan	1	1.500.000,00	1.500.000,00
17	Kasie Pembelian	1	1.500.000,00	1.500.000,00
18	Kasie Gudang	1	1.500.000,00	1.500.000,00
19	Kasie Personalia	1	1.500.000,00	1.500.000,00
20	Kasie Keamanan	1	1.500.000,00	1.500.000,00
21	Seksi Proses	20	1.000.000,00	20.000.000,00
22	Seksi Penelitian & Pengembangan	2	1.000.000,00	2.000.000,00
23	Seksi Utilitas	8	1.000.000,00	8.000.000,00
24	Seksi Pemeliharaan & Perbaikan	6	1.000.000,00	6.000.000,00
25	Seksi Laboratorium & QC	4	1.000.000,00	4.000.000,00
26	Seksi Promosi & Penjualan	4	1.000.000,00	4.000.000,00
27	Seksi Keuangan	2	1.000.000,00	2.000.000,00
28	Seksi Pembelian	2	1.000.000,00	2.000.000,00
29	Seksi Personalia	2	1.000.000,00	2.000.000,00
30	Seksi Gudang	6	800.000,00	4.800.000,00
31	Seksi Keamanan	10	800.000,00	8.000.000,00
32	Sopir & Pesuruh	8	600.000,00	4.800.000,00
TOTAL		96		116.600.000,00

Total gaji karyawan per bulan = Rp. 116.600.000,00

Ditetapkan 1 tahun produksi adalah 12 bulan + 1 bulan tunjangan, jadi gaji karyawan per tahun :

= Rp. 116.600.000,00 x 13

= Rp. 1.515.800.000,00

E. Pehitungan Biaya Utilitas

1. Kebutuhan Air

   Air yang harus disuplai per hari = 1028,1907 m^3/hari

   Harga pengolahan air sumur = Rp.1000,- / m^3

   Biaya air = 1028,1907 m^3/hari x Rp.1000,- / m^3 x 330 hari/tahun

   = Rp. 339.302.931,- / tahun

2. Kebutuhan Listrik

   Kebutuhan listrik untuk penerangan = 29,690 kVA

   Kebutuhan listrik untuk motor penggerak peralatan & utilitas, perkantoran

   = 258,4686 kVA

   Total kebutuhan listrik = 288,1586 kVA

   Beban listrik terpasang =1,25 × 288,1586 = 360,2 kVA

   Biaya beban per bulan = Rp.25.000,-

   Biaya beban per tahun = 12 bulan x Rp.25.000,-/bulan = Rp.300.000,-

   Biaya listrik : WBP = Rp. 455,-/kVA (pk. 18.00 – 22.00)

   LWBP = Rp. 350,-/kVA (pk. 22.00 – 18.00)

   Biaya listrik terpakai per tahun :

   = [((4 jam x 288,1586 kVA x Rp. 455,-/kVA) + (20 jam x 288,1586 kVA x Rp. 350,-/kVA)) x 330 hari/tahun] + [30 hari x 29,690 kVA x(4 jam x Rp. 455,-/kVA + 20 jam x Rp. 350,-/kVA)]

   = Rp.846.570.395,-

   Biaya listrik total per tahun = biaya beban + biaya listrik terpakai

   = Rp.300.000,- + Rp.846.570.395,-

   = Rp.846.870.395,-

3. Kebutuhan bahan bakar

   Kebutuhan bahan bakar per bulan = 63996 lt

   Harga bahan bakar per liter = Rp.1440,-

   Biaya bahan bakar per tahun = 63996 lt/bln x 12 bln/th x Rp.1440,-

   = Rp.1.105.850.880,-

Total biaya utilitas per tahun = Rp.1.105.850.880,- + Rp.846.870.395,- + Rp.339.302.931,-

= Rp. 2.292.024.206,-