APPENDIX A

PERHITUNGAN NERACA MASSA

Kapasitas produksi = 10.000 ton / tahun

= 30,3031 ton / hari = 1262,63 kg / jam

(asumsi 1 tahun = 330 hari dan 1 hari = 24 jam)

Basis operasi = 1 jam

Berat molekul :

$Ca_3(PO_4)_2$	= 310	HCl	= 36,5
$CaCO_3$	= 100	H_2O	= 18
$CaCl_2$	= 111	CO_2	= 44
$Mg_3(PO_4)_2$	= 262	H_3PO_4	= 98
$MgCO_3$	= 84	$Ca(OH)_2$	= 74
$MgCl_2$	= 95		

Protein = 7139 (www.ccp4.ac.uk)

Lemak = 539 (www.usd.edu/biol/courses/cellthies/cpa3answers.html)

Perhitungan :

- Produk akhir berupa gelatin dengan kadar 99,47 % berat.
- Feed berupa bongkahan tulang yang mempunyai komposisi sebagai berikut (Nicholas-Simonnot, dkk., 1997) :

- $Ca_3(PO_4)_2$ 52%
- Protein 29%
- Garam mineral 12%
- Lemak 1%
- H_2O 6%

- Komposisi protein adalah sebagai berikut (Nicholas-Simonnot, dkk., 1997) :

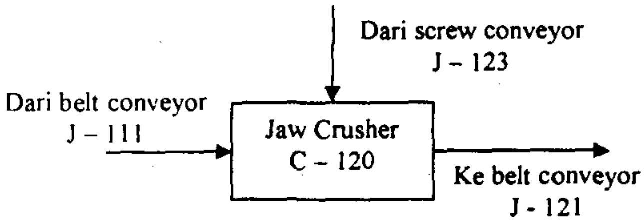
- Arginine	7,8%	- Lycine	3,5%
- Asperic acid	6,0%	- Methionine	0,7%
- Glutamic acid	10,0%	- Phenylanine	2,4%
- Glycine	21,4%	- Proline	12,4%
- Histidine	0,8%	- Serine	3,6%
- Hydoxylysine	1,0%	- Theronine	2,1%
- Hydroxyproline	11,9%	- Tyrosine	0,5%
- Isoleucine	1,5%	- Valine	2,2%

- Komposisi garam mineral adalah sebagai berikut (Nicholas-Simonnot, dkk., 1997):
  - $CaCO_3$ 30%
  - $MgCO_3$ 30%
  - $Mg_3(PO_4)_2$ 40%
- Total kebutuhan tulang masuk adalah 505,05 kg untuk setiap kebutuhan 1262,63 kg produk gelatin.
- Impurities adalah Kalsium Fosfat ($Ca_3(PO_4)_2$) dan garam-garam mineral.

- ρ HCl pada 30 °C = 1,16775 kg / lt (Perry, 1999)
- ρ H_2O pada 30 °C = 0,99568 kg / lt (Perry, 1999)
- Kelarutan $Ca_3(PO_4)_2$ adalah 0,0025 gram dalam 100 gram H_2O (Perry, 1999)

NERACA MASSA PADA JAW CRUSHER C – 120

Recycle yang masuk dari Screw Conveyor J – 123 sebesar 20% dari massa total yang keluar dari Jaw Crusher C – 120 dan mempunyai komposisi yang sama dengan feed masuknya.



- **Masuk**
  - Dari Belt Conveyor J – 111

    Tulang sebanyak 505,05 kg yang terdiri dari :

    » $Ca_3(PO_4)_2$ = 52% . 505,05 kg = 262,63 kg

    » Protein = 29% . 505,05 kg = 146,46 kg

    » Garam mineral = 12% . 505,05 kg = 60,61 kg

    ⇒ $CaCO_3$ = 30% . 60,61 kg = 18,18 kg

    ⇒ $MgCO_3$ = 30% . 60,61 kg = 18,18 kg

    ⇒ $Mg_3(PO_4)_2$ = 40% . 60,61 kg = 24,25 kg

» Lemak = 1% . 505,05 kg = 5,05 kg

» H_2O = 6% . 505,05 kg = 30,3 kg

- <u>Dari Screw Conveyor J – 123</u>

Massa masuk dari Belt Conveyor J – 111 + recycle = massa keluar dari Jaw Crusher C – 120

505,05 kg . R . massa keluar dari Jaw Crusher C 120
R . 20% massa keluar dari Jaw Crusher C 120

R = 0,25.505,05 kg

R = 126,26 kg

Tulang = 126,26 kg, yang terdiri dari :

» $Ca_3(PO_4)_2$ = 52% . 126,26 kg = 65,66 kg

» Protein = 29% . 126,26 kg = 36,62 kg

» Garam mineral = 12% . 126,26 kg = 15,14 kg

⇒ $CaCO_3$ = 30% . 15,14 kg = 4,54 kg

⇒ $MgCO_3$ = 30% . 15,14 kg = 4,54 kg

⇒ $Mg_3(PO_4)_2$ = 40% . 15,14 kg = 6,06 kg

» Lemak = 1% . 126,26 kg = 1,26 kg

» H_2O = 6% . 126,26 kg = 7,58 kg

- **Keluar**

- <u>Ke Belt Conveyor J – 121</u>

Tulang = tulang dari (J – 111 + J – 123)

= (505,05 + 126,26) kg

= 631,31 kg , yang terdiri dari :

» $Ca_3(PO_4)_2$ = $Ca_3(PO_4)_2$ dari (J – 111 + J – 123)

= (262,63 + 65,66) kg = 328,29 kg

» Protein = Protein dari (J – 111 + J – 123)

= (146,46 + 36,62) kg

= 183,08 kg

» Garam mineral = Garam mineral dari (J – 111 + J – 123)

= (60,61 + 15,14) kg

= 75,75 kg

⇒ $CaCO_3$ = $CaCO_3$ dari (J – 111 + J – 123)

= (18,18 + 4,54) kg = 22,72 kg

⇒ $MgCO_3$ = $MgCO_3$ dari (J – 111 + J – 123)

= (18,18 + 4,54) kg = 22,72 kg

⇒ $Mg_3(PO_4)_2$ = $Mg_3(PO_4)_2$ dari (J – 111 + J – 123)

= (24,25 + 6,06) kg = 30,31 kg

» Lemak = Lemak dari (J – 111 + J – 123)

= (5,05 + 1,26) kg

= 6,31 kg

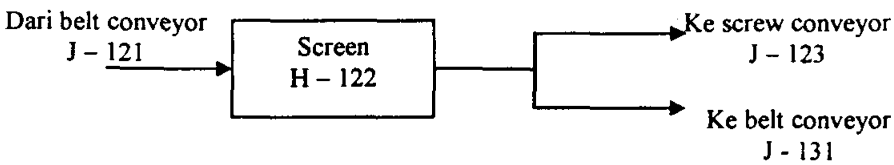
» H_2O = Air dari (J – 111 + J – 123)

= (30,3 + 7,58) kg

= 37,88 kg

NERACA MASSA PADA SCREEN H – 122

Tulang yang masuk ke screw conveyor J – 123 merupakan oversize sedangkan yang masuk ke belt conveyor J – 131 merupakan undersize.



- **Masuk**

  - Dari Belt Conveyor J – 121

  Tulang = tulang dari (J – 111 + J – 123)

  = (505,05 + 126,26) kg = 631,31 kg , yang terdiri dari :

  » $Ca_3(PO_4)_2$ = $Ca_3(PO_4)_2$ dari (J – 111 + J – 123)

  = (262,63 + 65,66) kg

  = 328,29 kg

  » Protein = Protein dari (J – 111 + J – 123)

  = (146,46 + 36,62) kg

  = 183,03 kg

  » Garam mineral = Garam mineral dari (J – 111 + J – 123)

  = (60,61 + 15,14) kg

  = 75,75 kg

  ⇒ $CaCO_3$ = $CaCO_3$ dari (J – 111 + J – 123)

  = (18,18 + 4,54) kg = 22,72 kg

⇒ $MgCO_3$ = $MgCO_3$ dari (J – 111 + J – 123)

= (18,18 + 4,54) kg = 22,72 kg

⇒ $Mg_3(PO_4)_2$ = $Mg_3(PO_4)_2$ dari (J – 111 + J – 123)

= (24,25 + 6,06) kg = 30,31 kg

» Lemak = Lemak dari (J – 111 + J – 123)

= (5,05 + 1,26) kg

= 6,31 kg

» H_2O = H_2O dari (J – 111 + J – 123)

= (30,3 + 7,58) kg

= 37,88 kg

- **Keluar**

- Ke Screw Conveyor J – 123

Tulang = tulang masuk ke Jaw Crusher C – 120 dari Screw Conveyor J – 123

= 126,26 kg , yang terdiri dari :

» $Ca_3(PO_4)_2$ = 52% . 126,26 kg = 65,66 kg

» Protein = 29% . 126,26 kg = 36,62 kg

» Garam mineral = 12% . 126,26 kg = 15,14 kg

⇒ $CaCO_3$ = 30% . 15,14 kg = 4,54 kg

⇒ $MgCO_3$ = 30% . 15,14 kg = 4,54 kg

⇒ $Mg_3(PO_4)_2$ = 40% . 15,14 kg = 6,06 kg

» Lemak = 1% . 126,26 kg = 1,26 kg

» H_2O = 6% . 126,26 kg = 7,58 kg

- <u>Ke *Belt Conveyor* J – 131</u>

Tulang = (tulang masuk dari Belt Conveyor J – 121) – (tulang keluar ke Screw Conveyor J – 123)

= 631,31 kg – 126,26 kg

= 505,05 kg , yang terdiri dari :

» $Ca_3(PO_4)_2$ = 52% . 505,05 kg = 262,63 kg

» Protein = 29% . 505,05 kg = 146,46 kg

» Garam mineral = 12% . 505,05 kg = 60,61 kg

⇒ $CaCO_3$ = 30% . 60,61 kg = 18,18 kg

⇒ $MgCO_3$ = 30% . 60,61 kg = 18,18 kg

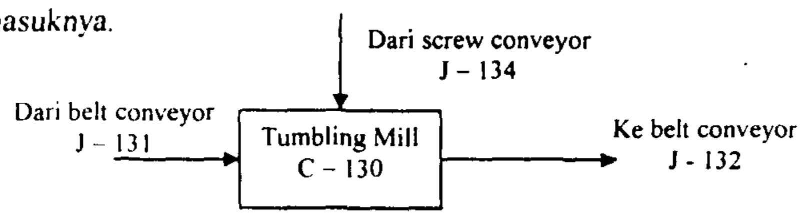
⇒ $Mg_3(PO_4)_2$ = 40% . 60,61 kg = 24,25 kg

» Lemak = 1% . 505,05 kg = 5,05 kg

» H_2O = 6% . 505,05 kg = 30,3 kg

NERACA MASSA PADA TUMBLING MILL *C – 130*

Recycle yang masuk dari Screw Conveyor J – 134 sebesar 20% dari massa total yang keluar dari Tumbling Mill C – 130 dan mempunyai komposisi yang sama dengan feed masuknya.



- **Masuk**

  - Dari Belt Conveyor J – 131

    Tulang sebanyak 505,05 kg yang terdiri dari :

    » $Ca_3(PO_4)_2$ = 52% . 505,05 kg = 262,63 kg

    » Protein = 29% . 505,05 kg = 146,46 kg

    » Garam mineral = 12% . 505,05 kg = 60,61 kg

    ⇒ $CaCO_3$ = 30% . 60,61 kg = 18,18 kg

    ⇒ $MgCO_3$ = 30% . 60,61 kg = 18,18 kg

    ⇒ $Mg_3(PO_4)_2$ = 40% . 60,61 kg = 24,25 kg

    » Lemak = 1% . 505,05 kg = 5,05 kg

    » H_2O = 6% . 505,05 kg = 30,3 kg

  - Dari Screw Conveyor J – 134 (recycle = R)

    Massa masuk dari Belt Conveyor J – 131 + R = massa keluar dari Tumbling Mill C - 130

    505,05 kg . R . massa keluar dari Tumbling Mill C 130
    R . 20% massa keluar dari Tumbling Mill C 130

    $$R = \frac{1}{4} . 505,05 \text{ kg}$$

    R = 126,26 kg

    Tulang = 126,26 kg , yang terdiri dari :

    » $Ca_3(PO_4)_2$ = 52% . 126,26 kg = 65,66 kg

    » Protein = 29% . 126,26 kg = 36,62 kg

    » Garam mineral = 12% . 126,26 kg = 15,14 kg

⇒ $CaCO_3$ = 30% . 15,14 kg = 4,54 kg

⇒ $MgCO_3$ = 30% . 15,14 kg = 4,54 kg

⇒ $Mg_3(PO_4)_2$ = 40% . 15,14 kg = 6,06 kg

» Lemak = 1% . 126,26 kg = 1,26 kg

» H_2O = 6% . 126,26 kg = 7,58 kg

- **Keluar**

- <u>Ke Belt Conveyor J – 132</u>

Tulang = tulang dari (J – 131 + J – 134)

= (505,05 + 126,26) kg

= 631,31 kg, yang terdiri dari :

» $Ca_3(PO_4)_2$ = $Ca_3(PO_4)_2$ dari (J – 131 + J – 134)

= (262,63 + 65,66) kg

= 328,29 kg

» Protein = Protein dari (J – 131 + J – 134)

= (146,46 + 36,62) kg = 183,03 kg

» Garam mineral = Garam mineral dari (J – 131 + J – 134)

= (60,61 + 15,14) kg = 75,75 kg

⇒ $CaCO_3$ = $CaCO_3$ dari (J – 131 + J – 134)

= (18,18 + 4,54) kg = 22,72 kg

⇒ $MgCO_3$ = $MgCO_3$ dari (J – 131 + J – 134)

= (18,18 + 4,54) kg = 22,72 kg

⇒ $Mg_3(PO_4)_2$ = $Mg_3(PO_4)_2$ dari (J – 131 + J – 134)

= (24,25 + 6,06) kg = 30,31 kg

» Lemak = Lemak dari (J – 131 + J – 134)

= (5,05 + 1,26) kg

= 6,31 kg

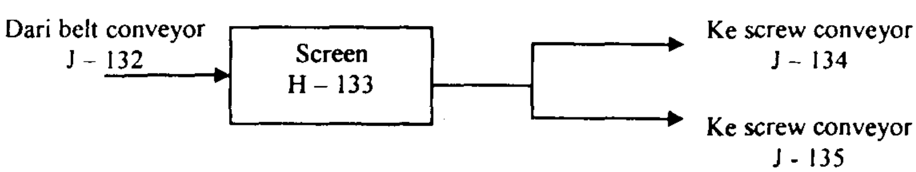
» H_2O = H_2O dari (J – 131 + J – 134)

= (30,3 + 7,58) kg

= 37,88 kg

NERACA MASSA PADA SCREEN H – 133

Tulang yang masuk ke screw conveyor J – 134 merupakan oversize sedangkan yang masuk ke screw conveyor J – 135 merupakan undersize.



- **Masuk**

  - Dari Belt Conveyor J – 132

    Tulang = tulang dari (J – 131 + J – 134)

    = (505,05 + 126,26) kg

    = 631,31 kg, yang terdiri dari :

» $Ca_3(PO_4)_2$ = $Ca_3(PO_4)_2$ dari (J – 131 + J – 134)

= (262,63 + 65,66) kg

= 328,29 kg

» Protein = Protein dari (J – 131 + J – 134)

= (146,46 + 36,62) kg

= 183,03 kg

» Garam mineral = Garam mineral dari (J – 131 + J – 134)

= (60,61 + 15,14) kg

= 75,75 kg

⇒ $CaCO_3$ = $CaCO_3$ dari (J – 131 + J – 134)

= (18,18 + 4,54) kg = 22,72 kg

⇒ $MgCO_3$ = $MgCO_3$ dari (J – 131 + J – 134)

= (18,18 + 4,54) kg = 22,72 kg

⇒ $Mg_3(PO_4)_2$ = $Mg_3(PO_4)_2$ dari (J – 131 + J – 134)

= (24,25 + 6,06) kg = 30,31 kg

» Lemak = Lemak dari (J – 131 + J – 134)

= (5,05 + 1,26) kg

= 6,31 kg

» H_2O = H_2O dari (J – 131 + J – 134)

= (30,3 + 7,58) kg

= 37,88 kg

- **Keluar**

- <u>Ke Screw Conveyor J – 134</u>

Tulang = tulang masuk ke Tumbling Mill C – 130 dr Screw Conveyor J – 134

= 126,26 kg , yang terdiri dari :

» $Ca_3(PO_4)_2$ = 52% . 126,26 kg = 65,66 kg

» Protein = 29% . 126,26 kg = 36,62 kg

» Garam mineral = 12% . 126,26 kg = 15,14 kg

⇒ $CaCO_3$ = 30% . 15,14 kg = 4,54 kg

⇒ $MgCO_3$ = 30% . 15,14 kg = 4,54 kg

⇒ $Mg_3(PO_4)_2$ = 40% . 15,14 kg = 6,06 kg

» Lemak = 1% . 126,26 kg = 1,26 kg

» H_2O = 6% . 126,26 kg = 7,58 kg

- <u>Ke Screw Conveyor J – 135</u>

Tulang = (tulang masuk dari Belt Conveyor J – 132) – (tulang keluar ke Screw Conveyor J – 134)

= 631,31 kg – 126,26 kg

= 505,05 kg , yang terdiri dari :

» $Ca_3(PO_4)_2$ = 52% . 505,05 kg = 262,63 kg

» Protein = 29% . 505,05 kg = 146,46 kg

» Garam mineral = 12% . 505,05 kg = 60,61 kg

⇒ $CaCO_3$ = 30% . 60,61 kg = 18,18 kg

⇒ $MgCO_3$ = 30% . 60,61 kg = 18,18 kg

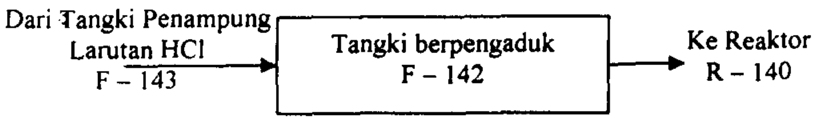
⇒ $Mg_3(PO_4)_2$ = 40% . 60,61 kg = 24,25 kg

» Lemak = 1% . 505,05 kg = 5,05 kg

» H_2O = 6% . 505,05 kg = 30,3 kg

NERACA MASSA PADA TANGKI BERPENGADUK F – 142

Larutan asam klorida yang masuk berlebih dan mempunyai kadar 35% berat diencerkan sampai mempunyai konsentrasi 50 gr / lt.



$Ca_3(PO_4)_2$ masuk reaktor = $Ca_3(PO_4)_2$ dari screw conveyor J – 135

= 262,63 kg

= 0,8472 kmol

$CaCO_3$ masuk reaktor = $CaCO_3$ dari screw conveyor J – 135

= 18,18 kg

= 0,1818 kmol

$MgCO_3$ masuk reaktor = $MgCO_3$ dari screw conveyor J – 135

= 18,18 kg

= 0,2164 kmol

$Mg_3(PO_4)_2$ masuk reaktor = $Mg_3(PO_4)_2$ dari screw conveyor J – 135

= 24,25 kg = 0,0926 kmol

Reaksi yang terjadi pada reaktor R – 140 adalah :

I. $Ca_3(PO_4)_2 + 6\ HCl \rightarrow 3\ CaCl_2 + 2\ H_3PO_4$

0,8472 ~ 5,0832 ~ 2,5416 ~ 1,6944

II. $CaCO_3 + 2\ HCl \rightarrow CaCl_2 + H_2O + CO_2$

0,1818 ~ 0,3636 ~ 0,1818 ~ 0,1818 ~ 0,1818

III. $MgCO_3 + 2\ HCl \rightarrow MgCl_2 + H_2O + CO_2$

0,2164 ~ 0,4328 ~ 0,2164 ~ 0,2164 ~ 0,2164

IV. $Mg_3(PO_4)_2 + 6\ HCl \rightarrow 3\ MgCl_2 + 2\ H_3PO_4$

0,0926 ~ 0,5556 ~ 0,2778 ~ 0,1852

HCl yang dibutuhkan = (5,0832 + 0,3636 + 0,4328 + 0,5556) kmol

= 6,4352 kmol

= 234,88 kg

Asumsi : HCl masuk = 7 kmol = 255,5 kg

- **Masuk**

  - Dari Tangki Penampung Larutan HCl F – 143

    Larutan asam klorida :

    » HCl = 255,5 kg

    » H_2O $= \frac{65\%}{35\%} \cdot 255{,}5\ kg = 474{,}5\ kg$

    $= \frac{474{,}5\ kg}{0{,}99568\ kg/lt} = 476{,}5587\ lt$

    Massa larutan asam klorida total = (255,5 + 474,5) kg = 730 kg

- <u>Dari WD (Water Demineralized)</u>

$$\text{Volume HCl} = \frac{\text{massa HCl}}{\rho\ \text{HCl}} = \frac{255{,}5\ \text{kg}}{1{,}16775\ \text{kg/lt}} = 218{,}7968\ \text{lt}$$

Volume larutan HCl dari Tangki Penampung F – 143

= volume HCl + volume air

V_1 = 218,7968 lt + 476,5587 lt

V_1 = 695,3555 lt

Konsentrasi larutan HCl dari Tangki Penampung F – 143 $= \frac{255{,}5\ \text{kg} \cdot 1000\ \text{gr/kg}}{695{,}3555\ \text{lt}}$

M_1 = 367,438 gr/lt

$V_1 \cdot M_1 = V_2 \cdot M_2$

$695{,}3555\ \text{lt} \cdot 367{,}438\ \text{gr/lt} = V_2 \cdot 50\ \text{gr/lt}$

V_2 = 5110 lt

H_2O dari WD yang perlu ditambahkan = V_2 – volume HCl

= 5110 lt – 218,7968 lt

= 4891,2032 lt

= 4870,07 kg

- **Keluar**

- <u>Ke Reaktor R – 140</u>

Larutan asam klorida :

» HCl = 255,5 kg

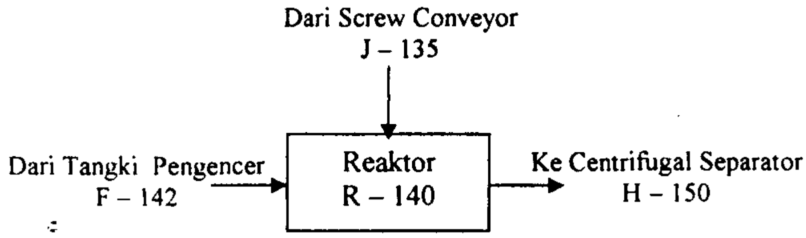
» H_2O = H_2O dari (WD + L – 145)

= (4870,07 +474,5) kg

= 5344,57 kg

Massa total larutan asam klorida = 255,5 kg + 5344,57 kg = 5600,07 kg

NERACA MASSA PADA REAKTOR R – 140



HCl masuk = 255,5 kg = 7 kmol

Reaksi I

	$Ca_3(PO_4)_2$	+ 6 HCl	→ 3 $CaCl_2$	+ 2 H_3PO_4
Awal :	0,8472	7	-	-
Reaksi :	0,8472	~ 5,0832	~ 2,5416	~ 1,6944
Akhir :	-	~ 1,9168	~ 2,5416	~ 1,6944

Reaksi II

	$CaCO_3$	+ 2 HCl	→ $CaCl_2$	+ H_2O	+ CO_2
Awal :	0,1818	1,9168	-	-	-
Reaksi :	0,1818	~ 0,3636	~ 0,1818	~ 0,1818	~ 0,1818
Akhir :	-	~ 1,5532	~ 0,1818	~ 0,1818	~ 0,1818

Reaksi III

$$MgCO_3 + 2\,HCl \rightarrow MgCl_2 + H_2O + CO_2$$

	$MgCO_3$	HCl	$MgCl_2$	H_2O	CO_2
Awal :	0,2164	1,5532	-	-	-
Reaksi :	0,2164 ~	0,4328 ~	0,2164 ~	0,2164 ~	0,2164
Akhir :	- ~	1,1204 ~	0,2164 ~	0,2164 ~	0,2164

Reaksi IV

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

	$Mg_3(PO_4)_2$	HCl	$MgCl_2$	H_3PO_4
Awal :	0,0926	1,1204	-	-
Reaksi :	0,0926	~ 0,5556 ~	0,2778 ~	0,1852
Akhir :	-	~ 0,5648 ~	0,2778 ~	0,1852

- **Masuk**
  - Dari Screw Conveyor J – 135

    Tulang = (tulang masuk dari Belt Conveyor J – 132) – (tulang keluar ke Screw Conveyor J – 134)

    = 631,31 kg – 126,26 kg

    = 505,05 kg , yang terdiri dari :

    » $Ca_3(PO_4)_2$ = 52% . 505,05 kg = 262,63 kg

    » Protein = 29% . 505,05 kg = 146,46 kg

    » Garam mineral = 12% . 505,05 kg = 60,61 kg

    ⇒ $CaCO_3$ = 30% . 60,61 kg = 18,18 kg

    ⇒ $MgCO_3$ = 30% . 60,61 kg = 18,18 kg

$\Rightarrow$ $Mg_3(PO_4)_2$ = 40% . 60,61 kg = 24,25 kg

» Lemak = 1% . 505,05 kg = 5,05 kg

» H_2O = 6% . 505,05 kg = 30,3 kg

- Dari Tangki Pengencer F – 142

Larutan asam klorida :

» HCl = 255,5 kg

» H_2O = air dari (WD + L – 145)

= (4870,07 +474,5) kg

= 5344,57 kg

Massa total larutan asam klorida = 255,5 kg + 5344,57 kg = 5600,07 kg

- **Keluar**

- Ke Centrifugal Separator H – 150

Wet ossein = $\frac{505{,}05 \text{ kg}}{600 \text{ gr}}$ 1500 gr = 1262,63 kg ; yang terdiri dari :

» Protein = protein masuk dari screw conveyor J – 135 = 146,46 kg

» Lemak = lemak masuk dari screw conveyor J – 135 = 5,05 kg

» H_2O = berat (wet oseein – protein – lemak)

= (1262,63 – 146,46 – 5,05) kg

= 1111,12 kg

Garam mineral :

» $CaCl_2$ = hasil reaksi I + hasil reaksi II

= (2,5416 + 0,1818) kmol × 111 kg / kmol

= 302,3 kg

» $MgCl_2$ = hasil reaksi III + hasil reaksi IV

= (0,2164 + 0,2778) kmol × 95 kg / kmol

= 46,95 kg

Massa garam mineral total = 302,3 kg + 46,95 kg = 349,25 kg

H_3PO_4 yang terbentuk = hasil reaksi I + hasil reaksi IV

= (1,6944 + 0,1852) × 98 kg / kmol

= 184,2 kg

HCl sisa = HCl sisa dari reaksi IV

= 0,5648 kmol

= 20,62 kg

CO_2 yang terbentuk = hasil reaksi II + hasil reaksi III

= (0,1818 + 0,2164) × 44 kg / kmol

= 17,52 kg

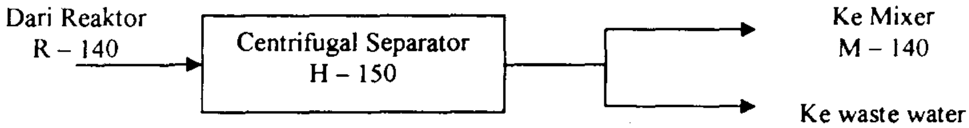
H_2O yang tidak larut dalam wet ossein

= H_2O masuk + H_2O hasil reaksi (II + III) – H_2O dalam wet ossein

= (30,3 + 5344,57)kg + [(0,1818 + 0,2164)kg × 18 kg/kmol] – 1111,12 kg

= 4270,9 kg

NERACA MASSA PADA CENTRIFUGAL SEPARATOR H – 150



- **Masuk**

  - <u>Dari Reaktor R – 140</u>

Wet ossein = $\frac{505{,}05 \text{ kg}}{600 \text{ gr}}$ 1500 gr = 1262,63 kg ; yang terdiri dari :

» Protein = protein masuk dari screw conveyor J – 135 = 146,46 kg

» Lemak = lemak masuk dari screw conveyor J – 135 = 5,05 kg

» H_2O = berat H_2O (wet oseein – protein – lemak)

= (1262,63 – 146,46 – 5,05) kg

= 1111,12 kg

Garam mineral :

» $CaCl_2$ = hasil reaksi I + hasil reaksi II

= (2,5416 + 0,1818) kmol × 111 kg / kmol

= 302,3 kg

» $MgCl_2$ = hasil reaksi III + hasil reaksi IV

= (0,2164 + 0,2778) kmol × 95 kg / kmol

= 46,95 kg

Massa garam mineral total = 302,3 kg + 46,95 kg = 349,25 kg

H_3PO_4 yang terbentuk = hasil reaksi I + hasil reaksi IV

= (1,6944 + 0,1852) × 98 kg / kmol

= 184,2 kg

HCl sisa = HCl sisa dari reaksi IV

= 0,5648 kmol

= 20,62 kg

CO_2 yang terbentuk = hasil reaksi II + hasil reaksi III

= (0,1818 + 0,2164) × 44 kg / kmol

= 17,52 kg

H_2O yang tidak larut dalam wet ossein

= H_2O masuk + H_2O hasil reaksi (II + III) – H_2O dalam wet ossein

= (30,3 + 5344,57)kg + [(0,1818 + 0,2164)kg × 18 kg/kmol] – 1111,12 kg

= 4270,9 kg

- **Keluar**
  - Ke Mixer M – 160

    Wet ossein = wet ossein dari Reaktor R – 140 =1262,63 kg; yang terdiri dari :

    » Protein = protein masuk dari Reaktor R – 140 = 146,46 kg

    » Lemak = lemak masuk dari Reaktor R – 140 = 5,05 kg

    » H_2O = H_2O (dlm gelatin) masuk dari Reaktor R – 140 = 1111,12 kg
  - Ke *Waste Water*

    Garam mineral :

» $CaCl_2$ = $CaCl_2$ masuk dari Reaktor R – 140 = 302,3 kg

» $MgCl_2$ = $MgCl_2$ masuk dari Reaktor R – 140 = 46,95 kg

Massa garam mineral total = 302,3 kg + 46,95 kg

= 349,25 kg

H_3PO_4 = H_3PO_4 masuk dari Reaktor R – 140 = 184,2 kg

HCl = HCl masuk dari Reaktor R – 140 = 20,62 kg

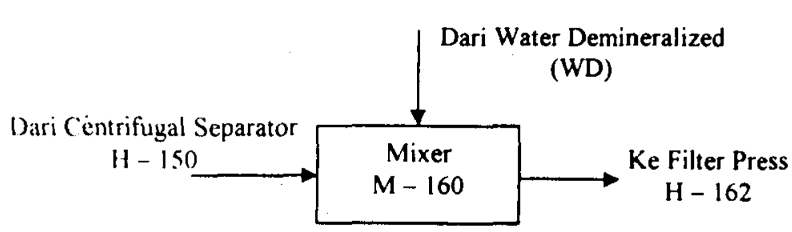
CO_2 = CO_2 masuk dari Reaktor R – 140 = 17,52 kg

H_2O yang tidak larut dalam wet ossein = H_2O masuk dari Reaktor R – 140

= 4270,9 kg

NERACA MASSA PADA MIXER M – 160

H_2O masuk dari WD diasumsi sama dengan massa total gelatin yang masuk dari Screw Conveyor J – 151.



- **Masuk**
  - Dari Centrifugal Separator H – 150

    Wet ossein = wet ossein dari Reaktor R – 140 = 1262,63 kg; yg terdiri dari :

    » Protein = protein masuk dari Reaktor R – 140 = 146,46 kg

» Lemak = lemak masuk dari Reaktor R – 140 = 5,05 kg

» H_2O = H_2O (dalam gelatin) masuk dari Reaktor R – 140

= 1111,12 kg

- <u>Dari Water Demineralized (WD)</u>

H_2O demineralisasi = 1262,63 kg

- **Keluar**

- <u>Ke Filter Press H – 162</u>

Wet ossein terdiri dari :

» Protein = protein masuk dr Centrifugal Separator H–150 = 146,46 kg

» Lemak = lemak masuk dari Centrifugal Separator H–150 = 5,05 kg

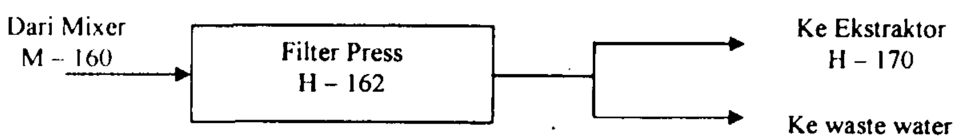
» H_2O = H_2O dari (Centrifugal Separator H–150 + WD)

= 1111,12 kg + 1262,63 kg

= 2373,75 kg

NERACA MASSA PADA FILTER PRESS H – 162

Asumsi : garam mineral yang terlarut dalam filtrat sangat sedikit sehingga dianggap bahan keluar ke Waste Water sama dengan air



- **Masuk**

  - Dari Mixer M – 160

    Wet ossein terdiri dari :

    » Protein = protein masuk dari Centrifugal Separator H–150 = 146,46 kg

    » Lemak = lemak masuk dari Centrifugal Separator H–150 = 5,05 kg

    » H_2O = H_2O dari (Centrifugal Separator H–150 + WD)

    = 1111,12 kg + 1262,63 kg

    = 2373,75 kg

  ∴ Massa total wet ossein masuk = (146,46 + 5,05 + 2373,75) kg

  = 2525,26 kg

- **Keluar**

  - Ke Ekstraktor H – 170

    Wet ossein = 1262,63 kg; yang terdiri dari :

    » Protein = protein masuk dari Mixer M – 160 = 146,46 kg

    » Lemak = lemak masuk dari Mixer M – 160 = 5,05 kg

    » H_2O = H_2O masuk dari Mixer M – 160 – filtrat keluar

    = 2373,75 kg – 1262,63 kg

    = 1111,12 kg

  - Ke Waste Water

    Filtrat = 1262,63 kg

NERACA MASSA PADA EKSTRAKTOR H – 170

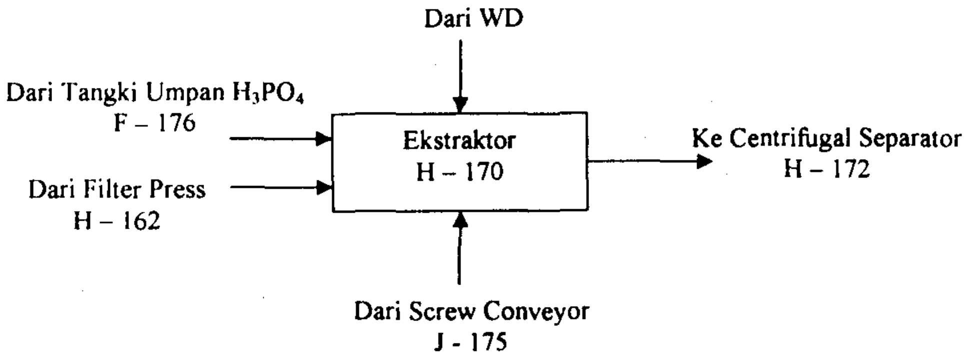
pH pada reaktor dipertahankan 2,25 dengan menambahkan H_3PO_4, selain itu ekstraktor dilengkapi dengan jaket pemanas dan koil yang berfungsi untuk mempertahankan suhu dalam ekstraktor pada suhu 75°C.

H_3PO_4 yang ditambahkan mempunyai kadar 85%.

Feed masuk terekstrak 90% menjadi gelatin dan 10%-nya dikembalikan sebagai recycle.

Massa air dari Water Demineralized (WD) yang ditambahkan sebanding dengan massa total wet ossein yang masuk.

Recycle dari Screw Conveyor J – 175 besarnya sama dengan 20% massa yang keluar dari ekstraktor R – 170.



- **Masuk**
  - Dari Filter Press H – 162

    Wet ossein = wet ossein dari Mixer M – 160 = 1262,63 kg; yang terdiri dari :

    » Protein = protein masuk dari Mixer M – 160 = 146,46 kg

    » Lemak = lemak masuk dari Mixer M – 160 = 5,05 kg

» H_2O = H_2O masuk dari Mixer M – 160 – filtrat keluar ke waste water

= 2373,75 kg – 1262,63 kg

= 1111,12 kg

- <u>Dari WD</u>

  H_2O demineralisasi = 1262,63 kg

- <u>Dari Tangki Umpan H_3PO_4 F – 176</u>

  pH = - log [H^+]

  2,25 = - log [H^+]

  ∴ [H^+] = 5,6234 . 10^{-3} M

  H_3PO_4 □ 3 H^+ + PO_4^{3-}

  1,8745 . 10^{-3} ~ 5,6234 . 10^{-3} ~ 1,8745 . 10^{-3}

  Konsentrasi H_3PO_4 = 1,8745 . 10^{-3} mol / lt

  = 0,1837 gr/lt

  Massa ke H – 172 = massa dari (H – 172 + WD + F – 176 + J – 175)

  = (1262,63 + 1262,63 + F – 176 + R) kg

  R = 10% massa ke L – 171

  R = 10% massa dari (H – 162 + WD + F – 176 + J – 175)

  R = 10% (1262,63 + 1262,63 + F – 176 + R) kg

  90% R = 10% (1262,63 + 1262,63 + F – 176) kg

  R = $\frac{1}{9}$ (1262,63 + 1262,63 + F – 176) kg

Total massa feed masuk

= massa wet ossein + massa H_2O demineralisasi + massa recycle + massa larutan H_3PO_4

= (1262,63 + 1262,63 + R + F – 176) kg

= $(1262{,}63 + 1262{,}63 + \frac{1}{9}(1262{,}63 + 1262{,}63 + F - 176) + F - 176)$ kg

= $(2525{,}26 + 280{,}58 + \frac{10}{9}.F - 176)$ kg

= $(2805{,}84 + \frac{10}{9}.F - 176)$ kg

$$\text{Volume feed masuk} = \frac{\text{massa feed masuk}}{\text{densitas } H_2O}$$

$$\text{Volume feed masuk} = \frac{(2805{,}84 + \frac{10}{9}.F - 176)\ \text{kg}}{995{,}568\ \text{kg/m}^3}$$

H_3PO_4 yang ditambahkan = konsentrasi H_3PO_4 × volume feed masuk

$$= 0{,}1837\frac{\text{gr}}{\text{lt}} \times \frac{(2805{,}84 + \frac{10}{9}.F - 176)\ \text{kg}}{995{,}568\ \text{kg/m}^3}$$

$$= 0{,}1837\frac{\text{gr}}{\text{lt}} \times \frac{(2805{,}84 + \frac{10}{9}.F - 176)\ \text{kg}}{995{,}568\ \frac{\text{kg}}{\text{m}^3}.10^{-3}\frac{\text{m}^3}{\text{lt}}}$$

$$= 0{,}1845 \times \left(2805{,}84 + \frac{10}{9}.F - 176\right)\ \text{gr}$$

= (517,68 + 0,205 . F – 176) gr

Larutan H_3PO_4 yang ditambahkan $= \frac{100\%}{85\ \%}(517{,}68 + 0{,}205 . F - 176)$ gr

$$F - 176 = 609{,}04 \text{ gr} + 0{,}2412 . F - 176$$

$$0{,}7588 . F - 176 = 609{,}04 \text{ gr}$$

$$F - 176 = 802{,}63 \text{ gr} = 0{,}8 \text{ kg}$$

» H_2O dalam H_3PO_4 $= \frac{15\%}{100\ \%}\ 0{,}8 \text{ kg} = 0{,}12 \text{ kg}$

» H_3PO_4 $= \frac{85\%}{100\ \%}\ 0{,}8\text{kg} = 0{,}68 \text{ kg}$

- <u>Dari Screw Conveyor J – 175</u>

R $= \frac{1}{9}$ (1262,63 + 1262,63 + F – 176) kg

R $= \frac{1}{9}$ (1262,63 + 1262,63 + 0,8) kg

R $= \frac{1}{9}$. 2526,06 kg

R = 280,67 kg , yang terdiri dari :

Wet ossein = 10% wet ossein keluar ke Centrifugal Separator H – 172

R = 10% . (1262,63 kg + R)

90% R = 126,26 kg

R = 140,3 kg ; yang terdiri dari :

» Protein = 10% protein keluar ke Centrifugal Separator H – 172

R = 10% . (146,46 kg + R)

90% R = 14,65 kg

R = 16,28 kg

» Lemak = 10% . lemak keluar ke Centrifugal Separator H – 172

R = 10% . (5,05 kg + R)

90% R = 0,505 kg

R = 0,56 kg

» H_2O = 10% . H_2O (dlm gelatin) keluar ke Centrifugal Separator H–172

R= 10% . (1111,12 kg + R)

90% R = 111,11 kg

R= 123,46 kg

Larutan H_3PO_4 = 10% larutan H_3PO_4 yang keluar ke Centrifugal Separator H–172

R = 10% . (0,8 kg + R)

90% R = 0,08 kg

R = 0,09 kg

» H_2O dalam H_3PO_4 $= \frac{15\%}{100\ \%}\ 0{,}09\ \text{kg} = 0{,}01\ \text{kg}$

» H_3PO_4 $= \frac{85\%}{100\ \%}\ 0{,}09\ \text{kg} = 0{,}08\ \text{kg}$

H_2O demineralisasi = 10%H_2O demineralisasi yg keluar ke Centrifugal Separator H–172

R = 10% . (1262,63 kg + R)

90% R = 126,26 kg

R = 140,29 kg

Jadi massa larutan H_3PO_4 total = massa H_3PO_4 + massa H_2O

= 0,08 kg + (0,01 + 140,29) kg

= 0,08 kg + 140,3 kg

= 140,38 kg

- **Keluar**

- Ke Centrifugal Separator H – 172

Wet ossein = 10% wet ossein keluar ke Centrifugal Separator H–172

= 10% (1262,63 kg + 140,3 kg)

= 140,3 kg; yang terdiri dari :

» Protein = 10% protein keluar ke Centrifugal Separator H–172

= 10% . (146,46 kg + 16,28 kg)

= 16,28 kg

» Lemak = 10% lemak keluar ke Centrifugal Separator H–172

= 10% . (5,05 kg + 3,78 kg)

= 3,78 kg

» H_2O = 10% air (dalam wet ossein) keluar ke Centrifugal Separator H–172

= 10% . (1111,12 kg + 123,46 kg)

= 123,46 kg

Gelatin = 90% wet ossein keluar ke Centrifugal Separator H–172

= 90% . (1262,63 kg + 140,3 kg)

= 1262,63 kg ; yang terdiri dari :

» Protein = 90% protein keluar ke Centrifugal Separator H–172

= 90% . (146,46 kg + 16,28 kg)

= 146,46 kg

» Lemak = 90% . lemak keluar ke Centrifugal Separator H–172

= 90% . (5,05 kg + 3,78 kg)

= 5,05 kg

» H_2O = 90% . air (dalam gelatin) keluar ke Centrifugal Separator H–172

= 90% . (1111,12 kg + 123,46 kg)

= 1111,12 kg

Larutan H_3PO_4 = larutan H_3PO_4 masuk dari (F – 176 + J – 175 + WD)

= (0,8 + 140,38 + 1262,63) kg

= 1403,81 kg

» H_3PO_4 = H_3PO_4 masuk dari (F – 176 + J – 175)

= (0,68 + 0,08) kg

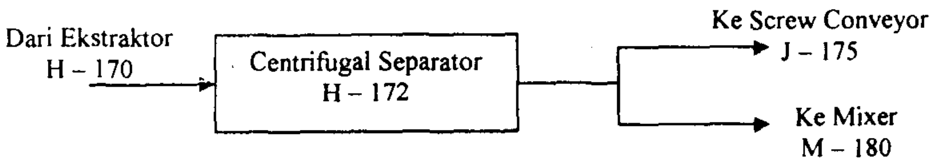
= 0,76 kg

» H_2O = air masuk dari (F – 176 + J – 175 + WD)

= (0,12 + 140,3 + 1262,63) kg

= 1403,05 kg

NERACA MASSA PADA CENTRIFUGAL SEPARATOR H – 172



- **Masuk**

  - <u>Dari Ekstraktor H – 170</u>

Wet ossein = 10% wet ossein keluar ke Centrifugal Separator H–172

= 10% (1262,63 kg + 140,3 kg)

= 140,3 kg; yang terdiri dari :

» Protein = 10% protein keluar ke Centrifugal Separator H–172

= 10% . (146,46 kg + 16,28 kg)

= 16,28 kg

» Lemak = 10% lemak keluar ke Centrifugal Separator H–172

= 10% . (5,05 kg + 3,78 kg)

= 3,78 kg

» H_2O = 10% H_2O (dalam wet ossein) keluar ke Centrifugal Separator H–172

= 10% . (1111,12 kg + 123,46 kg)

= 123,46 kg

Gelatin = 90% wet ossein keluar ke Centrifugal Separator H–172

= 90% . (1262,63 kg + 140,29 kg)

= 1262,63 kg ; yang terdiri dari :

» Protein = 90% protein keluar ke Centrifugal Separator H–172

= 90% . (146,46 kg + 16,28 kg)

= 146,46 kg

» Lemak = 90% . lemak keluar ke Centrifugal Separator H–172

= 90% . (5,05 kg + 3,78 kg)

= 5,05 kg

» H_2O = 90% . H_2O (dalam gelatin) keluar ke Centrifugal Separator H–172

= 90% . (1111,12 kg + 123,46 kg)

= 1111,12 kg

Larutan H_3PO_4 = larutan H_3PO_4 masuk dari (F – 176 + J – 175 + WD)

= (0,8 + 140,38 + 1262,63) kg

= 1403,81 kg

» H_3PO_4 = H_3PO_4 masuk dari (F – 176 + J – 175)

= (0,68 + 0,08) kg

= 0,76 kg

» H_2O = H_2O masuk dari (F – 176 + J – 175 + WD)

= (0,12 + 140,3 + 1262,63) kg

= 1403,05 kg

- **Keluar**

  - Ke Screw Conveyor J – 175

Wet ossein = wet ossein masuk dari Ekstraktor H – 170

= 140,3 kg; yang terdiri dari :

» Protein = protein (dalam wet ossein) masuk dari Ekstraktor H – 170

= 16,28 kg

» Lemak = lemak (dlm wet ossein) masuk dari Ekstraktor H – 170

= 3,78 kg

» H_2O = H_2O (dlm wet ossein) masuk dari Ekstraktor H – 170

= 123,46 kg

Larutan H_3PO_4 = 10% larutan H_3PO_4 masuk dari Ekstraktor H – 170

= 10% . 1403,81 kg

= 140,39 kg

» H_3PO_4 = 10% H_3PO_4 masuk dari Ekstraktor H – 170

= 10% . 0,76 kg

= 0,08 kg

» H_2O = 10 % H_2O masuk dari Ekstraktor H – 170

= 10% . 1403,05 kg

= 140,3 kg

- Ke Mixer 160

Gelatin = gelatin masuk dari Ekstraktor H – 170

= 1262,63 kg ; yang terdiri dari :

» Protein = protein masuk dari Ekstraktor H – 170

= 146,46 kg

» Lemak = lemak masuk dari Ekstraktor H – 170 = 5,05 kg

» H_2O = H_2O (dlm gelatin) masuk dari Ekstraktor H – 170 = 1111,12 kg

Larutan H_3PO_4 = 90% larutan H_3PO_4 masuk dari Ekstraktor H – 170

= 90% . 1403,81 kg

= 1263,43 kg

» H_3PO_4 = 90% H_3PO_4 masuk dari Ekstraktor H – 170

= 90% . 0,76 kg

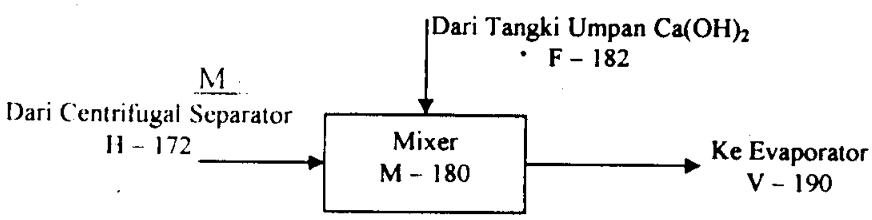
= 0,68 kg

» H_2O = 90 % air masuk dari Ekstraktor H – 170

= 90% . 1403,05 kg

= 1262,75 kg

NERACA MASSA PADA MIXER M – 180



- **Masuk**

- Dari Tangki Umpan $Ca(OH)_2$ F – 176

H_3PO_4 yang perlu diendapkan = 0,68 kg = 0,007 kmol

$2\ H_3PO_4 + 3\ Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + 6\ H_2O$

0,007 ~ 0,0105 ~ 0,0035 ~ 0,021

$Ca(OH)_2$ yang dibutuhkan utuk melarutkan H_3PO_4 dalam H_2O sebanyak

= 0,0105 kmol = 0,78 kg

- Dari Centrifugal Separator H – 172

Gelatin = gelatin masuk dari Ekstraktor H – 170

= 1262,63 kg ; yang terdiri dari :

» Protein = protein masuk dari Ekstraktor H – 170

= 146,46 kg

» Lemak = lemak masuk dari Ekstraktor H – 170 = 5,05 kg

» H_2O = H_2O (dlm gelatin) masuk dr Ekstraktor H – 170 = 1111,12 kg

Larutan H_3PO_4 = 90% larutan H_3PO_4 masuk dari Ekstraktor H – 170

= 90% . 1403,81 kg

= 1263,43 kg

» H_3PO_4 = 90% H_3PO_4 masuk dari Ekstraktor H – 170

= 90% . 0,76 kg

= 0,68 kg

» H_2O = 90 % H_2O masuk dari Ekstraktor H – 170

= 90% . 1403,05 kg

= 1262,75 kg

- **Keluar**

- <u>Ke Evaporator V – 190</u>

Gelatin = gelatin masuk dari Centrifugal Separator H – 172

= 1262,63 kg ; yang terdiri dari :

» Protein = protein masuk dari Centrifugal Separator H – 172

= 146,46 kg

» Lemak = lemak masuk dari Centrifugal Separator H – 172 = 5,05 kg

» H_2O = air (dlm gelatin) masuk dari Centrifugal Separator H – 172 = 1111,12 kg

$Ca_3(PO_4)_2$ yang terbentuk = 0,0035 kmol

= 1,09 kg

Larutan $Ca_3(PO_4)_2$:

» H_2O = H_2O masuk dari Centrifugal Separator H – 172 + H_2O hasil reaksi

= 1262,75 kg + (0,021 kmol × 18 kg/kmol)

= 1263,12 kg

» $Ca_3(PO_4)_2$ yang larut dalam H_2O = $\frac{1263,13 \text{ kg}}{100 \text{ gr}} 0,0025 \text{ gr} = 0,03 \text{ kg}$

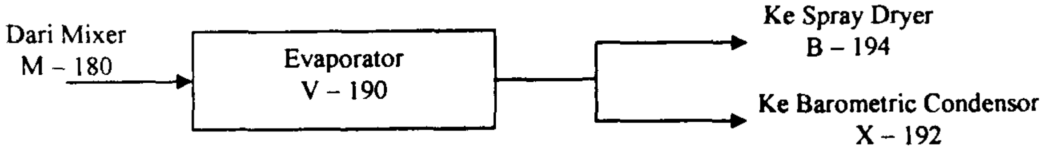
$Ca_3(PO_4)_2$ padat = 1,09 kg – 0,03 kg

= 1,06 kg

NERACA MASSA PADA EVAPORATOR V – 190

Asumsi : tidak ada padatan yang iku t keluar ke Barometric Condenser X - 192

Massa air menguap = 70% massa air masuk



- **Masuk**

  - Mixer M – 180

Gelatin = gelatin masuk dari Centrifugal Separator H – 172

= 1262,63 kg ; yang terdiri dari :

» Protein = protein masuk dari Centrifugal Separator H – 172

= 146,46 kg

» Lemak = lemak masuk dari Centrifugal Separator H – 172 = 5,05 kg

» H_2O = H_2O (dlm gelatin) masuk dr Centrifugal Separator H – 172 = 1111,12 kg

$Ca_3(PO_4)_2$ yang terbentuk = 0,0035 kmol

= 1,09 kg

Larutan $Ca_3(PO_4)_2$:

» H_2O = H_2O masuk dari Centrifugal Separator H – 172 + H_2O hasil reaksi

= 1262,75 kg + (0,021 kmol × 18 kg/kmol)

= 1263,12 kg

» $Ca_3(PO_4)_2$ yang larut dalam H_2O = $\frac{1263{,}12 \text{ kg}}{100 \text{ gr}} 0{,}0025 \text{ gr} = 0{,}03 \text{ kg}$

$Ca_3(PO_4)_2$ padat = 1,09 kg – 0,03 kg = 1,06 kg

- **Keluar**

  - <u>Ke Barometric Condensor X – 192</u>

    Uap air yang terbentuk = 70% H_2O masuk

    = 70% . 1263,12 kg = 884,18 kg

  - <u>Ke Spray Dryer B – 194</u>

    Gelatin = gelatin masuk dari Mixer M –160

    = 1262,63 kg ; yang terdiri dari :

    » Protein = protein masuk dari Mixer M –160

    = 146,46 kg

    » Lemak = lemak masuk dari Mixer M –160 = 5,05 kg

    » H_2O = H_2O (dalam gelatin) masuk dari Mixer M –160 = 1111,12 kg

    $Ca_3(PO_4)_2$ = $Ca_3(PO_4)_2$ yang masuk dari Mixer M –160 = 1,09 kg

    Larutan $Ca_3(PO_4)_2$:

    » H_2O = H_2O masuk dari Mixer M –160 – H_2O yang menguap

    = 1263,12 kg – 884,18 kg

    = 378,94 kg

    » $Ca_3(PO_4)_2$ yang larut dalam H_2O = $\frac{378,94 \text{ kg}}{100 \text{ gr}} 0,0025 \text{ gr} = 0,01 \text{ kg}$

    Larutan $Ca_3(PO_4)_2$ total = 378,94 kg + 0,01 kg

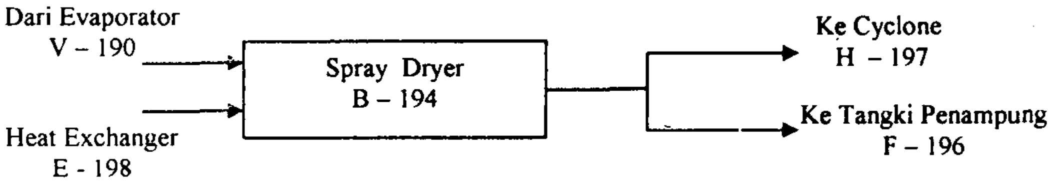
    = 378,95 kg

    $Ca_3(PO_4)_2$ padat = 1,09 kg – 0,01 kg = 1,08 kg

NERACA MASSA PADA SPRAY DRYER B – 194

Massa H_2O tersisa = 2% massa H_2O masuk

Massa bahan yang terikut udara kering ke Cyclone – 197 adalah 10%



- **Masuk**

  - Dari Evaporator V – 190

Gelatin = gelatin masuk dari Mixer M –160

= 1262,63 kg ; yang terdiri dari :

» Protein = protein masuk dari Mixer M –160

= 146,46 kg

» Lemak = lemak masuk dari Mixer M –160 = 5,05 kg

» H_2O = H_2O (dalam gelatin) masuk dari Mixer M –160 = 1111,12 kg

$Ca_3(PO_4)_2$ = $Ca_3(PO_4)_2$ yang masuk dari Mixer M –160 = 1,09 kg

Larutan $Ca_3(PO_4)_2$:

» H_2O = H_2O masuk dari Mixer M –160 – air yang menguap

= 1263,12 kg – 884,18 kg

= 378,94 kg

» $Ca_3(PO_4)_2$ yang larut dalam air = $\frac{378{,}94 \text{ kg}}{100 \text{ gr}} 0{,}0025 \text{ gr} = 0{,}01 \text{ kg}$

Larutan $Ca_3(PO_4)_2$ total = 378,94 kg + 0,01 kg

= 378,95 kg

$Ca_3(PO_4)_2$ padat = 1,09 kg – 0,01 kg

= 1,08 kg

- Dari Heat Exchanger E – 198

Asumsi : Percentage humudity (H_P) = 50%

Dengan menggunakan Humidity Chart, pada suhu keluar Spray Dryer B–194 = 70°C, dapat diperoleh : H = 0,1375 kg uap air / kg udara kering

(Geankoplis, 1993, pp. 529, fig. 9.3-2)

Uap air yang terbentuk = 98% air masuk

= 98% . 378,94 kg

= 371,36 kg

$$\text{Udara panas masuk yang dibutuhkan} = \frac{\text{massa uap air terbentuk}}{H}$$

$$= \frac{371{,}36\ \text{kg}}{0{,}1375\ \text{kg uap air / kg udara kering}}$$

= 2700,08 kg

- **Keluar**

- Ke Cyclone H – 197

Udara panas = udara panas dari Heat Exchanger E – 198 = 2700,08 kg

$H_2O_{(g)}$ = uap air terbentuk = 371,36 kg

Gelatin = 10% . gelatin masuk dari Evaporator V – 190

= 126,26 kg ; yang terdiri dari :

» Protein = 10% . protein masuk dari Evaporator V – 190

= 14,65 kg

» Lemak = 10% . lemak masuk dari Evaporator V – 190 = 0,50 kg

» H_2O = 10% . H_2O (dlm gelatin) masuk dari Evaporator V – 190

= 111,11 kg

$Ca_3(PO_4)_2$ = 10% . $Ca_3(PO_4)_2$ yang masuk dari Evaporator V – 190

= 0,11 kg

Larutan $Ca_3(PO_4)_2$:

» H_2O = 10% (H_2O masuk dari Mixer M – 180 – H_2O yang menguap)

= 10% (378,94 kg – 371,36 kg) = 0,76 kg

» $Ca_3(PO_4)_2$ yang larut dalam H_2O = $\frac{0,76\ kg}{100\ gr} 0,0025\ gr = 1,9.10^{-6}\ kg$

Karena $Ca_3(PO_4)_2$ yang larut dalam H_2O sangat kecil, maka dianggap tidak ada $Ca_3(PO_4)_2$ yang larut dalam H_2O, sehingga massa $Ca_3(PO_4)_2$ solid adalah 0,11 kg.

- Ke Tangki Penampung F – 196

Gelatin = gelatin masuk (dari Evaporator V – 190 – ke Cyclone H – 197)

= 1136,37 kg ; yang terdiri dari :

» Protein = protein masuk (dari Evaporator V – 190 – ke Cyclone H – 197)

= 131,81 kg

» Lemak = lemak masuk (dari Evaporator V – 190 – ke Cyclone H – 197)

= 4,55 kg

» H_2O = H_2O (dlm gelatin) masuk (dr Evaporator V – 190 – ke Cyclone H – 197)

= 1000,01 kg

$Ca_3(PO_4)_2$ = $Ca_3(PO_4)_2$ yg masuk dari Evaporator V – 190 = 0,98 kg

Larutan $Ca_3(PO_4)_2$:

» H_2O = H_2O masuk dari Evaporator V – 190 – H_2O yang menguap – ke Cyclone H – 197

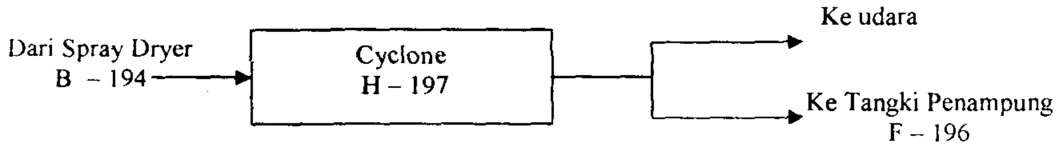
= 378,94 kg – 371,36 kg – 0,76 kg

= 6,82 kg

» $Ca_3(PO_4)_2$ yang larut dalam H_2O = $\frac{6,82\ kg}{100\ gr} 0,0025\ gr = 1,705.10^{-4}\ kg$

Karena $Ca_3(PO_4)_2$ yang larut dalam H_2O sangat kecil, maka dianggap tidak ada $Ca_3(PO_4)_2$ yang larut dalam H_2O, sehingga massa $Ca_3(PO_4)_2$ solid adalah 0,98 kg.

NERACA MASSA PADA CYCLONE – 197



- **Masuk**

  - Dari Spray Dryer B – 194

    Udara panas = udara panas keluar dari Spray Dryer B – 194 = 2700,08 kg

    $H_2O_{(g)}$ = uap air dari Spray Dryer B – 194 = 371,36 kg

    Gelatin = 126,26 kg ; yang terdiri dari :

    » Protein = 14,65 kg

    » Lemak = 0,50 kg

    » H_2O = 111,11 kg

    $Ca_3(PO_4)_2$ = 0,11 kg

    H_2O = 0,76 kg

- **Keluar**

  - Ke udara

    Udara panas = udara panas dari Spray Dryer B – 194 = 2700,08 kg

    $H_2O_{(g)}$ = uap air dari Spray Dryer B – 194 = 371,36 kg

  - Ke Screw Conveyor J – 195

    Gelatin = gelatin masuk dari Spray Dryer B – 194

    = 126,26 kg ; yang terdiri dari :

    » Protein = protein masuk dari Spray Dryer B – 194 = 14,65 kg

» Lemak = lemak masuk dari Spray Dryer B – 194 = 0,50 kg

» H_2O = H_2O (dlm gelatin) masuk dari Spray Dryer B – 194

= 111,11 kg

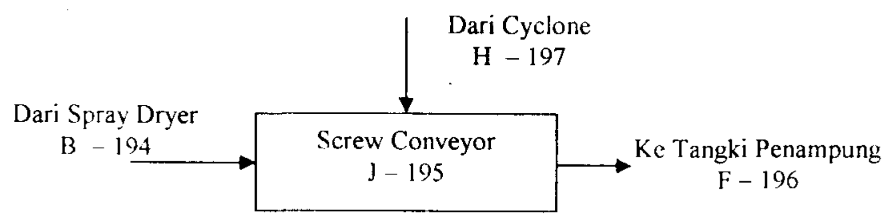
$Ca_3(PO_4)_2$ = $Ca_3(PO_4)_2$ yang masuk dari Spray Dryer B – 194

= 0,11 kg

H_2O = H_2O masuk dari Spray Dryer B – 194

= 0,76 kg

NERACA MASSA PADA SCREW CONVEYOR J – 195



- **Masuk**
  - Dari Spray Dryer B – 194

Gelatin = 1136,37 kg ; yang terdiri dari :

» Protein = 131,81 kg

» Lemak = 4,55 kg

» H_2O = 1000,01 kg

$Ca_3(PO_4)_2$ = 0,98 kg

H_2O = 6,82 kg

Karena $Ca_3(PO_4)_2$ yang larut dalam H_2O sangat kecil, maka dianggap tidak ada $Ca_3(PO_4)_2$ yang larut dalam H_2O, sehingga massa $Ca_3(PO_4)_2$ solid adalah 0,98 kg.

- Dari Cyclone H – 197

Gelatin = 126,26 kg ; yang terdiri dari :

» Protein = 14,65 kg

» Lemak = 0,50 kg

» H_2O = 111,11 kg

$Ca_3(PO_4)_2$ = 0,11 kg

H_2O = 0,76 kg

- **Keluar**

- Ke Tangki Penampung F – 196

Gelatin = gelatin dari (Cyclone H – 197 + Spray Dryer B – 194)

= 1262,63 kg ; yang terdiri dari :

» Protein = protein dari (Cyclone H – 197 + Spray Dryer B – 194)

= 146,46 kg

» Lemak = lemak dari (Cyclone H – 197 + Spray Dryer B – 194)

= 5,05 kg

» H_2O = H_2O dari (Cyclone H – 197 + Spray Dryer B – 194)

= 1111,12 kg

$Ca_3(PO_4)_2$ = $Ca_3(PO_4)_2$ dari (Cyclone H – 197 + Spray Dryer B – 194)

= 1,09 kg

H_2O = H_2O dari (Cyclone H – 197 + Spray Dryer B – 194)

= 7,58 kg

H_2O 7,58 kg
$Ca_3(PO_4)_2$ padat 1,09 kg } impurities = 8,67 kg

JADI DARI 505,05 KG TULANG MASUK DAPAT DIHASILKAN 1262,63 KG GELATIN DENGAN IMPURITIES SEBANYAK 8,67 KG

APPENDIX B

PERHITUNGAN NERACA PANAS

APPENDIX B

PERHITUNGAN NERACA PANAS

Basis : 1 jam

Suhu refrensi = 25°C = 298 K

Cp untuk zat-zat yang digunakan :

- Rumus :

1. Cp (cal / mol . K) = A + B . T + C / T^2
2. Cp (J / kmol . K) = A + B . T + C . T^2 + D . T^3 + E . T^4

(Perry, 1999)

3. Cp (kJ / kgmol) = A + B . T + C . T^2 + D . T^3
4. Cp (kJ / kgmol) = A + B . T + C / T^2

(Himmelblau, 1989)

- Data-data :

Zat	Rumus	A	B	C	D	E
$Ca_3(PO_4)_2$	1 (K)	18,52	0,02197	-156800	-	-
$CaCO_3$	4 (K)	82,34	$4{,}975.10^{-2}$	$-12{,}87.10^{-5}$	-	-
$MgCO_3$	1 (K)	16,9	-	-	-	-
$Mg_3(PO_4)_2$	1 (K)	26,7	-	-	-	-
$MgCl_2$	3(K)	72,4	$1{,}58.10^{-2}$	-	-	-
$CaCl_2$	1 (K)	16,9	0,00386	-	-	-
$Ca(OH)_2$	1 (K)	21,4	-	-	-	-
CO_2	3 (°C)	36,11	$4{,}233.10^{-2}$	$-2{,}887.10^{-5}$	$7{,}464.10^{-9}$	-
$HCl_{(l)}$	2 (K)	$4{,}73.10^{4}$	90	-	-	-
$H_2O_{(l)}$	3 (K)	18,2964	$47{,}212.10^{-2}$	$-133{,}88.10^{-5}$	$1314{,}2.10^{-9}$	-
$H_2O_{(g)}$	3 (°C)	33,46	$0{,}688.10^{-2}$	$0{,}7604.10^{-5}$	$-3{,}593.10^{-9}$	-

Cp H_3PO_4 = 0,5704 cal / gr°C = 232,9133 kJ / kmol . K

(Perry, 1999)

Cp protein = 3,18 kJ / kmol . K

Cp lemak = 2,85 kJ / kmol . K

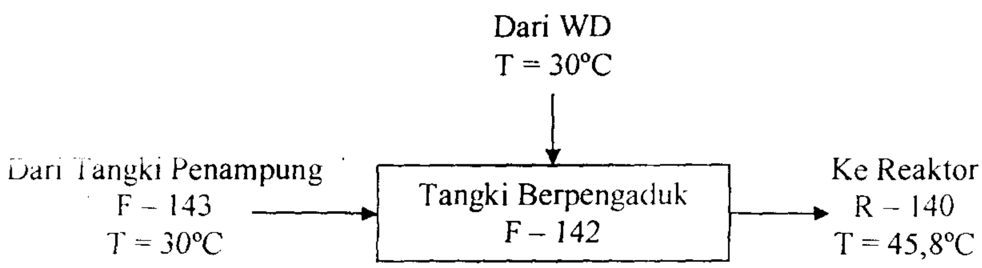
(Geankoplis, 1983)

BM : protein = 7139 gr/mol (**www.ccp4.ac.uk**)

Lemak = 593 gr/mol (www.usd.edu/biol/courses/cellthies/cpa3answers.html)

Udara = 28,97 kg / kmol

TANGKI BERPENGADUK F – 142



Entalpi masuk :

Suhu masuk = 30°C = 303 K

- **Dari Tangki Penampung F – 143**
  - HCl

$$\Delta H = \frac{m}{BM}\int_{298}^{303}\left(A + B.T + C.T^2 + D.T^3 + E.T^4\right) dT$$

$$\Delta H = \frac{255,5}{36,5}\text{kmol}.\left[4,73.10^4.(303-298)+45.\left(303^2-298^2\right)\right]J/\text{kmol}$$

$$\Delta H = \frac{255,5}{36,5}\text{kmol}.371725\ J/\text{kmol}$$

$$\Delta H = 2602075\ J = 2602,08\ kJ$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}\int_{298}^{303}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{474,5}{18}\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(303+298) - \frac{133,88.10^{-5}}{3}\left(303^2+303.298+298^2\right) + \frac{1314,2.10^{-9}}{4}\left(303^2+298^2\right)(303+298)\right]$$

$$(303-298)\ kJ/\text{kmol}$$

$$\Delta H = \frac{474,5}{18}\text{kmol}.74,9353\ (303-298)\ kJ/\text{kmol}$$

$$\Delta H = 9876,89\,kJ$$

- Panas pelarutan :

$$\frac{\text{mol } H_2O}{\text{mol HCl}} = \frac{474,5/18}{255,5/36,5} = 3,7651$$ → dengan menggunakan Hougen & Watson (1954) hal. 320 fig. 75 diperoleh :

ΔH of solution = -14200 kcal / kgmol asam

$$= -14200 . \frac{255,5}{36,5}\ \text{kcal}$$

= -99400 kcal

= -414166,67 kJ

Entalpi masuk total dari Tangki Penampung F – 143

= (2602,08 + 9876,89 + 414166,67) kJ

= 426645,63 kJ

- **Dari WD**

  - $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}\int_{298}^{303}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{4870,07}{18}\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(303+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.\left(303^2 + 303.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(303^2 + 298^2\right)(303+298)\right]$$

$$(303 - 298)\ \text{kJ/kmol}$$

$$\Delta H = \frac{4870,07}{18}\text{kmol}.74,9353\ (303-298)\text{kJ/kmol}$$

$$\Delta H = 101372,23\ \text{kJ}$$

Total entalpi masuk = entalpi masuk dari (Tangki Penampung F – 143 + WD)

= (426645,43 + 101372,23) kJ

= 528017,86 kJ

<u>Entalpi keluar :</u>

- **Ke Reaktor R – 140**

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

528017,86 kJ = ΔH keluar + 10% (528017,86 kJ)

ΔH keluar = 475216,08 kJ

Mol larutan = mol HCl + mol H_2O

$$= \left(\frac{255,5}{36,5} + \frac{5344,57}{18}\right) \text{kmol}$$

$$= 7 \text{ kmol} + 296,92 \text{ kmol}$$

$$= 303,92 \text{ kmol}$$

$$X_{HCl} = \frac{7}{303,92} = 0,023$$

$$X_{H_2O} = \frac{296,92}{303,92} = 0,977$$

- HCl

$$\int_{298}^{T_{out}} C_P \, dT = \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 + E.T^4\right) dT$$

$$= \left[4,73.10^4.(T_{out} - 298) + 45.\left(T_{out}^{\ 2} - 298^2\right)\right] J/kmol$$

$$= \left[47,30.(T_{out} - 298) + 0,045.\left(T_{out}^{\ 2} - 298^2\right)\right] kJ/kmol$$

- H_2O

$$\int_{298}^{T_{out}} C_P \, dT = \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3\right) dT$$

$$= \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out} + 298) - \frac{133{,}88.10^{-5}}{3}\left(T_{out}^{\ 2} + T_{out}.\right.\right.$$

$$\left.\left. 298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)(T_{out} + 298)\right](T_{out} - 298)$$

kJ / kmol

ΔH keluar = m . Cp camp . ΔT

$$475216{,}08 \text{ kJ} = 303{,}92 \text{ kmol} . \left(0{,}023 . \int_{298}^{T_{out}} C_{P\ HCl}\, dT + 0{,}977 . \int_{298}^{T_{out}} C_{P\, H_2O}\, dT \right)$$

$$475216{,}08 \text{ kJ} = 303{,}92 \text{ kmol} . \left\{ 0{,}023 . 47{,}30 . (T_{out} - 298) + 0{,}045 . \left(T_{out}^{\ 2} - 298^2\right) + 0{,}977 . \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out} + 298) - \frac{133{,}88 . 10^{-5}}{3}\left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)(T_{out} + 298)\right](T_{out} - 298)\right\} \frac{\text{kJ}}{\text{kmol}}$$

Dengan cara trial, dapat diperoleh : T_{out} = 318,8 K = 45,8°C, maka :

- <u>HCl</u>

$$\Delta H = \frac{m}{BM} \int_{298}^{318{,}8} \left(A + B.T + C.T^2 + D.T^3 + E.T^4\right) dT$$

$$\Delta H = \frac{255{,}5}{36{,}5}\,\text{kmol}.\left[4{,}73.10^4.(318{,}8 - 298) + 45.\left(318{,}8^2 - 298^2\right)\right]\text{J / kmol}$$

$$\Delta H = 10938023{,}9109\ \text{J} = 10938{,}02\ \text{kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}\int_{298}^{318{,}8}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{5344{,}57}{18}\,\text{kmol}.\Bigg[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(318{,}8 + 298) - \frac{133{,}88.10^{-5}}{3}$$

$$\left(318{,}8^2 + 318{,}8\,.\,298 + 298^2\right) + \frac{1314{,}2\,.10^{-9}}{4}\left(318{,}8^2 + 298^2\right)$$

$$(318{,}8 + 298)\Bigg](318{,}8 - 298)\text{kJ / kmol}$$

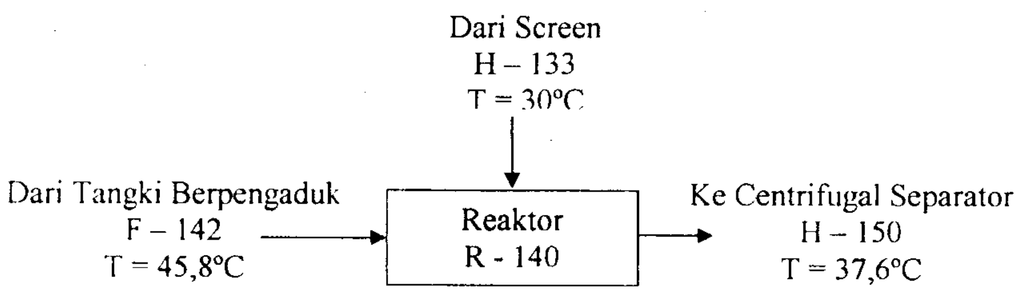
$$\Delta H = 464278{,}05\ \text{kJ}$$

Q_{loss} = 10% . entalpi masuk = 10% . (528017,86 kJ) = 52801,79 kJ

Total entalpi keluar = (10938,02 + 464278,05) kJ

= 475216,08 kJ

REAKTOR R – 140



Entalpi masuk :

- **Dari Tangki Berpengaduk F – 142**

Suhu masuk = 318,8 K = 45,8°C

- ΔH_{HCl} = 10938,02 kJ
- ΔH_{H_2O} = 464278,05 kJ +

ΔH_{F-142} = 475216,08 kJ

- **Dari Screen H – 133**

Suhu masuk = 303 K = 30°C

- $Ca_3(PO_4)_2$

$$\Delta H = \frac{m}{BM} . \int_{298}^{303} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{262{,}63.10^3}{310} mol \left[18{,}52(303 - 298) + \frac{0{,}02197}{2}\left(303^2 - 298^2\right) + \left(\frac{156800}{303} - \frac{156800}{298}\right)\right] cal/mol$$

= 412,75 kJ

- Protein

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$= \frac{146{,}46}{7139} kmol . 3{,}18 \frac{kJ}{kmol.K} (303 - 298) K$$

= 0,33 kJ

- $CaCO_3$

$$\Delta H = \frac{m}{BM}.\int_{298}^{303}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{18,18}{100}\text{kmol}\left[82,34 + 0,04975(303 + 298) - \frac{0,0001287}{303.298}\right](303 - 298)\frac{kJ}{kmol}$$

$$= 102,03 \text{ kJ}$$

- $MgCO_3$

$$\Delta H = \frac{m}{BM}.\int_{298}^{303}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{18,18.10^3}{84}\text{mol}.16,9\ (303 - 298)\ \text{cal/mol}$$

$$= 76,2 \text{ kJ}$$

- $Mg_3(PO_4)_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{303}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{24,25.10^3}{262}\text{mol}.26,7\ (303 - 298)\ \text{cal/mol}$$

$$= 51,49 \text{ kJ}$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{5,05}{593}\text{kmol}.2,85\frac{kJ}{kmol.K}(303 - 298)K = 0,12 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{m}{BM}\int_{298}^{303}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{30,3}{18}\text{kmol}\left[18,2964 + \frac{47,212.10^{-2}}{2}(303+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left(303^2 + 303\ .\ 298 + 298^2\right) + \frac{1314,2\ .10^{-9}}{4}\left(303^2 + 298^2\right)$$

$$\left.(303+298)\right](303-298)\text{kJ / kmol}$$

$$\Delta H = 630,71\ \text{kJ}$$

Total entalpi masuk dari Screen H – 133

$= \Delta H_{Ca_3(PO_4)_2} + \Delta H_{protein} + \Delta H_{CaCO_3} + \Delta H_{MgCO_3} + \Delta H_{Mg_3(PO_4)_2} + \Delta H_{lemak}$

$+ \Delta H_{H_2O}$

= (412,75 + 0,33 + 102,03 + 76,2 + 51,49 + 0,12 + 630,71) kJ

= 1273,61 kJ

Total entalpi masuk = entalpi masuk dari (Tangki Berpengaduk F – 142 + Screen H – 133)

= (475216,08 – 1273,61) kJ

= 476489,69 kJ

Entalpi keluar :

- **Ke Centrifugal Separator H – 150**

Data-data ΔH^0_{298} :

$\Delta H^0_{298\ CaCl_2} = -794{,}9\ kJ/mol$ $\Delta H^0_{298\ MgCl_2} = -641{,}83\ kJ/mol$

$\Delta H^0_{298\ H_2O} = -285{,}84\ kJ/mol$ $\Delta H^0_{298\ CO_2} = -393{,}51\ kJ/mol$

$\Delta H^0_{298\ Ca_3(PO_4)_2} = -4137{,}6\ kJ/mol$ $\Delta H^0_{298\ CaCO_3} = -1206{,}87\ kJ/mol$

$\Delta H^0_{298\ HCl} = -92{,}311\ kJ/mol$

(Geankoplis, 1993)

$\Delta H^0_{298\ MgCO_3} = -266\ kcal/mol = -1108{,}3333\ kJ/mol$

$\Delta H^0_{298\ Mg_3(PO_4)_2} = -305{,}5\ kcal/mol = -1272{,}9167\ kJ/mol$

$\Delta H^0_{298\ H_3PO_4} = -228{,}2\ kcal/mol = -950{,}8333\ kJ/mol$

(Hougen, 1981)

$$\Delta H_{reaksi} = \Delta H^0_{298}$$

$$\Delta H^0_{298} = \Big[\left(n\,.\,\Delta H^0_{298}\right)_{CaCl_2} + \left(n\,.\,\Delta H^0_{298}\right)_{MgCl_2} + \left(n\,.\,\Delta H^0_{298}\right)_{H_2O} + \left(n\,.\,\Delta H^0_{298}\right)_{CO_2} + \left(n\,.\,\Delta H^0_{298}\right)_{H_3PO_4}\Big] - \Big[\left(n\,.\,\Delta H^0_{298}\right)_{Ca_3(PO_4)_2} + \left(n\,.\,\Delta H^0_{298}\right)_{CaCO_3} + \left(n\,.\,\Delta H^0_{298}\right)_{MgCO_3} + \left(n\,.\,\Delta H^0_{298}\right)_{Mg_3(PO_4)_2} + \left(n\,.\,\Delta H^0_{298}\right)_{HCl}\Big]$$

$$\Delta H^0_{298} = [((2{,}5416 + 0{,}1818).10^3\,mol(-794{,}9\,kJ/mol)) + ((0{,}2164 + 0{,}0926).10^3\,mol(-641{,}83\,kJ/mol)) + ((0{,}1818 + 0{,}2164).10^3\,mol(-285{,}84\,kJ/mol)) + ((0{,}1818 + 0{,}2164).10^3\,mol(-393{,}51\,kJ/mol)) + ((1{,}6944 + 0{,}1852).10^3\,mol(-950{,}8333\,kJ/mol))] - [(0{,}8472.10^3\,mol(-4137{,}6\,kJ/mol)) + (0{,}1818.10^3\,mol(-1206{,}87\,kJ/mol)) + (0{,}2164.10^3\,mol(-108{,}3333\,kJ/mol)) + (0{,}0926.10^3\,mol(-1272{,}9167\,kJ/mol)) + ((5{,}0832 + 0{,}3636 + 0{,}4328 + 0{,}5556).10^3\,mol(-92{,}311\,kJ/mol))]$$

$$\Delta H^0_{298} = 136812{,}3\ kJ$$

$$\Delta H_{keluar} = \Delta H_{wet\ ossein} + \Delta H_{garam\ mineral} + \Delta H_{H_3PO_4} + \Delta H_{HCl} + \Delta H_{CO_2} + \Delta H_{H_2O}$$

$$= \left[\left(\frac{m}{BM}Cp.\Delta T\right)_{protein} + \left(\frac{m}{BM}Cp.\Delta T\right)_{lemak} + \left(\frac{m}{BM}Cp.\Delta T\right)_{H_2O}\right] + \left[\left(\frac{m}{BM}Cp.\Delta T\right)_{CaCl_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{MgCl_2}\right] + \left(\frac{m}{BM}Cp.\Delta T\right)_{H_3PO_4} + \left(\frac{m}{BM}Cp.\Delta T\right)_{HCl} + \left(\frac{m}{BM}Cp.\Delta T\right)_{CO_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{H_2O}$$

Wet ossein :

- $\Delta H_{protein} = \frac{m}{BM}Cp.\Delta T$

$$= \frac{146{,}46}{7139}kmol.3{,}18\frac{kJ}{kmol.K}(T_{out} - 298)K$$

- $\Delta H_{lemak} = \frac{m}{BM} Cp.\Delta T$

$$= \frac{5{,}05}{593} \text{kmol}.2{,}85 \frac{kJ}{kmol.K} (T_{out} - 298) K$$

- $\Delta H_{H_2O} = \frac{m}{BM} Cp.\Delta T$

$$= \frac{1111{,}12}{18} \text{kmol} \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} (T_{out} + 298) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. (T_{out}^2 + T_{out}.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4} (T_{out}^2 + 298^2)(T_{out} + 298) \right]$$

$$(T_{out} - 298) \text{ kJ / kmol}$$

Garam mineral :

- $\Delta H_{CaCl_2} = \frac{m}{BM}.Cp.\Delta T$

$$= 2{,}7234.10^3 \text{ mol} \left[16{,}9(T_{out} - 298) + \frac{0{,}000386}{2} (T_{out}^2 - 298^2) \right]$$

cal/ mol

$$= 191{,}7728(T_{out} - 298) + 2{,}1901.10^{-3} (T_{out}^2 - 298^2) \text{ kJ}$$

- $\Delta H_{MgCl_2} = \frac{m}{BM}.Cp.\Delta T$

$$= 0{,}4942 \text{ kmol} \left[\left(72{,}4 + \frac{1{,}58.10^{-2}}{2} (T_{out} + 298) \right) (T_{out} - 298) \right]$$

kJ / mol

$$\Delta H_{H_3PO_4} = \frac{m}{BM}.Cp.\Delta T$$

$$= \frac{184,2}{98}\ kmol.212,9133\ \frac{kJ}{kmol.K}(T_{out} - 298)\ K$$

$$\Delta H_{HCl} = \frac{m}{BM}.Cp.\Delta T$$

$$= \frac{20,62}{36,5}\ kmol\left[47,3.10^{4}(T_{out} - 298) + 45\left(T_{out}^{\ 2} - 298^{2}\right)\right]J / kmol$$

$$= 26,715(T_{out} - 298) + 0,0254\left(T_{out}^{\ 2} - 298^{2}\right) kJ$$

$$\Delta H_{H_2O} = \frac{m}{BM}.Cp.\Delta T$$

$$= \frac{4270,9}{18} kmol\left[18,2964 + \frac{47,212.10^{-2}}{2}(T_{out} + 298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{\ 2} + 298.T_{out} + 298^{2}\right) + \frac{1314,2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^{2}\right)\left(T_{out} + 298\right)\right]$$

$$(T_{out} - 298)\ kJ / kmol$$

$$\Delta H_{CO_2} = \frac{m}{BM}.Cp.\Delta T$$

$$= 0,3982\, kmol\left[36,11 + \frac{4,233.10^{-2}}{2}(T_{out} + 25) - \frac{2,887.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{\ 2} + 25.T_{out} + 25^{2}\right) + \frac{7,464.10^{-9}}{4}\left(T_{out}^{\ 2} + 25^{2}\right)\left(T_{out} + 25\right)\right]$$

$$(T_{out} - 25)\ kJ / kmol$$

Dengan cara trial diperoleh : T_{out} = 310,6 K = 37,6°C, maka :

Wet ossein :

- $\Delta H_{protein} = \frac{146,46}{7139} kmol.3,18 \frac{kJ}{kmol.K}(310,6-298)K = 0,82\ kJ$

- $\Delta H_{lemak} = \frac{5,05}{593} kmol.2,85 \frac{kJ}{kmol.K}(310,6-298)K = 0,31\ kJ$

- $\Delta H_{H_2O} = \frac{1111,12}{18} kmol\left[18,2964 + \frac{47,212.10^{-2}}{2}(310,6+298) - \frac{133,88.10^{-5}}{3}\right.$

$\left(310,6^2 + 298.310,6 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(310,6^2 + 298^2\right)$

$\left.(310,6+298)\right](310,6-298)\ kJ/kmol$

$= 58368,46\ kJ$

Garam mineral :

- $\Delta H_{CaCl_2} = 191,7728(310,6-298) + 2,1901.10^{-3}\left(310,6^2 - 298^2\right) kJ$

$= 2585,11\ kJ$

- $\Delta H_{MgCl_2} = 0,4942\ kmol\left[\left(72,4 + \frac{1,58.10^{-2}}{2}(310,6+298)\right)(310,6-298)\right] kJ/mol$

$= 480,93\ kJ$

$\Delta H_{H_3PO_4} = \frac{184,2}{98} kmol.212,9133 \frac{kJ}{kmol.K}(310,6-298)\ K$

$= 5517,78\ kJ$

$$\Delta H_{HCl} = 26{,}715(310{,}6 - 298) + 0{,}0254\left(310{,}6^2 - 298^2\right) \text{ kJ}$$

$$= 531{,}80 \text{ kJ}$$

$$\Delta H_{H_2O} = \frac{4270{,}9}{18} \text{kmol}\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(310{,}6+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left(310{,}6^2 + 298.310{,}6 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(310{,}6^2 + 298^2\right)$$

$$\left.(310{,}6+298)\right]\left(310{,}6 - 298\right) \text{ kJ/kmol}$$

$$= 224355{,}48 \text{ kJ}$$

$$\Delta H_{CO_2} = 0{,}3982 \text{kmol}\left[36{,}11 + \frac{4{,}233.10^{-2}}{2}(37{,}6+25) - \frac{2{,}887.10^{-5}}{3}\right.$$

$$\left(37{,}6^2 + 25.37{,}6 + 25^2\right) + \frac{7{,}464.10^{-9}}{4}\left(37{,}6^2 + 25^2\right)$$

$$\left.(37{,}6+25)\right]\left(37{,}6 - 25\right) \text{ kJ/kmol}$$

$$= 187{,}73 \text{ kJ}$$

$$\Delta H \text{ keluar} = \left(\Delta H_{\text{protein}} + \Delta H_{\text{lemak}} + \Delta H_{H_2O}\right) + \left(\Delta H_{CaCl_2} + \Delta H_{MgCl_2}\right) +$$

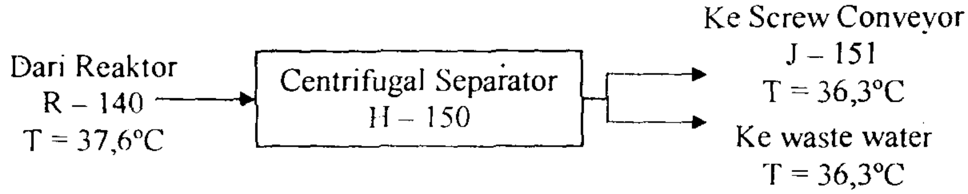
$$\Delta H_{H_3PO_4} + \Delta H_{HCl} + \Delta H_{H_2O} + \Delta H_{CO_2}$$

$$\Delta H \text{ keluar} = \left(0{,}82 + 0{,}31 + 58368{,}46 + 2585{,}11 + 480{,}93 + 5517{,}78 + 531{,}80 + \right.$$

$$\left.224355{,}48 + 187{,}73\right) \text{ kJ}$$

$$\Delta H \text{ keluar} = 292028{,}42 \text{ kJ}$$

CENTRIFUGAL SEPARATOR H – 150



Entalpi masuk :

Suhu masuk = 37,6°C = 310,6 K

- **Dari Reaktor R – 140**

  Wet ossein :

  - $\Delta H_{protein}$ = 0,82 kJ
  - ΔH_{lemak} = 0,31 kJ
  - ΔH_{H_2O} = 58368,46 kJ

  Garam mineral :

  - ΔH_{CaCl_2} = 2585,11 kJ
  - ΔH_{MgCl_2} = 480,93 kJ
  - $\Delta H_{H_3PO_4}$ = 5517,78 kJ
  - ΔH_{HCl} = 531,80 kJ
  - ΔH_{H_2O} = 224355,48 kJ
  - ΔH_{CO_2} = 187,73 kJ +

  ΔH masuk = 292028,42 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

292028,42 kJ = ΔH keluar + 10% (292028,42 kJ)

ΔH keluar = 262825,58 kJ

- **Ke Screw Conveyor J – 151**

  Wet ossein :

  - Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{146,46}{7139}\,kmol.3,18\,\frac{kJ}{kmol.K}.(T_{out} - 298)K$$

  - Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{5,05}{593}\,kmol.2,85\,\frac{kJ}{kmol.K}.(T_{out} - 298)K$$

  - H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1111,12}{18}\,kmol\int_{298}^{T_{out}}\left(A + BT + CT^2 + DT^3\right)\,dT$$

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out} + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{2} + T_{out}.298 + 298^{2}\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}^{2} + 298^{2}\right)\left(T_{out} + 298\right)\right]$$

$$(T_{out} - 298)\ \text{kJ / kmol}$$

- **Ke Waste Water**

  - $\underline{CaCl_2}$

$$\Delta H_{CaCl_2} = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + BT + CT^{2} + DT^{3} + ET^{4}\right)dT$$

$$= 2{,}7234.10^{3}\ \text{mol}\left[16{,}9(T_{out} - 298) + \frac{0{,}000386}{2}\left(T_{out}^{2} - 298^{2}\right)\right].$$

$$\text{cal / mol}$$

$$= 191{,}7728(T_{out} - 298) + 2{,}1901.10^{-3}\left(T_{out}^{2} - 298^{2}\right)\text{kJ}$$

  - $\underline{MgCl_2}$

$$\Delta H_{MgCl_2} = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + BT + CT^{2} + DT^{3}\right)dT$$

$$= \frac{46{,}95}{95}\ \text{kmol}\left[\left(72{,}4 + \frac{1{,}58.10^{-2}}{2}(T_{out} + 298)\right)(T_{out} - 298)\right]$$

$$\text{kJ / mol}$$

  - $\underline{H_3PO_4}$

$$\Delta H_{H_3PO_4} = \frac{m}{BM}.Cp.\Delta T$$

$$= \frac{184,2}{98} \text{ kmol}.212,9133 \frac{\text{kJ}}{\text{kmol.K}} \left(T_{out} - 298\right) \text{K}$$

- HCl

$$\Delta H_{P\ HCl} = \frac{m}{BM}.\int_{298}^{T_{out}} \left(A + BT + \frac{C}{T^2} \right) dT$$

$$= \frac{20,62}{36,5} \text{ kmol}\left[47,3.10^4\left(T_{out} - 298\right) + 45\left(T_{out}^{\ 2} - 298^2\right)\right] \text{J/kmol}$$

$$= 26,715\left(T_{out} - 298\right) + 0,0254\left(T_{out}^{\ 2} - 298^2\right) \text{kJ}$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{4270,9}{18} \text{kmol} \int_{298}^{T_{out}} \left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{4270,9}{18} \text{kmol.}\left[18,2964 + \frac{47,212.10^{-2}}{2}\left(T_{out} + 298\right) - \frac{133,88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)\left(T_{out} + 298\right) \right]$$

$$\left(T_{out} - 298\right) \text{kJ/kmol}$$

- CO_2

$$\Delta H_{CO_2} = \frac{m}{BM}.\int_{25}^{T_{out}} \left(A + BT + CT^2 + DT^3\right) dT$$

$$= 0{,}3982\,\text{kmol}\left[36{,}11 + \frac{4{,}233.10^{-2}}{2}\left(T_{out} + 25\right) - \frac{2{,}887.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{2} + 25.T_{out} + 25^{2}\right) + \frac{7{,}464.10^{-9}}{4}\left(T_{out}^{2} + 25^{2}\right)\left(T_{out} + 25\right)\right]$$

$$\left(T_{out} - 25\right)\ \text{kJ/kmol}$$

Entalpi keluar = entalpi keluar ke (Screw Conveyor J – 151 + Waste Water)

262825,58 kJ $= \left\{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\right\} + \left\{\Delta H_{CaCl_2} + \Delta H_{MgCl_2} + \Delta H_{H_3PO_4}\right.$

$\left. + \Delta H_{HCl} + \Delta H_{H_2O} + \Delta H_{CO_2}\right\}$

Dengan cara trial diperoleh : T_{out} = 309,3 K = 36,3°C, maka :

- **Ke Screw Conveyor J – 151**

Wet ossein :

- Protein

$$\Delta H = \frac{146{,}46}{7139}\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.(309{,}3 - 298)\text{K}$$

$$= 0{,}74\ \text{kJ}$$

- Lemak

$$\Delta H = \frac{5{,}05}{593}\text{kmol}.2{,}85\frac{\text{kJ}}{\text{kmol.K}}.(309{,}3 - 298)\text{K}$$

$$= 0{,}28\,\text{kJ}$$

- H_2O

$$\Delta H = \frac{1111{,}12}{18}\,\text{kmol}\Big[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(309{,}3+298) - \frac{133{,}88.10^{-5}}{3}$$

$$\left(309{,}3^2 + 309{,}3.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(309{,}3^2+298^2\right)$$

$$(309{,}3+298)\Big](309{,}3-298)\ \text{kJ/kmol}$$

$$= 52531{,}47\ \text{kJ}$$

Entalpi keluar ke Screw Conveyor J – 151 $= \Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}$

$= (0{,}74 + 0{,}28 + 52531{,}47)$ kJ

$= 52532{,}49$ kJ

- **Ke Waste Water**

- $CaCl_2$

$$\Delta H = 191{,}7728(309{,}3-298) + 2{,}1901.10^{-3}\left(309{,}3^2 - 298^2\right)\text{kJ}$$

$$= 2326{,}71\ \text{kJ}$$

- $MgCl_2$

$$\Delta H = \frac{46{,}95}{95}\,\text{kmol}\left[\left(72{,}4 + \frac{1{,}58.10^{-2}}{2}(309{,}3+298)\right)(309{,}3-298)\right]$$

$$\text{kJ/mol}$$

$$= 432{,}86\ \text{kJ}$$

- $\underline{H_3PO_4}$

$$\Delta H = \frac{184{,}2}{98}\ \text{kmol}.212{,}9133\ \frac{\text{kJ}}{\text{kmol.K}}\left(T_{out} - 298\right) \text{K}$$

$$= 4966{,}91 \text{ kJ}$$

- $\underline{HCl}$

$$\Delta H = 26{,}715(309{,}3 - 298) + 0{,}0254\left(309{,}3^2 - 298^2\right) \text{kJ}$$

$$= 478{,}34 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{4270{,}9}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(309{,}3 + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left(309{,}3^2 + 309{,}3.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(309{,}3^2 + 298^2\right)$$

$$\left.(309{,}3 + 298)\right](309{,}3 - 298) \text{ kJ/kmol}$$

$$= 201919{,}39 \text{ kJ}$$

- $\underline{CO_2}$

$$\Delta H = 0{,}3982 \text{ kmol}\left[36{,}11 + \frac{4{,}233.10^{-2}}{2}(36{,}3 + 25) - \frac{2{,}887.10^{-5}}{3}\left(36{,}3^2\right.\right.$$

$$\left.\left. + 25.36{,}3 + 25^2\right) + \frac{7{,}464.10^{-9}}{4}\left(36{,}3^2 + 25^2\right)(36{,}3 + 25)\right]$$

$$(36{,}3 - 25) \text{ kJ/kmol}$$

$$= 168{,}87 \text{ kJ}$$

Entalpi keluar ke Waste water

$= \Delta H_{CaCl_2} + \Delta H_{MgCl_2} + \Delta H_{H_3PO_4} + \Delta H_{HCl} + \Delta H_{H_2O} + \Delta H_{CO_2}$

= (2326,71 + 432,86 + 4966,91 + 478,34 + 201919,39 + 168,87) kJ

= 210293,09 kJ

Entalpi keluar = entalpi keluar ke (Screw Conveyor J – 151 + Waste water)

= 52532,49 kJ + 210293,09 kJ

= 262825,58 kJ

SCREW CONVEYOR J – 151

Dari Centrifugal Separator H – 150, T = 36,3°C → Screw Conveyor J – 151 → Ke Mixer M – 160, T = 35,2°C

Entalpi masuk :

Suhu masuk = 36,3°C = 309,3 K

- **Dari Centrifugal Separator H – 150**

  Wet ossein :

  - $\Delta H_{protein}$ = 0,74 kJ
  - ΔH_{lemak} = 0,28 kJ
  - ΔH_{H_2O} = 52531,47 kJ +

  ΔH masuk = 52532,49 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

52532,49 kJ = ΔH keluar + 10% (52532,49 kJ)

ΔH keluar = 47279,24 kJ

- **Ke Mixer M – 160**

Wet ossein :

- Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{146,46}{7139}\text{kmol}.3,18\frac{\text{kJ}}{\text{kmol.K}}.(T_{out} - 298)K$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{5,05}{593}\text{kmol}.2,85\frac{\text{kJ}}{\text{kmol.K}}.(T_{out} - 298)K$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1111,12}{18}\text{kmol}\int_{298}^{T_{out}}\left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out}+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(T_{out}^2 + T_{out}.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(T_{out}^2 + 298^2)(T_{out}+298)\right]$$

$$(T_{out} - 298)\ \text{kJ/kmol}$$

Entalpi keluar $= \Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}$

47279,24 kJ $= \Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}$

Dengan cara trial diperoleh : T_{out} = 308,2 K = 35,2°C, maka :

- **Ke Mixer M – 160**

  Wet ossein :

  - Protein

    $$\Delta H = \frac{146{,}46}{7139}\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.(308{,}2 - 298)\text{K}$$

    $$\Delta H = 0{,}67\ \text{kJ}$$

  - Lemak

    $$\Delta H = \frac{5{,}05}{593}\text{kmol}.2{,}85\frac{\text{kJ}}{\text{kmol.K}}.(308{,}2 - 298)\text{K}$$

    $$\Delta H = 0{,}25\ \text{kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{1111{,}12}{18}\,\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(308{,}2+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left(308{,}2^2 + 308{,}2.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(308{,}2^2 + 298^2\right)$$

$$\left.(308{,}2+298)\right](308{,}2-298)\ \text{kJ/kmol}$$

$$= 47278{,}33\ \text{kJ}$$

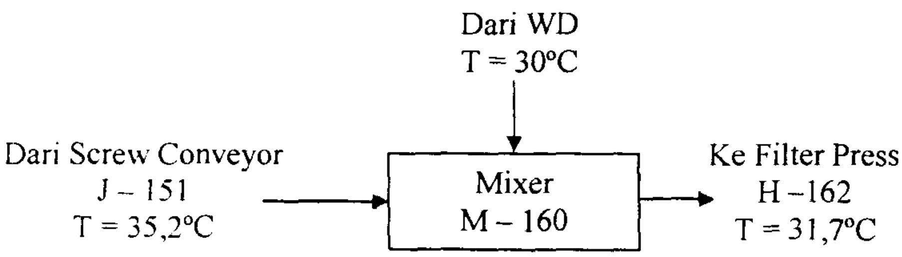
Total entalpi keluar ke Mixer M – 160 $= \Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}$

$= (0{,}67 + 0{,}25 + 47278{,}33)$ kJ

$= 47279{,}24$ kJ

MIXER M – 160

<u>Asumsi</u> : garam mineral yang ikut dari Screw Conveyor J – 151 jumlahnya sangat sedikit sehingga panas pelarutannya oleh H_2O (dari WD) dapat diabaikan



<u>Entalpi masuk :</u>

- **Dari Screw Conveyor J – 151**

  Suhu masuk = 35,2°C = 308,2 K

Wet ossein :

- $\Delta H_{protein}$ = 0,67 kJ
- ΔH_{lemak} = 0,25 kJ
- ΔH_{H_2O} = 47278,33 kJ +

ΔH_{J-151} = 47279,24 kJ

- **Dari WD**

Suhu masuk = 30°C = 303 K

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}\int_{298}^{303}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{1262,63}{18}\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(303+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.\left(303^2 + 303.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(303^2+298^2\right)(303+298)\right]$$

$$(303-298)\ \text{kJ/kmol}$$

$$\Delta H = \frac{1262,63}{18}\text{kmol}.74,9353\ (303-298)\ \text{kJ/kmol}$$

$$\Delta H = 26282,09\ \text{kJ}$$

Total entalpi masuk = entalpi mask dari (Screw Conveyor J – 151 + WD)

= 47279,24 kJ +26282,09 kJ

= 73561,33 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

73561,33 kJ = ΔH keluar + 10% (73561,33 kJ)

ΔH keluar = 66205,20 kJ

- **Ke Filter Press H – 162**

Wet ossein :

- Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{146,46}{7139}\text{kmol}.3,18\frac{\text{kJ}}{\text{kmol.K}}.(T_{out} - 298)K$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{5,05}{593}\text{kmol}.2,85\frac{\text{kJ}}{\text{kmol.K}}.(T_{out} - 298)K$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1111,12}{18}\text{kmol}\int_{298}^{T_{out}}\left(A + BT + CT^2 + DT^3\right)dT$$

$$\Delta H = \frac{1111{,}12}{18} \text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out} + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(T_{out}^2 + T_{out}.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(T_{out}^2 + 298^2)(T_{out} + 298)\right]$$

$$(T_{out} - 298) \text{ kJ/kmol}$$

$\underline{H_2O}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1262{,}63}{18} \text{kmol} \int_{298}^{T_{out}} (A + BT + CT^2 + DT^3)\, dT$$

$$\Delta H = \frac{1262{,}63}{18} \text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out} + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(T_{out}^2 + T_{out}.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(T_{out}^2 + 298^2)(T_{out} + 298)\right].$$

$$(T_{out} - 298) \text{ kJ/kmol}$$

Entalpi keluar $= \Delta H_{\text{wet ossein}} + \Delta H_{H_2O}$

66205,20 $= (\Delta H_{\text{protein}} + \Delta H_{\text{lemak}} + \Delta H_{H_2O}) + \Delta H_{H_2O}$

Dengan cara trial diperoleh : T_{out} = 304,7 K = 31,7°C, maka :

- **Ke Filter Press H – 162**

Wet ossein :

- Protein

$$\Delta H = \frac{146,46}{7139} \text{kmol}.3,18 \frac{\text{kJ}}{\text{kmol.K}}.(304,7 - 298)\text{K}$$

$$\Delta H = 0,44 \text{ kJ}$$

- Lemak

$$\Delta H = \frac{5,05}{593} \text{kmol}.2,85 \frac{\text{kJ}}{\text{kmol.K}}.(304,7 - 298)\text{K}$$

$$\Delta H = 0,16 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{1111,12}{18} \text{kmol}\left[18,2964 + \frac{47,212.10^{-2}}{2}(304,7 + 298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left(304,7^2 + 304,7.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(304,7^2 + 298^2\right)$$

$$\left.(304,7 + 298)\right](304,7 - 298) \text{ kJ/kmol}$$

$$= 30989,47 \text{ kJ}$$

H_2O

$$\Delta H = \frac{1262,63}{18} \text{kmol}\left[18,2964 + \frac{47,212.10^{-2}}{2}(304,7 + 298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left(304,7^2 + 304,7.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(304,7^2 + 298^2\right)$$

$$\left.(304,7 + 298)\right](304,7 - 298) \text{ kJ/kmol}$$

$$= 35215,13 \text{ kJ}$$

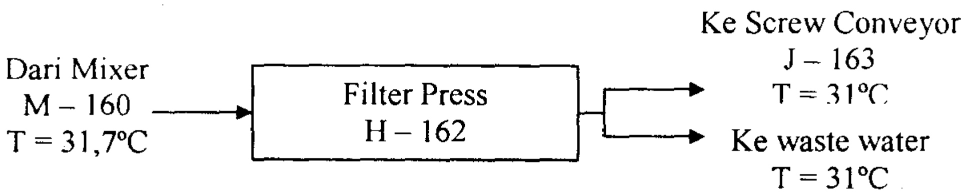
Total entalpi keluar $= (\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}) + \Delta H_{H_2O}$

$= (0,44 + 0,16 + 30989,47 + 35215,13)$ kJ

$= 66205,20$ kJ

FILTER PRESS H – 162

Asumsi : garam mineral yang terlarut dalam filtrat sangat sedikit sehingga dianggap bahan keluar ke Waste Water sama dengan air



Entalpi masuk :

Suhu masuk = 31,7°C = 304,7 K

- **Dari Mixer M – 160**

  Wet ossein :

  - $\Delta H_{protein}$ = 0,44 kJ
  - ΔH_{lemak} = 0,16 kJ
  - ΔH_{H_2O} = 30989,47 kJ

  ΔH_{H_2O} = 35215,13 kJ

  ——————————————— +

  ΔH masuk = 66205,20 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

66205,20 kJ = ΔH keluar + 10% (66205,20 kJ)

ΔH keluar = 59584,68 kJ

- **Ke Screw Conveyor J – 163**

  Wet ossein :

  - Protein

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{146,46}{7139} kmol . 3,18 \frac{kJ}{kmol.K} . (T_{out} - 298) K$$

  - Lemak

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{5,05}{593} kmol . 2,85 \frac{kJ}{kmol.K} . (T_{out} - 298) K$$

  - H_2O

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{1111,12}{18} kmol \int_{298}^{T_{out}} \left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out} + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(T_{out}^2 + T_{out}.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(T_{out}^2 + 298^2)(T_{out} + 298)\right]$$

$$(T_{out} - 298)\ \text{kJ/kmol}$$

- **Ke Waste Water**

  - $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1262{,}63}{18}\text{kmol}\int_{298}^{T_{out}}(A + BT + CT^2 + DT^3)\,dT$$

$$\Delta H = \frac{1262{,}63}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out} + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(T_{out}^2 + T_{out}.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(T_{out}^2 + 298^2)(T_{out} + 298)\right]$$

$$(T_{out} - 298)\ \text{kJ/kmol}$$

Entalpi keluar $= \{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\} + \Delta H_{H_2O}$

59584,68 kJ $= \{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\} + \Delta H_{H_2O}$

Dengan cara trial diperoleh : T_{out} = 304 K = 31°C, maka :

- **Ke Screw Conveyor J – 163**

  Wet ossein :

- Protein

$$\Delta H = \frac{146{,}46}{7139}\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.(304-298)\text{K}$$

$$= 0{,}39 \text{ kJ}$$

- Lemak

$$\Delta H = \frac{5{,}05}{593}\text{kmol}.2{,}85\frac{\text{kJ}}{\text{kmol.K}}.(304-298)\text{K}$$

$$= 0{,}15 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(304+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left(304^2 + 304.\,298 + 298^2\right) + \frac{1314{,}2\,.\,10^{-9}}{4}\left(304^2 + 298^2\right)$$

$$\left.(304+298)\right](304-298)\ \text{kJ/kmol}$$

$$= 27890{,}52 \text{ kJ}$$

Entalpi keluar ke Screw Conveyor J – 163 $= \Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}$

$= (0{,}39 + 0{,}15 + 27890{,}52)$ kJ

$= 27891{,}06$ kJ

- **Ke Waste Water**

  - <u>H_2O</u>

$$\Delta H = \frac{1262,63}{18}\text{kmol}\left[18,2964 + \frac{47,212.10^{-2}}{2}(304+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left(304^2 + 304.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(304^2 + 298^2\right)$$

$$\left.(304+298)\right](304-298)\ \text{kJ/kmol}$$

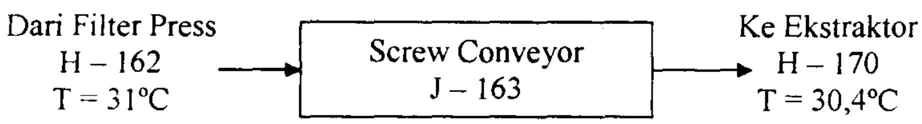
$$= 31693,62\ \text{kJ}$$

Total entalpi keluar = entalpi keluar ke (Screw Conveyor J – 163 + Waste Water)

= (27891,06 + 31693,62) kJ

= 59584,68 kJ

SCREW CONVEYOR J – 163



<u>Entalpi masuk :</u>

- **Dari Filter Press H – 162**

  Suhu masuk = 31°C = 304 K

Wet ossein :

- $\Delta H_{protein}$ = 0,39 kJ
- ΔH_{lemak} = 0,15 kJ
- ΔH_{H_2O} = 27890,52 kJ +

ΔH masuk = 27891,06 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

27891,06 kJ = ΔH keluar + 10% (27891,06 kJ)

ΔH keluar = 25101,96 kJ

- **Ke Ekstraktor H – 170**

Wet ossein :

- Protein

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{146,46}{7139} kmol . 3,18 \frac{kJ}{kmol . K} . (T_{out} - 298) K$$

- Lemak

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{5,05}{593} kmol . 2,85 \frac{kJ}{kmol . K} . (T_{out} - 298) K$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}\int_{298}^{T_{out}}\left(A + BT + CT^2 + DT^3\right)dT$$

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}\left(T_{out} + 298\right) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)\left(T_{out} + 298\right)\right]$$

$$\left(T_{out} - 298\right)\ \text{kJ / kmol}$$

Entalpi keluar $= \Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}$

25101,96 kJ $= \Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}$

Dengan cara trial diperoleh : T_{out} = 303,4 K = 30,4°C, maka :

- **Ke Ekstraktor H – 170**

Wet ossein :

- Protein

$$\Delta H = \frac{146{,}46}{7139}\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.\left(303{,}4 - 298\right)\text{K}$$

$= 0{,}35$ kJ

- Lemak

$$\Delta H = \frac{5{,}05}{593}\text{kmol}.2{,}85\frac{\text{kJ}}{\text{kmol.K}}.(303{,}4 - 298)\text{K}$$

$$= 0{,}13 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(303{,}4 + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left(303{,}4^2 + 303{,}4.\ 298 + 298^2\right) + \frac{1314{,}2\ .\ 10^{-9}}{4}\left(303{,}4^2 + 298^2\right)$$

$$\left.(303{,}4 + 298)\right]\left(303{,}4 - 298\right) \text{kJ/kmol}$$

$$= 25101{,}47 \text{ kJ}$$

Total entalpi keluar $= \Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}$

$= (0{,}35 + 0{,}13 + 25101{,}47)$ kJ

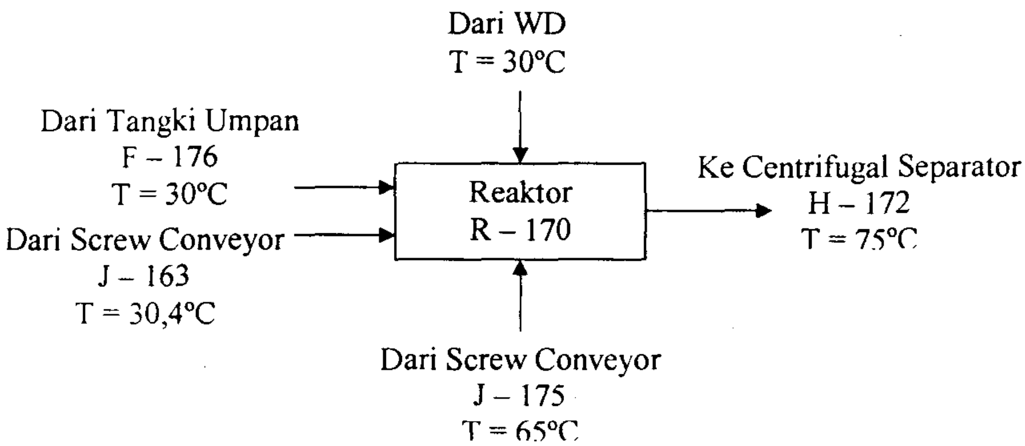
$= 25101{,}96$ kJ

EKSTRAKTOR H – 170

Suhu operasi ekstraktor = 75°C = 348 K

Ada panas suplai dari jaket pemanas dan koil.

Asumsi : Q_{loss} pada Screw Conveyor J – 175 ± 10% dari panas masuk sehingga suhu bahan dari Screw Conveyor J – 175 = 65°C



Entalpi masuk :

- **Dari Screw Conveyor J – 163**

  Suhu masuk = 30,4°C = 303,4 K

  Wet ossein :

  - $\Delta H_{protein}$ = 0,35 kJ
  - ΔH_{lemak} = 0,13 kJ
  - ΔH_{H_2O} = 25101,47 kJ +

  ΔH_{J-163} = 25101,96 kJ

- **Dari WD**

  Suhu masuk = 30°C = 303 K

  - H_2O

  $$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

  $$\Delta H = \frac{1262,63}{18}\text{kmol} \int_{298}^{303}\left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{1262{,}63}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(303+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(303^2+303.298+298^2) + \frac{1314{,}2.10^{-9}}{4}(303^2+298^2)(303+298)\right]$$

$$(303-298)\ \text{kJ/kmol}$$

$$\Delta H = 26282{,}09\ \text{kJ}$$

- **Dari Tangki Umpan F – 176**

Suhu masuk = 30°C = 303 K

- H_3PO_4

$$\Delta H_{H_3PO_4} = \frac{m}{BM}.Cp.\Delta T$$

$$= \frac{0{,}68}{98}\ \text{kmol}.212{,}9133\ \frac{\text{kJ}}{\text{kmol.K}}(303-298)\ \text{K}$$

$$= 8{,}08\ \text{kJ}$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{0{,}12}{18}\text{kmol}\int_{298}^{303}(A + BT + CT^2 + DT^3)\ dT$$

$$\Delta H = \frac{0{,}12}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(303+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(303^2+303.298+298^2) + \frac{1314{,}2.10^{-9}}{4}(303^2+298^2)(303+298)\right]$$

$$(303-298)\ \text{kJ/kmol}$$

$$\Delta H = 2{,}50\ \text{kJ}$$

Total entalpi masuk dari Tangki Umpan F – 176 $= \Delta H_{H_3PO_4} + \Delta H_{H_2O}$

$= 8{,}08\ \text{kJ} + 2{,}50\ \text{kJ}$

$= 10{,}58\ \text{kJ}$

- **Dari Screw Conveyor J – 175**

Suhu masuk = 65°C = 338 K

Wet ossein :

- Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{16{,}28}{7139}\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.(338-298)\text{K}$$

$$\Delta H = 0{,}29\ \text{kJ}$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{0,56}{593}\text{kmol}.2,85\frac{\text{kJ}}{\text{kmol.K}}.(338-298)\text{K}$$

$$\Delta H = 0,11 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{123,46}{18}\text{kmol}\int_{298}^{338}\left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{123,46}{18}\text{kmol.}\Bigg[18,2964 + \frac{47,212.10^{-2}}{2}(338+298) - \frac{133,88.10^{-5}}{3}$$

$$\left(338^2 + 338.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(338^2+298^2\right)(338+298)\Bigg]$$

$$(338-298)\text{ kJ/kmol}$$

$$\Delta H = 20657,80 \text{ kJ}$$

Larutan H_3PO_4 :

- $\underline{H_3PO_4}$

$$\Delta H_{H_3PO_4} = \frac{m}{BM}.Cp.\Delta T$$

$$= \frac{0,08}{98}\text{ kmol}.212,9133\frac{\text{kJ}}{\text{kmol.K}}(338-298)\text{ K}$$

$$= 7,61 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{0,01}{18} kmol \int_{298}^{338} \left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{0,01}{18} kmol. \left[18,2964 + \frac{47,212.10^{-2}}{2} (338 + 298) - \frac{133,88.10^{-5}}{3} \right.$$

$$\left. \left(338^2 + 338.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4} \left(338^2 + 298^2\right)(338 + 298) \right]$$

$$(338 - 298) \text{ kJ / kmol}$$

$$\Delta H = 1,67 \text{ kJ}$$

Total entalpi masuk dari Screw Conveyor J – 163

$= \Delta H_{wet\ ossein} + \Delta H_{larutan\ H_3PO_4}$

$= \left(\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\right) + \left(\Delta H_{H_3PO_4} + \Delta H_{H_2O}\right)$

= (0,29 + 0,11 + 20657,80) kJ + (7,61 + 1,67) kJ

= 20667,47 kJ

Total entalpi masuk = entalpi masuk dari (WD + Tangki Umpan F – 176 + Screw Conveyor J – 163 + Screw Conveyor J – 175)

= (25101,96 + 26282,09 + 10,58 + 20667,47) kJ

= 72062,10 kJ

Entalpi keluar :

Suhu keluar = 75°C = 348 K

- **Ke Centrifugal Separator H – 172**

  Wet ossein :

- Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{16{,}28}{7139} kmol.3{,}18\frac{kJ}{kmol.K}.(348-298)K$$

$$\Delta H = 0{,}36\ kJ$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{0{,}56}{593} kmol.2{,}85\frac{kJ}{kmol.K}.(348-298)K$$

$$\Delta H = 0{,}13\ kJ$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{123{,}46}{18} kmol \int_{298}^{348} \left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{123{,}46}{18} kmol.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(348+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(348^2 + 348.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(348^2+298^2\right)(348+298)\right]$$

$$(348-298)\ kJ/kmol$$

$$\Delta H = 25853{,}95\ kJ$$

Gelatin :

- Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{146,46}{7139}\text{kmol}.3,18\frac{\text{kJ}}{\text{kmol.K}}.(348-298)\text{K}$$

$$\Delta H = 3,26 \text{ kJ}$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{5,05}{593}\text{kmol}.2,85\frac{\text{kJ}}{\text{kmol.K}}.(348-298)\text{K}$$

$$\Delta H = 1,21 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1111,12}{18}\text{kmol}\int_{298}^{348}\left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{1111,12}{18}\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(348+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.\left(348^2+348.298+298^2\right)+\frac{1314,2.10^{-9}}{4}\left(348^2+298^2\right)(348+298)\right]$$

$$(348-298)\text{ kJ/kmol}$$

$$\Delta H = 232681,33 \text{ kJ}$$

Larutan H_3PO_4 :

- $\underline{H_3PO_4}$

$$\Delta H_{H_3PO_4} = \frac{m}{BM}.Cp.\Delta T$$

$$= \frac{0,76}{98}\ \text{kmol}.212,9133\ \frac{\text{kJ}}{\text{kmol.K}}(348-298)\ \text{K}$$

$$= 90,31\ \text{kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1403,05}{18}\text{kmol}\int_{298}^{348}\left(A + BT + CT^2 + DT^3\right)dT$$

$$\Delta H = \frac{1403,05}{18}\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(348+298) - \frac{133,88.10^{-5}}{3}\left(348^2 + 348.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(348^2 + 298^2\right)(348+298)\right]$$

$$(348-298)\ \text{kJ/kmol}$$

$$\Delta H = 293814,82\ \text{kJ}$$

Total entalpi keluar

$= \Delta H_{\text{wet ossein}} + \Delta H_{\text{gelatin}} + \Delta H_{\text{larutan } H_3PO_4}$

= (0,36 + 0,13 + 25853,95) kJ + (3,26 + 1,21 + 232681,33) kJ + (90,31 + 293814,82) kJ

= 552445,38 kJ

Asumsi : Q_{loss} = 10% . Q_{suplai}

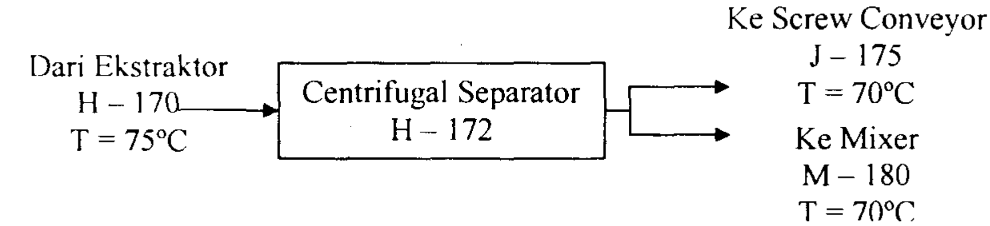
Entalpi masuk + Q_{suplai} = entalpi keluar + Q_{loss}

72062,10 kJ + Q_{suplai} = 552445,38 kJ + 10% . Q_{suplai}

$$Q_{suplai} = \frac{552445{,}38 \text{ kJ} - 72062{,}10 \text{ kJ}}{0{,}9}$$

$$Q_{suplai} = 533759{,}20 \text{ kJ}$$

CENTRIFUGAL SEPARATOR H – 172



Entalpi masuk :

Dari Ekstraktor H – 170

Suhu masuk = 75°C = 348 K

Wet ossein :

$\Delta H_{protein}$ = 0,36 kJ

ΔH_{lemak} = 0,13 kJ

ΔH_{H_2O} = 25853,95 kJ

Gelatin :

$\Delta H_{protein}$ = 3,26 kJ

ΔH_{lemak} = 1,21 kJ

ΔH_{H_2O} = 232681,32 kJ

Larutan H_3PO_4 :

$\Delta H_{H_3PO_4}$ = 90,31 kJ

ΔH_{H_2O} = 293814,82 kJ +

ΔH masuk = 552445,38 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

552445,38 kJ = ΔH keluar + 10% (552445,38 kJ)

ΔH keluar = 497200,84 kJ

- **Ke Screw Conveyor J – 175**

  Wet ossein :

  - Protein

    $$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

    $$\Delta H = \frac{16,28}{7139} \text{kmol} . 3,18 \frac{\text{kJ}}{\text{kmol.K}} . (T_{out} - 298) K$$

  - Lemak

    $$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{0{,}56}{593} \text{kmol}.2{,}85 \frac{\text{kJ}}{\text{kmol.K}}.(T_{out} - 298)K$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{123{,}46}{18} \text{kmol} \int_{298}^{T_{out}} \left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{123{,}46}{18} \text{kmol.} \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} (T_{out} + 298) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^2 + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4} \left(T_{out}^2 + 298^2\right)\left(T_{out} + 298\right) \right]$$

$$(T_{out} - 298) \text{ kJ/kmol}$$

Larutan H_3PO_4 :

- $\underline{H_3PO_4}$

$$\Delta H_{H_3PO_4} = \frac{m}{BM}.Cp.\Delta T$$

$$= \frac{0{,}08}{98} \text{kmol}.212{,}9133 \frac{\text{kJ}}{\text{kmol.K}} (T_{out} - 298) K$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{140{,}3}{18} \text{kmol} \int_{298}^{T_{out}} \left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{140,3}{18}\,\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}\left(T_{out}+298\right) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{2} + T_{out}.298 + 298^{2}\right) + \frac{1314,2.10^{-9}}{4}\left(T_{out}^{2}+298^{2}\right)\left(T_{out}+298\right)\right]$$

$$\left(T_{out} - 298\right)\ \text{kJ/kmol}$$

- **Ke Mixer M – 180**

Gelatin :

- Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{146,46}{7139}\,\text{kmol}.3,18\frac{\text{kJ}}{\text{kmol.K}}.\left(T_{out} - 298\right)\text{K}$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{5,05}{593}\,\text{kmol}.2,85\frac{\text{kJ}}{\text{kmol.K}}.\left(T_{out} - 298\right)\text{K}$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1111,12}{18}\,\text{kmol}\int_{298}^{T_{out}}\left(A + BT + CT^{2} + DT^{3}\right)\,dT$$

$$\Delta H = \frac{1111,12}{18}\text{kmol.}\left[18,2964 + \frac{47,212.10^{-2}}{2}(T_{out} + 298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.(T_{out}^{2} + T_{out}.298 + 298^{2}) + \frac{1314,2.10^{-9}}{4}(T_{out}^{2} + 298^{2})(T_{out} + 298)\right]$$

$$(T_{out} - 298)\ \text{kJ/kmol}$$

Larutan H_3PO_4 :

- $\underline{H_3PO_4}$

$$\Delta H_{H_3PO_4} = \frac{m}{BM}.Cp.\Delta T$$

$$= \frac{0,68}{98}\ \text{kmol}.212,9133\ \frac{kJ}{kmol.K}(T_{out} - 298)\ K$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1262,75}{18}\text{kmol}\int_{298}^{T_{out}}(A + BT + CT^2 + DT^3)\ dT$$

$$\Delta H = \frac{1262,75}{18}\text{kmol.}\left[18,2964 + \frac{47,212.10^{-2}}{2}(T_{out} + 298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.(T_{out}^{2} + T_{out}.298 + 298^{2}) + \frac{1314,2.10^{-9}}{4}(T_{out}^{2} + 298^{2})(T_{out} + 298)\right]$$

$$(T_{out} - 298)\ \text{kJ/kmol}$$

Entalpi keluar = entalpi ke (Screw Conveyor J – 175 + Mixer M – 180)

497200,84 kJ = entalpi (wet ossein + larutan asam fosfat) + entalpi (gelatin + larutan asam fosfat)

$$497200{,}84 \text{ kJ} = \left\{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O} + \Delta H_{H_3PO_4} + \Delta H_{H_2O}\right\} + \left\{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O} + \Delta H_{H_3PO_4} + \Delta H_{H_2O}\right\}$$

Dengan cara trial diperoleh : T_{out} = 343 K = 70°C, maka :

- **Ke Screw Conveyor J – 175**

Wet ossein :

- Protein

$$\Delta H = \frac{16{,}28}{7139}\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.(343-298)\text{K}$$

$$\Delta H = 0{,}33 \text{ kJ}$$

- Lemak

$$\Delta H = \frac{0{,}56}{593}\text{kmol}.2{,}85\frac{\text{kJ}}{\text{kmol.K}}.(343-298)\text{K}$$

$$\Delta H = 0{,}12 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{123{,}46}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(343+298) - \frac{133{,}88.10^{-5}}{3}\left(343^2 + 343.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(343^2+298^2\right)(343+298)\right]$$

$$(343-298) \text{ kJ/kmol}$$

$$\Delta H = 23268{,}55 \text{ kJ}$$

Larutan H_3PO_4 :

- $\underline{H_3PO_4}$

$$\Delta H_{H_3PO_4} = \frac{0,08}{98} \text{ kmol}.212,9133 \frac{\text{kJ}}{\text{kmol.K}}(343-298)\text{ K}$$

$$= 8,56 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{140,3}{18}\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(343+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.(343^2+343.298+298^2)+\frac{1314,2.10^{-9}}{4}(343^2+298^2)(343+298)\right]$$

$$(343-298)\text{ kJ / kmol}$$

$$= 26442,39 \text{ kJ}$$

Total entalpi keluar ke Screw Conveyor J – 175

$= \Delta H_{\text{wet ossein}} + \Delta H_{\text{larutan } H_3PO_4}$

= (0,33 + 0,12 + 23268,55) kJ + (8,56 + 26442,39) kJ

= 49719,95 kJ

- **Ke Mixer M – 180**

Gelatin :

- Protein

$$\Delta H = \frac{146,46}{7139}\text{kmol}.3,18\frac{\text{kJ}}{\text{kmol.K}}.(343-298)\text{K}$$

$$= 2,94 \text{ kJ}$$

- Lemak

$$\Delta H = \frac{5{,}05}{593}\,\text{kmol}.\,2{,}85\,\frac{\text{kJ}}{\text{kmol.K}}.(343-298)\text{K}$$

$$= 1{,}09\ \text{kJ}$$

- H_2O

$$\Delta H = \frac{1111{,}12}{18}\,\text{kmol}.\Big[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(343+298) - \frac{133{,}88.10^{-5}}{3}$$

$$(343^2 + 343.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(343^2 + 298^2)(343+298)\Big]$$

$$(343-298)\ \text{kJ/kmol}$$

$$= 209413{,}17\ \text{kJ}$$

Larutan H_3PO_4 :

- H_3PO_4

$$\Delta H_{H_3PO_4} = \frac{0{,}68}{98}\,\text{kmol}.212{,}9133\,\frac{\text{kJ}}{\text{kmol.K}}(343-298)\ \text{K}$$

$$= 72{,}77\ \text{kJ}$$

- H_2O

$$\Delta H = \frac{1262{,}75}{18}\,\text{kmol}.\Big[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(343+298) - \frac{133{,}88.10^{-5}}{3}$$

$$(343^2 + 343.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(343^2 + 298^2)(343+298)\Big]$$

$$(343-298)\ \text{kJ/kmol}$$

$$= 237990{,}93\ \text{kJ}$$

Total entalpi keluar ke Mixer M – 180

$= \Delta H_{gelatin} + \Delta H_{larutan\ H_3PO_4}$

$= (2{,}94 + 1{,}09 + 209413{,}17 + 72{,}77 + 237990{,}93)$ kJ

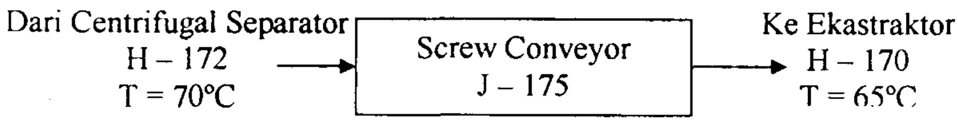
= 447480,89 kJ

Total entalpi keluar = entalpi keluar ke (Screw Conveyor J – 175 + Mixer M – 180)

= (49719,95 + 447840,89) kJ

= 497200,84 kJ

SCREW CONVEYOR J – 175



Entalpi masuk :

Suhu masuk = 70°C = 343 K

- **Dari Centrifugal Separator H – 172**

Wet ossein :

- $\Delta H_{protein}$ = 0,33 kJ
- ΔH_{lemak} = 0,12 kJ
- ΔH_{H_2O} = 23268,55 kJ

Larutan H_3PO_4 :

- $\Delta H_{H_3PO_4}$ = 8,56 kJ

- ΔH_{H_2O} = 26442,39 kJ +

ΔH masuk = 49719,95 kJ

Entalpi keluar :

Suhu keluar = 65°C = 338 K

- **Ke Ekstraktor H –170**

Wet ossein :

- Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{16,28}{7139}\text{kmol}.3,18\frac{\text{kJ}}{\text{kmol.K}}.(338-298)\text{K}$$

$$\Delta H = 0,29 \text{ kJ}$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{0,56}{593}\text{kmol}.2,85\frac{\text{kJ}}{\text{kmol.K}}.(338-298)\text{K}$$

$$\Delta H = 0,11 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{123,46}{18}\text{kmol}\int_{298}^{338}\left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{123{,}46}{18}\text{kmol.}\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(338+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(338^2+338.298+298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(338^2+298^2\right)(338+298)\right]$$

$$(338-298)\ \text{kJ/kmol}$$

$$\Delta H = 20657{,}80\ \text{kJ}$$

Larutan H_3PO_4 :

- $\underline{H_3PO_4}$

$$\Delta H_{H_3PO_4} = \frac{m}{BM}.Cp.\Delta T$$

$$= \frac{0{,}08}{98}\text{kmol}.212{,}9133\ \frac{\text{kJ}}{\text{kmol.K}}(338-298)\ \text{K}$$

$$= 7{,}61\ \text{kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{140{,}3}{18}\text{kmol}\int_{298}^{338}\left(A+BT+CT^2+DT^3\right)\,dT$$

$$\Delta H = \frac{140,3}{18}\,\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(338+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.(338^2 + 338.298 + 298^2) + \frac{1314,2.10^{-9}}{4}(338^2 + 298^2)(338+298)\right]$$

$$(338-298)\ \text{kJ/kmol}$$

$$\Delta H = 23475,53\ \text{kJ}$$

Entalpi keluar = entalpi (wet ossein + larutan asam fosfat)

$= \{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\} + \{\Delta H_{H_3PO_4} + \Delta H_{H_2O}\}$

$= \{0,29 + 0,11 + 20657,80\}\ \text{kJ} + \{7,61 + 23475,53\}\ \text{kJ}$

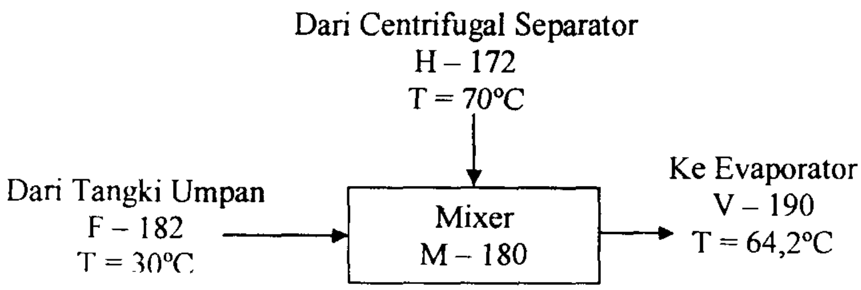
$= 44141,33\ \text{kJ}$

ΔH masuk = ΔH keluar + Q_{loss}

49719,95 kJ = 44141,33 kJ + Q_{loss}

Q_{loss} = 5578,63 kJ

MIXER M – 180



<u>Entalpi masuk :</u>

Suhu masuk = 343 K = 70°C

- **Dari Centrifugal Separator H – 172**

  Gelatin :

  - $\Delta H_{protein}$ = 2,94 kJ
  - ΔH_{lemak} = 1,09 kJ
  - ΔH_{H_2O} = 209413,17 kJ

  Larutan H_3PO_4 :

  - $\Delta H_{H_3PO_4}$ = 72,77 kJ
  - ΔH_{H_2O} = 237990,93 kJ

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  ΔH_{H-172} = 447480,89 kJ

- **Dari Tangki Umpan F – 182**

  Suhu masuk = 30°C = 303 K

  - <u>$Ca(OH)_2$</u>

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{303} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$\Delta H = \frac{0{,}78.10^3}{74} \text{mol}.21{,}4\ (303 - 298)\ \text{cal / mol}$$

$$= 4{,}70\ \text{kJ}$$

Entalpi total masuk = entalpi masuk dari (Centrifugal Separator H – 172 + Tangki Umpan F – 182)

$= 447480{,}89 \text{ kJ} + 4{,}70 \text{ kJ}$

$= 447485{,}59 \text{ kJ}$

Entalpi keluar :

- **Ke Evaporator V – 190**

Data-data ΔH^0_{298} :

$\Delta H^0_{298}\ _{Ca_3(PO_4)_2} = -4137{,}6 \text{ kJ / mol}$

$\Delta H^0_{298}\ _{H_2O} = -285{,}840 \text{ kJ / mol}$

(Geankoplis, 1983)

$\Delta H^0_{298}\ _{H_3PO_4} = -228{,}2 \text{ kcal / mol} = -950{,}8333 \text{ kJ / mol}$

(Hougen, 1981)

$\Delta H^0_{298}\ _{Ca(OH)_2} = -986{,}09 \text{ J / mol} = -0{,}9861 \text{ kJ / mol}$

(Smith Van Ness, 1996)

$\Delta H \text{ reaksi} = \Delta H_{298}$

$$\Delta H^0_{298} = \left[\left(n \,.\, \Delta H^0_{298}\right)_{H_2O} + \left(n \,.\, \Delta H^0_{298}\right)_{Ca_3(PO_4)_2}\right] - \left[\left(n \,.\, \Delta H^0_{298}\right)_{H_3PO_4} + \left(n \,.\, \Delta H^0_{298}\right)_{Ca(OH)_2}\right]$$

$$\left[\left(0{,}021.10^3\,\text{mol}(\quad 285{,}840\,\text{kJ/mol}\right)\right)\ \left(0{,}0035.10^3\,\text{mol}(\quad 4137{,}6\,\text{kJ/mol})\right)\right]$$

$$\left[\left(0{,}007\,.\,10^3\,\text{mol}\,(\quad 950{,}8333\,\text{kJ/mol})\right)\ \left(0{,}0105\,.\,10^3\,\text{mol}\right.\right.$$

$$\left.\left.(-\,0{,}9861\,\text{kJ/mol})\right)\right]$$

$$= -13818{,}01\ \text{kJ}$$

$$\Delta H_{masuk} = \Delta H_{reaksi} + \Delta H_{keluar} + Q_{loss}$$

$$447485{,}59\ \text{kJ} = 13818{,}01\ \text{kJ} + \Delta H_{keluar} + 10\%.447485{,}59\ \text{kJ}$$

$$\Delta H_{keluar} = 388919{,}02\ \text{kJ}$$

Gelatin :

- <u>Protein</u>

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{146{,}46}{7139}\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.\left(T_{out} - 298\right)K$$

- <u>Lemak</u>

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{5{,}05}{593}\text{kmol}.2{,}85\frac{\text{kJ}}{\text{kmol.K}}.\left(T_{out} - 298\right)K$$

- <u>H_2O</u>

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1111{,}12}{18} \text{kmol} \int_{298}^{T_{out}} \left(A + BT + CT^2 + DT^3\right)\, dT$$

$$\Delta H = \frac{1111{,}12}{18} \text{kmol.} \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} \left(T_{out} + 298\right) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4} \left(T_{out}^{\ 2} + 298^2\right)\left(T_{out} + 298\right) \right]$$

$$\left(T_{out} - 298\right) \text{kJ/kmol}$$

Larutan $Ca_3(PO_4)_2$:

- $\underline{Ca_3(PO_4)_2}$

$$\Delta H = \frac{m}{BM} . \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2}\right) dT$$

$$= \frac{0{,}03.10^3}{310} \text{mol} \left[18{,}52\left(T_{out} - 298\right) + \frac{0{,}02197}{2} \left(T_{out}^{\ 2} - 298^2\right) + \left(\frac{156800}{T_{out}} \right. \right.$$

$$\left. \left. - \frac{156800}{298}\right)\right] \text{cal/mol}$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{1263{,}12}{18} \text{kmol} \int_{298}^{T_{out}} \left(A + BT + CT^2 + DT^3\right)\, dT$$

$$\Delta H = \frac{1263{,}12}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out} + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(T_{out}^2 + T_{out}.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(T_{out}^2 + 298^2)(T_{out} + 298)\right]$$

$$(T_{out} - 298)\ \text{kJ/kmol}$$

Padatan $Ca_3(PO_4)_2$:

- $\underline{Ca_3(PO_4)_2}$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{1{,}06.10^3}{310}\text{mol}\left[18{,}52(T_{out} - 298) + \frac{0{,}02197}{2}(T_{out}^2 - 298^2) + \left(\frac{156800}{T_{out}}\right.\right.$$

$$\left.\left. - \frac{156800}{298}\right)\right]\text{cal/mol}$$

$$\Delta H\ \text{keluar} = \{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\} + \{\Delta H_{Ca_3PO_4} + \Delta H_{H_2O}\} + \Delta H_{Ca_3PO_4}$$

$$388919{,}02\ \text{kJ} = \{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\} + \{\Delta H_{Ca_3PO_4} + \Delta H_{H_2O}\} + \Delta H_{Ca_3PO_4}$$

Dengan cara trial diperoleh : T_{out} = 337,2 K = 64,2°C, maka :

Gelatin :

- Protein

$$\Delta H = \frac{146,46}{7139}\text{kmol}.3,18\frac{\text{kJ}}{\text{kmol.K}}.(337,2-298)\text{K}$$

$$\Delta H = 2,55 \text{ kJ}$$

- Lemak

$$\Delta H = \frac{5,05}{593}\text{kmol}.2,85\frac{\text{kJ}}{\text{kmol.K}}.(337,2-298)\text{K}$$

$$\Delta H = 0,95 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{1111,12}{18}\text{kmol}\left[18,2964+\frac{47,212.10^{-2}}{2}(337,2+298)-\frac{133,88.10^{-5}}{3}\right.$$

$$(337,2^2+337,2.298+298^2)+\frac{1314,2.10^{-9}}{4}(337,2^2+298^2)(337,2$$

$$\left.+298)\right](337,2-298)\text{ kJ/kmol}$$

$$\Delta H = 182004,82 \text{ kJ}$$

Larutan $Ca_3(PO_4)_2$:

- $Ca_3(PO_4)_2$

$$\Delta H = \frac{0,03.10^3}{310}\text{mol}\left[18,52(337,2-298)+\frac{0,02197}{2}(337,2^2-298^2)+\left(\frac{156800}{337,2}\right.\right.$$

$$\left.\left.-\frac{156800}{298}\right)\right]\text{cal/mol}$$

$$= 3,91 \text{ kJ}$$

- <u>H_2O</u>

$$\Delta H = \frac{1263{,}12}{18}\text{kmol.}\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(337{,}2+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left(337{,}2^2 + 337{,}2.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(337{,}2^2 + 298^2\right)(337{,}2$$

$$\left.+298)\right](337{,}2 - 298)\ \text{kJ/kmol}$$

$$= 206902{,}88\ \text{kJ}$$

Padatan $Ca_3(PO_4)_2$:

- <u>$Ca_3(PO_4)_2$</u>

$$\Delta H = \frac{1{,}06.10^3}{310}\text{mol}\left[18{,}52(337{,}2-298) + \frac{0{,}02197}{2}\left(337{,}2^2 - 298^2\right) + \left(\frac{156800}{337{,}2}\right.\right.$$

$$\left.\left.-\frac{156800}{298}\right)\right]\ \text{cal/mol}$$

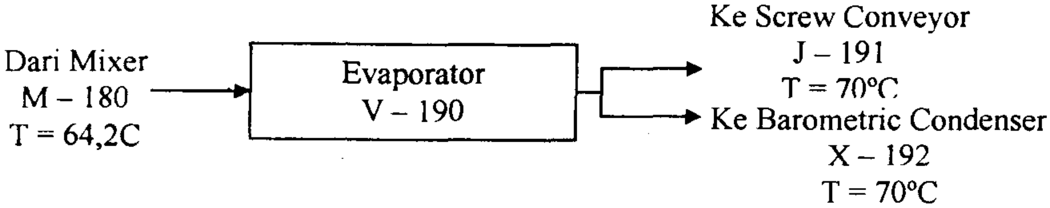
$$= 3{,}91\ \text{kJ}$$

$$\text{Entalpi keluar} = \Delta H_{\text{gelatin}} + \Delta H_{\text{larutan } H_3PO_4} + \Delta H_{\text{padatan } Ca_3(PO_4)_2}$$

= (2,55 + 0,95 + 182004,82) kJ + (3,91 + 206902,88) kJ + 3,91 kJ

= 388919,02 kJ

EVAPORATOR V – 190



<u>Entalpi masuk :</u>

Suhu masuk = 337,2 K = 64,2°C

- **Dari Mixer M – 180**

  Gelatin :

  - $\Delta H_{protein}$ = 2,55 kJ
  - ΔH_{lemak} = 0,95 kJ
  - ΔH_{H_2O} = 182004,82 kJ

  Larutan Ca_3PO_4 :

  - $\Delta H_{Ca_3PO_4}$ = 3,91 kJ
  - ΔH_{H_2O} = 206902,88 kJ

  $\Delta H_{Ca_3PO_4\ (s)}$ = 3,91 kJ

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  ΔH masuk = 388919,02 kJ

<u>Entalpi keluar :</u>

Suhu keluar = 343 K = 70°C

- **Ke Screw Conveyor J – 191**

  Gelatin :

  - <u>Protein</u>

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{146{,}46}{7139}\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.(343-298)\text{K}$$

$$\Delta H = 2{,}94 \text{ kJ}$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{5{,}05}{593}\text{kmol}.2{,}85\frac{\text{kJ}}{\text{kmol.K}}.(343-298)\text{K}$$

$$\Delta H = 1{,}09 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}\int_{298}^{343}\left(A + BT + CT^2 + DT^3\right)\,dT$$

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}\Big[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(343+298) - \frac{133{,}88.10^{-5}}{3}$$

$$\left(343^2 + 343.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(343^2+298^2\right)(343+298)\Big]$$

$$(343-298)\text{ kJ/kmol}$$

$$\Delta H = 209285{,}51 \text{ kJ}$$

Larutan $Ca_3(PO_4)_2$:

- $\underline{Ca_3(PO_4)_2}$

$$\Delta = \frac{\cdot}{\cdot} \int_{298}^{343} \left(. + . \ T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}01.10^3}{310} mol \left[18{,}52(343-298) + \frac{0{,}02197}{2}(343^2 - 298^2) + \left(\frac{156800}{343} - \frac{156800}{298} \right) \right] cal/mol$$

$$= 4{,}51 kJ$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{378{,}94}{18} kmol \int_{298}^{343} (A + BT + CT^2 + DT^3)\ dT$$

$$\Delta H = \frac{378{,}94}{18} kmol \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(343+298) - \frac{133{,}88.10^{-5}}{3} (343^2 + 343.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(343^2 + 298^2)(343+298) \right]$$

$$(343 - 298)\ kJ/kmol$$

$$\Delta H = 71375{,}42\ kJ$$

Padatan $Ca_3(PO_4)_2$:

- $\underline{Ca_3(PO_4)_2}$

$$\Delta \;= \frac{\cdot}{-} \int_{298}^{343} \left(. \;+ .\; T + \frac{C}{T^2} \right) dT$$

$$= \frac{1{,}08.10^3}{310} mol \left[18{,}52(343-298) + \frac{0{,}02197}{2}\left(343^2 - 298^2\right) + \left(\frac{156800}{343} - \frac{156800}{298} \right) \right] cal/mol$$

$= 4{,}51$ kJ

Total entalpi keluar dari Screw Conveyor J – 191

$= \Delta H_{gelatin} + \Delta H_{larutan\ Ca_3(PO_4)_2} + \Delta H_{padatan\ Ca_3(PO_4)_2}$

= (2,94 + 1,09 + 209285,51) kJ + (4,51 + 71375,42) kJ + 4,51 kJ

= 280673,97 kJ

- **Ke Barometric Condensor X – 192**

Panas laten air menguap $= \frac{m}{BM} . \lambda$

$= \frac{884{,}18.10^3}{18} mol \,.\, 40{,}65 \frac{kJ}{mol}$

= 1996773,17 kJ

- $\underline{H_2O_{(g)}}$

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{884,18}{18}\text{kmol}\int_{25}^{70}\left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{884,18}{18}\text{kmol}\left[33,46 + \frac{0,688.10^{-2}}{2}(70+25) + \frac{0,7604.10^{-5}}{3}\right.$$

$$\left.\left(70^2 + 70.25 + 25^2\right) - \frac{3,593.10^{-9}}{4}\left(70^2 + 25^2\right)(70 + 25)\right]$$

$$(70 - 25)\ \text{kJ/kmol}$$

$$\Delta H = 1660,53\ \text{kJ}$$

Total entalpi keluar dari Barometric Condenser X – 192

= (1996773,17 + 1660,53) kJ

= 1998433,69 kJ

Total entalpi keluar = entalpi keluar ke (Barometric Condensor X – 192 + Screw Conveyor J – 191)

= 1998433,69 kJ + 280673,97 kJ

= 2279107,66 kJ

Asumsi : Q_{loss} = 10% . Q_{suplai}

Entalpi masuk + Q_{suplai} = entalpi keluar + Q_{loss}

388919,02 kJ + Q_{suplai} = 2279107,66 kJ + 10% . Q_{suplai}

$$Q_{suplai} = \frac{2279107,66 - 388919,02\ \text{kJ}}{0,9}$$

$$Q_{suplai} = 2100209,60\ \text{kJ}$$

SCREW CONVEYOR J – 191

Dari Evaporator V – 190 T = 70°C → Screw Conveyor J – 191 → Ke Spray Dryer B – 194 T = 65,5°C

Entalpi masuk :

Suhu masuk = 343 K = 70°C

- **Dari Evaporator V – 190**

  Gelatin :

  - $\Delta H_{protein}$ = 2,94 kJ
  - ΔH_{lemak} = 1,09 kJ
  - ΔH_{H_2O} = 209285,51 kJ

  Larutan $Ca_3(PO_4)_2$:

  - $\Delta H_{Ca_3(PO_4)_2}$ = 4,51 kJ
  - ΔH_{H_2O} = 71375,42 kJ

  Padatan $Ca_3(PO_4)_2$ = 4,51 kJ

  ———————————————— +

  ΔH masuk = 280673,97 kJ

Entalpi keluar :

- **Ke Spray Dryer B – 194**

$$. H_{masuk} \cdot \cdot H_{keluar} \cdot Q_{loss}$$

$$280673{,}97 \text{ kJ} . \; . H_{keluar} \cdot 10\%.280673{,}97 \text{ kJ}$$

$$\Delta H_{keluar} = 252606{,}57 \text{ kJ}$$

Gelatin :

- Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{146{,}46}{7139}\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.(T_{out} - 298)\text{K}$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{5{,}05}{593}\text{kmol}.2{,}85\frac{\text{kJ}}{\text{kmol.K}}.(T_{out} - 298)\text{K}$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}\int_{298}^{T_{out}}\left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{1111{,}12}{18} \text{kmol} \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} (T_{out} + 298) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. (T_{out}^2 + T_{out}.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4} (T_{out}^2 + 298^2)(T_{out} + 298) \right]$$

$$(T_{out} - 298)\ \text{kJ/kmol}$$

Larutan $Ca_3(PO_4)_2$:

- $Ca_3(PO_4)_2$

$$\Delta H = \frac{m}{BM} . \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}01.10^3}{310} \text{mol} \left[18{,}52(T_{out} - 298) + \frac{0{,}02197}{2} (T_{out}^2 - 298^2) + \left(\frac{156800}{T_{out}} \right. \right.$$

$$\left. \left. - \frac{156800}{298} \right) \right] \text{cal/mol}$$

- H_2O

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{378{,}94}{18} \text{kmol} \int_{298}^{T_{out}} (A + BT + CT^2 + DT^3)\ dT$$

$$\Delta H = \frac{378{,}94}{18} \text{kmol} \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} (T_{out} + 298) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. (T_{out}^2 + T_{out}.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4} (T_{out}^2 + 298^2)(T_{out} + 298) \right]$$

$$(T_{out} - 298) \text{ kJ/kmol}$$

Padatan $Ca_3(PO_4)_2$:

- $\underline{Ca_3(PO_4)_2}$

$$\Delta H = \frac{m}{BM} . \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{1{,}08.10^3}{310} \text{mol} \left[18{,}52(T_{out} - 298) + \frac{0{,}02197}{2} (T_{out}^2 - 298^2) + \left(\frac{156800}{T_{out}} \right. \right.$$

$$\left. \left. - \frac{156800}{298} \right) \right] \text{cal/mol}$$

$$\Delta H \text{ keluar} = \{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\} + \{\Delta H_{Ca_3PO_4} + \Delta H_{H_2O}\} + \Delta H_{Ca_3PO_4}$$

$$252606{,}57 \text{ kJ} = \{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\} + \{\Delta H_{Ca_3PO_4} + \Delta H_{H_2O}\} + \Delta H_{Ca_3PO_4}$$

Dengan cara trial diperoleh : T_{out} = 338,5 K = 65,5°C, maka :

Gelatin :

- Protein

$$\Delta H = \frac{146,46}{7139}\text{kmol}.3,18\frac{\text{kJ}}{\text{kmol.K}}.(338,5-298)\text{K}$$

$$\Delta H = 2,64\ \text{kJ}$$

- Lemak

$$\Delta H = \frac{5,05}{593}\text{kmol}.2,85\frac{\text{kJ}}{\text{kmol.K}}.(338,5-298)\text{K}$$

$$\Delta H = 0,98\ \text{kJ}$$

- H_2O

$$\Delta H = \frac{1111,12}{18}\text{kmol}\left[18,2964+\frac{47,212.10^{-2}}{2}(338,5+298)-\frac{133,88.10^{-5}}{3}\right.$$

$$\left(338,5^2+338,5.298+298^2\right)+\frac{1314,2.10^{-9}}{4}\left(338,5^2+298^2\right)(338,5$$

$$\left.+298)\right](338,5-298)\ \text{kJ/kmol}$$

$$\Delta H = 188356,97\ \text{kJ}$$

Larutan $Ca_3(PO_4)_2$:

- $Ca_3(PO_4)_2$

$$\Delta H = \frac{0,01.10^3}{310}\text{mol}\left[18,52(338,5-298)+\frac{0,02197}{2}\left(338,5^2-298^2\right)+\left(\frac{156800}{338,5}\right.\right.$$

$$\left.\left.-\frac{156800}{298}\right)\right]\text{cal/mol}$$

$$= 4,05\ \text{kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{378{,}94}{18}\text{kmol.}\Big[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(338{,}5+298) - \frac{133{,}88.10^{-5}}{3}$$

$$\left(338{,}5^2 + 338{,}5.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(338{,}5^2 + 298^2\right)(338{,}5$$

$$+298)\Big](338{,}5 - 298)\ \text{kJ/kmol}$$

$$= 64237{,}88\ \text{kJ}$$

Padatan $Ca_3(PO_4)_2$:

- $\underline{Ca_3(PO_4)_2}$

$$\Delta H = \frac{1{,}08.10^3}{310}\text{mol}\Big[18{,}52(338{,}5-298) + \frac{0{,}02197}{2}\left(338{,}5^2 - 298^2\right) + \left(\frac{156800}{338{,}5}\right.$$

$$\left.-\frac{156800}{298}\right)\Big]\ \text{cal/mol}$$

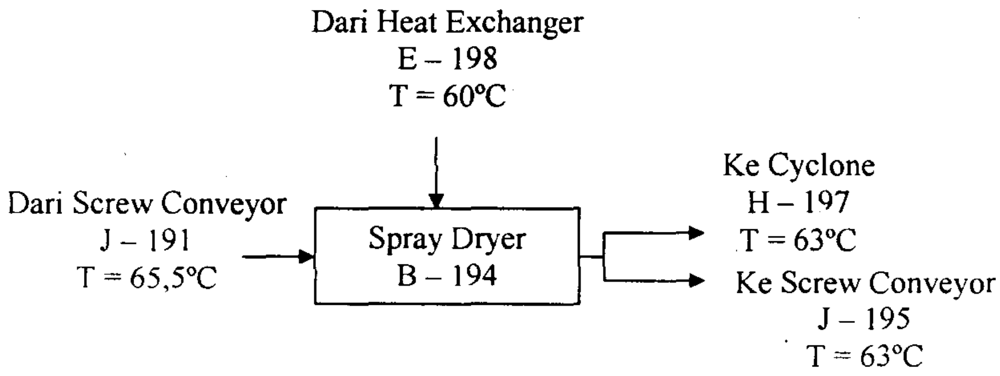
$$= 4{,}05\ \text{kJ}$$

Entalpi keluar $= \Delta H_{gelatin} + \Delta H_{larutan\ Ca_3(PO_4)_2} + \Delta H_{padatan\ Ca_3(PO_4)_2}$

$= (2{,}64 + 0{,}98 + 188356{,}97)\ \text{kJ} + (4{,}05 + 64237{,}88)\ \text{kJ} + 4{,}05\ \text{kJ}$

$= 252606{,}57\ \text{kJ}$

SPRAY DRYER B – 194



Entalpi masuk :

- **Dari Screw Conveyor J – 191**

Suhu masuk = 338,5 K = 65,5°C

Gelatin :

- $\Delta H_{protein}$ = 2,64 kJ
- ΔH_{lemak} = 0,98 kJ
- ΔH_{H_2O} = 188356,97 kJ

Larutan Ca_3PO_4 :

- $\Delta H_{Ca_3PO_4}$ = 4,05 kJ
- ΔH_{H_2O} = 64237,88 kJ

$\Delta H_{Ca_3PO_4}$ = 4,05 kJ
\+
ΔH_{J-191} = 252606,57 kJ

- **Dari Heat Exchanger E – 192**

Suhu masuk = 333 K = 60°C

Udara panas

$$. H . \frac{m}{BM}.C_P .. T$$

$$. H . 2700{,}08\ kg.1{,}0048\ \frac{kJ}{kg.K}.(333 \quad 298)K$$

$$. H = 94956{,}41\ kJ$$

Total entalpi masuk = entalpi masuk dari (Screw Conveyor J – 191 + Heat Exchanger E – 198)

= 252606,57 kJ + 94956,41 kJ

= 347562,98 kJ

Entalpi keluar :

Asumsi : Suhu keluar = 336 K = 63°C

- **Ke Cyclone H – 197**

Gelatin :

- Protein

$$\Delta H = \frac{m}{BM}.C_P . \Delta T$$

$$\Delta H = \frac{14{,}65}{7139} kmol.3{,}18 \frac{kJ}{kmol.K}.(336 - 298)K$$

$$\Delta H = 0{,}25\ kJ$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P . \Delta T$$

$$\Delta H = \frac{0,50}{593}\text{kmol}.2,85\frac{\text{kJ}}{\text{kmol.K}}.(336-298)\text{K}$$

$$\Delta H = 0,09\ \text{kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{111,11}{18}\text{kmol}\int_{298}^{336}\left(A+BT+CT^2+DT^3\right)dT$$

$$\Delta H = \frac{111,11}{18}\text{kmol}\left[18,2964+\frac{47,212.10^{-2}}{2}(336+298)-\frac{133,88.10^{-5}}{3}\right.$$

$$\left.\left(336^2+336.298+298^2\right)+\frac{1314,2.10^{-9}}{4}\left(336^2+298^2\right)(336+298)\right]$$

$$(336-298)\ \text{kJ/kmol}$$

$$\Delta H = 17657,37\ \text{kJ}$$

$\underline{Ca_3(PO_4)_{2\ (s)}}$

$$\Delta H = \frac{m}{BM}.\int_{298}^{336}\left(A+B.T+\frac{C}{T^2}\right)dT$$

$$= \frac{0,11.10^3}{310}\text{mol}\left[18,52(336-298)+\frac{0,02197}{2}\left(336^2-298^2\right)+\left(\frac{156800}{336}\right.\right.$$

$$\left.\left.-\frac{156800}{298}\right)\right]\text{cal/mol}$$

$$= 3,79\ \text{kJ}$$

$\underline{H_2O_{(l)}}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta = \frac{\cdot}{\cdot} \int_{298}^{336} \left(\quad + BT + CT^2 + DT^3 \right) dT$$

$$\Delta H = \frac{0,76}{18} kmol. \left[18,2964 + \frac{47,212.10^{-2}}{2} (336+298) - \frac{133,88.10^{-5}}{3} \right.$$

$$\left. (336^2 + 336.298 + 298^2) + \frac{1314,2.10^{-9}}{4} (336^2 + 298^2)(336+298) \right]$$

$$(336 - 298)\ kJ/kmol$$

$$\Delta H = 120,78\ kJ$$

Udara panas

- Udara panas

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = 2700,08\ kg.1,0048\ \frac{kJ}{kg.K}.(336 - 298)K$$

$$\Delta H = 1039095,53\ kJ$$

- $H_2O_{(g)}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{371,36}{18} kmol \int_{25}^{63} \left(A + BT + CT^2 + DT^3 \right) dT$$

$$\Delta H = \frac{371,36}{18}\text{kmol.}\left[33,46 + \frac{0,688.10^{-2}}{2}(63+25) + \frac{0,7604.10^{-5}}{3}\right.$$

$$\left.(63^2 + 63.25 + 25^2) - \frac{3,593.10^{-9}}{4}(63^2+25^2)(63+25)\right]$$

$$(63-25)\ \text{kJ/kmol}$$

$\Delta H = 696,88$ kJ

Panas laten air menguap $= \frac{m}{BM} . \lambda$

$= \frac{371,36.10^3}{18}\text{mol} . 40,65\ \frac{kJ}{mol}$

$= 838654,67$ kJ

Entalpi udara panas $= \Delta H_{udara\,kering} + \Delta H_{H_2O_{(g)}} +$ panas laten air menguap

$= 103095,53$ kJ + 696,88 kJ + 838654,67 kJ

$= 942447,08$ kJ

Total entalpi keluar ke Cyclone H – 197

$= \Delta H_{gelatin} + \Delta H_{padatan\,Ca_3(PO_4)_2} + \Delta H_{air} + \Delta H_{udara\,panas}$

= (0,25 + 0,09 + 17657,37) kJ + 3,88 kJ + 120,78 kJ + 942447,08 kJ

= 960229,35 kJ

- **Ke Screw Conveyor J – 195**

Gelatin :

- Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{131,81}{7139} kmol.3,18 \frac{kJ}{kmol.K}.(336-298)K$$

$$\Delta H = 2,23\ kJ$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{4,55}{593} kmol.2,85 \frac{kJ}{kmol.K}.(336-298)K$$

$$\Delta H = 0,83\ kJ$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1000,01}{18} kmol \int_{298}^{336} \left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{1000,01}{18} kmol.\left[18,2964 + \frac{47,212.10^{-2}}{2}(336+298) - \frac{133,88.10^{-5}}{3}\left(336^2 + 336.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(336^2+298^2\right)(336+298)\right]$$

$$(336-298)\ kJ/kmol$$

$$\Delta H = 158919,52\ kJ$$

$\underline{Ca_3(PO_4)_{2\,(s)}}$

$$\Delta \ = \frac{\cdot}{-}\int_{298}^{336}\left(. \ +. \ \ T+\frac{C}{T^2}\right) dT$$

$$= \frac{0{,}98.10^3}{310} mol \left[18{,}52(336-298)+\frac{0{,}02197}{2}\left(336^2-298^2\right)+\left(\frac{156800}{336} - \frac{156800}{298}\right)\right] cal/mol$$

$= 3{,}79$ kJ

$\underline{H_2O_{(l)}}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{6{,}82}{18} kmol \int_{298}^{336}\left(A+BT+CT^2+DT^3\right) dT$$

$$\Delta H = \frac{6{,}82}{18} kmol.\left[18{,}2964+\frac{47{,}212.10^{-2}}{2}(336+298)-\frac{133{,}88.10^{-5}}{3}\left(336^2+336.298+298^2\right)+\frac{1314{,}2.10^{-9}}{4}\left(336^2+298^2\right)(336+298)\right]$$

$$(336-298)\ kJ/kmol$$

$\Delta H = 1083{,}82$ kJ

Total entalpi keluar ke Screw Conveyor J – 195

$= \Delta H_{gelatin} + \Delta H_{padatan\ Ca_3(PO_4)_2} + \Delta H_{air}$

$= (2{,}23 + 0{,}83 + 158919{,}52)$ kJ + 3,79 kJ + 1083,82 kJ

$= 160010{,}19$ kJ

Total entalpi keluar = entalpi keluar ke (Cyclone H – 197 + Screw Conveyor J – 195)

= (960229,35 + 160010,19) kJ

= 1120239,55 kJ

<u>Asumsi</u> : Q_{loss} = 10% . Q_{suplai}

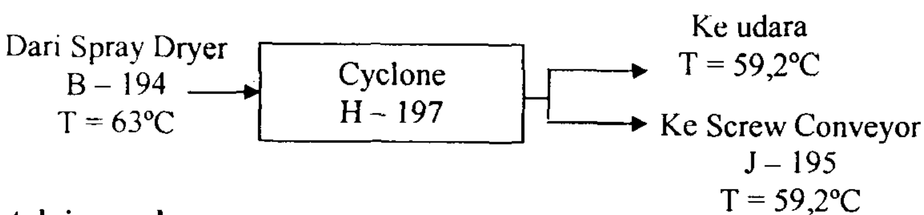
Entalpi masuk + Q_{suplai} = entalpi keluar + Q_{loss}

347562,98 kJ + Q_{suplai} = 1120239,55 kJ + 10% . Q_{suplai}

$$Q_{suplai} = \frac{1120239{,}55 \text{ kJ} - 347562{,}98 \text{ kJ}}{0{,}9}$$

$$Q_{suplai} = 858529{,}51 \text{ kJ}$$

CYCLONE H – 197



<u>Entalpi masuk :</u>

Suhu masuk = 338 K = 63°C

- **Dari Spray Dryer B – 194**

  Gelatin :

  - $\Delta H_{protein}$ = 0,25 kJ
  - ΔH_{lemak} = 0,09 kJ
  - ΔH_{H_2O} = 17657,37 kJ

  $\Delta H_{Ca_3PO_4}$ = 3,79 kJ

$\Delta H_{H_2O\,(l)}$ = 120,78 kJ

$\Delta H_{udara\ panas}$ = 103792,41 kJ
\+

ΔH masuk = 121574,69 kJ

Entalpi keluar :

$$\Delta H_{masuk} = \Delta H_{keluar} + Q_{loss}$$

$$121574{,}69\ kJ = \Delta H_{keluar} + 10\%.121574{,}69\ kJ$$

$$\Delta H_{keluar} = 109417{,}22\ kJ$$

- **Ke Udara**

  Udara panas :

  - Udara kering

    $$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

    $$\Delta H = 2700{,}08\ kg.1{,}0048\ \frac{kJ}{kg.K}.(T_{out} - 298)K$$

  - $H_2O_{(g)}$

    $$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

    $$\Delta H = \frac{371{,}36}{18}\,kmol \int_{25}^{T_{out}} \left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{371{,}36}{18}\,\text{kmol}\left[33{,}46 + \frac{0{,}688.10^{-2}}{2}\left(T_{out} + 25\right) + \frac{0{,}7604.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{\ 2} + T_{out}.25 + 25^2\right) - \frac{3{,}593.10^{-9}}{4}\left(T_{out}^{\ 2} + 25^2\right)\left(T_{out} + 25\right)\right]$$

$$\left(T_{out} - 25\right)\ \text{kJ / kmol}$$

- **Ke Screw Conveyor J – 195**

Gelatin :

- Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{14{,}65}{7139}\,\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.\left(T_{out} - 298\right)\text{K}$$

- Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{0{,}50}{593}\,\text{kmol}.2{,}85\frac{\text{kJ}}{\text{kmol.K}}.\left(T_{out} - 298\right)\text{K}$$

- H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{111{,}11}{18}\,\text{kmol}\int_{298}^{T_{out}}\left(A + BT + CT^2 + DT^3\right)\,dT$$

$$\Delta H = \frac{111,11}{18}\text{kmol.}\left[18,2964 + \frac{47,212.10^{-2}}{2}(T_{out} + 298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left(T_{out}^{2} + T_{out}.298 + 298^{2}\right) + \frac{1314,2.10^{-9}}{4}\left(T_{out}^{2} + 298^{2}\right)\left.(T_{out} + 298)\right]$$

$$(T_{out} - 298)\ \text{kJ/kmol}$$

<u>$Ca_3(PO_4)_{2\,(s)}$</u>

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{0,11.10^{3}}{310}\text{mol}\left[18,52(T_{out} - 298) + \frac{0,02197}{2}\left(T_{out}^{2} - 298^{2}\right) + \left(\frac{156800}{T_{out}}\right.\right.$$

$$\left.\left.- \frac{156800}{298}\right)\right]\ \text{cal/mol}$$

<u>$H_2O_{(l)}$</u>

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{0,76}{18}\text{kmol}\int_{298}^{T_{out}}\left(A + BT + CT^2 + DT^3\right)dT$$

$$\Delta H = \frac{0,76}{18}\text{kmol.}\left[18,2964 + \frac{47,212.10^{-2}}{2}(T_{out} + 298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left(T_{out}^{2} + T_{out}.298 + 298^{2}\right) + \frac{1314,2.10^{-9}}{4}\left(T_{out}^{2} + 298^{2}\right)\left.(T_{out} + 298)\right]$$

$$(T_{out} - 298)\ \text{kJ/kmol}$$

H keluar . entalpi keluar ke (Screw Conveyor J 195. udara)

$$109417{,}22\ \text{kJ} \ . \ \{ (H_{protein} \cdot \Delta H_{lemak} + \Delta H_{H_2O}) + \Delta H_{Ca_3PO_4} + \Delta H_{H_2O\,(l)} \} + \Delta H_{udara\,panas}$$

Dengan cara trial diperoleh : T_{out} = 332,2 K = 59,2°C, maka :

- **Ke Udara**

Udara panas :

- Udara kering

$$\Delta H = 2700{,}08\ \text{kg}.1{,}0048\ \frac{\text{kJ}}{\text{kg.K}}.(332{,}2 - 298)\text{K}$$

$$\Delta H = 92733{,}38\ \text{kJ}$$

- $H_2O_{(g)}$

$$\Delta H = \frac{371{,}36}{18}\text{kmol.}\left[33{,}46 + \frac{0{,}688.10^{-2}}{2}(59{,}2+25) + \frac{0{,}7604.10^{-5}}{3}\right.$$

$$\left.(59{,}2^2 + 59{,}2.25 + 25^2) - \frac{3{,}593.10^{-9}}{4}(59{,}2^2 + 25^2)(59{,}2+25)\right]$$

$$(59{,}2 - 25)\ \text{kJ/kmol}$$

$$\Delta H = 696{,}58\ \text{kJ}$$

Total entalpi keluar ke udara = $\Delta H_{H_2O_{(g)}} + \Delta H_{udara\,kering}$

= 696,58 kJ + 92733,38 kJ

= 93429,96 kJ

- **Ke Screw Conveyor J – 195**

Gelatin :

- Protein

$$\Delta H = \frac{14,65}{7139}\text{kmol}.3,18\frac{\text{kJ}}{\text{kmol.K}}.(332,2-298)\text{K}$$

$$\Delta H = 0,22 \text{ kJ}$$

- Lemak

$$\Delta H = \frac{0,50}{593}\text{kmol}.2,85\frac{\text{kJ}}{\text{kmol.K}}.(332,2-298)\text{K}$$

$$\Delta H = 0,08 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{111,11}{18}\text{kmol}\left[18,2964+\frac{47,212.10^{-2}}{2}(332,2+298)-\frac{133,88.10^{-5}}{3}\right.$$

$$\left.(332,2^2+332,2.298+298^2)+\frac{1314,2.10^{-9}}{4}(332,2^2+298^2)(332,2+298)\right]$$

$$(332,2-298)\ \text{kJ/kmol}$$

$$\Delta H = 15874,97 \text{ kJ}$$

$Ca_3(PO_4)_{2\,(s)}$

$$\Delta H = \frac{0,11.10^3}{310}\text{mol}\left[18,52(332,2-298)+\frac{0,02197}{2}(332,2^2-298^2)+\left(\frac{156800}{332,2}\right.\right.$$

$$\left.\left.-\frac{156800}{298}\right)\right]\text{cal/mol}$$

$$\Delta H = 3,40 \text{ kJ}$$

$\underline{H_2O_{(l)}}$

$$\Delta H = \frac{0{,}76}{18}\text{kmol.}\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(332{,}2+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(332{,}2^2 + 332{,}2.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(332{,}2^2 + 298^2\right)(332{,}2+298)\right]$$

$$(332{,}2 - 298)\ \text{kJ/kmol}$$

$\Delta H = 108{,}59$ kJ

Total entalpi keluar ke Screw Conveyor J – 195

$= \Delta H_{gelatin} + \Delta H_{padatan\ Ca_3(PO_4)_2} + \Delta H_{air}$

= (0,22 + 0,08 + 15874,97) kJ + 3,40 kJ + 108,59 kJ

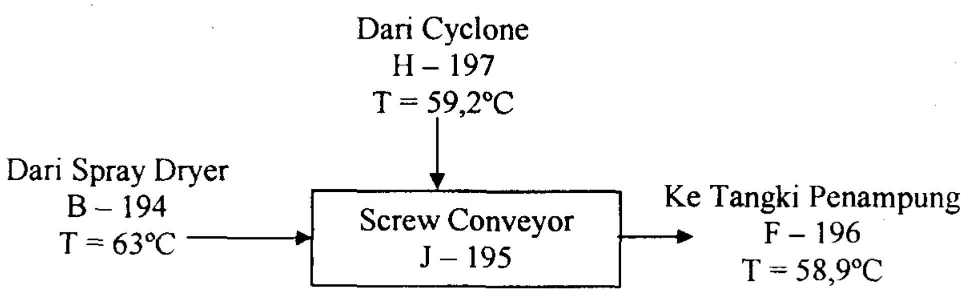
= 15987,26 kJ

Total entalpi keluar = entalpi keluar ke (Udara + Screw Conveyor J – 195)

= (93429,96 + 15987,26) kJ

= 109417,22 kJ

SCRREW CONVEYOR J – 195



Entalpi masuk :

- **Dari Spray Dryer B – 194**

  Suhu masuk = 336 K = 63°C

  Gelatin :

  - $\Delta H_{protein}$ = 2,23 kJ
  - ΔH_{lemak} = 0,83 kJ
  - ΔH_{H_2O} = 158919,52 kJ

  $\Delta H_{Ca_3PO_4}$ = 3,79 kJ

  $\Delta H_{H_2O\,(l)}$ = 1083,82 kJ (+)

  ΔH_{B-194} = 160010,19 kJ

- **Dari Cyclone H – 197**

  Suhu masuk = 332,2 K = 59,2°C

  Gelatin :

  - $\Delta H_{protein}$ = 0,22 kJ
  - ΔH_{lemak} = 0,08 kJ
  - ΔH_{H_2O} = 15874,97 kJ

  $\Delta H_{Ca_3PO_4}$ = 3,40 kJ

  $\Delta H_{H_2O\,(l)}$ = 108,59 kJ (+)

  ΔH_{H-197} = 15987,26 kJ

Total entalpi masuk = entalpi masuk dari (Spray Dryer B – 194 + Cyclone H – 197)

= (160010,19 + 15987,26) kJ

= 175997,45 kJ

Entalpi keluar :

$. H_{masuk} \cdot \ . H_{keluar} \cdot Q_{loss}$

$175997,45 \text{ kJ} \ . \ H_{keluar} \cdot 10\%.175997,45 \text{ kJ}$

$\Delta H_{keluar} = 158397,71 \text{ kJ}$

- **Ke Tangki Penampung F – 196**

  Gelatin :

  - Protein

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{146,46}{7139} \text{kmol}.3,18 \frac{\text{kJ}}{\text{kmol.K}}.(T_{out} - 298)K$$

  - Lemak

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{4,55}{593} \text{kmol}.2,85 \frac{\text{kJ}}{\text{kmol.K}}.(T_{out} - 298)K$$

  - H_2O

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{1111{,}12}{18}\text{kmol}\int_{298}^{T_{out}}\left(A + BT + CT^2 + DT^3\right)\,dT$$

$$\Delta H = \frac{1111{,}12}{18}\text{kmol.}\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}\left(T_{out} + 298\right) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)\left(T_{out} + 298\right)\right]$$

$$\left(T_{out} - 298\right)\text{kJ/kmol}$$

$Ca_3(PO_4)_{2\,(s)}$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{1{,}09.10^3}{310}\text{mol}\left[18{,}52\left(T_{out} - 298\right) + \frac{0{,}02197}{2}\left(T_{out}^{\ 2} - 298^2\right) + \left(\frac{156800}{T_{out}}\right.\right.$$

$$\left.\left. - \frac{156800}{298}\right)\right]\text{cal/mol}$$

$H_2O_{(l)}$

$$\Delta H = \frac{m}{BM}.C_P.\Delta T$$

$$\Delta H = \frac{7{,}58}{18}\text{kmol}\int_{298}^{T_{out}}\left(A + BT + CT^2 + DT^3\right)\,dT$$

$$\Delta H = \frac{7{,}58}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}\left(T_{out} + 298\right) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)\left(T_{out} + 298\right)\right]$$

$$\left(T_{out} - 298\right) \text{kJ/kmol}$$

ΔH keluar $= \left\{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\right\} + \Delta H_{Ca_3PO_4} + \Delta H_{H_2O}$.

175997,71 kJ $= \left\{\Delta H_{protein} + \Delta H_{lemak} + \Delta H_{H_2O}\right\} + \Delta H_{Ca_3PO_4} + \Delta H_{H_2O}$

Dengan cara trial diperoleh : T_{out} = 331,9 K = 58,9°C, maka :

- **Ke Tangki Umpan F – 176**

Gelatin :

- Protein

$$\Delta H = \frac{146{,}46}{7139}\text{kmol}.3{,}18\frac{\text{kJ}}{\text{kmol.K}}.(331{,}9 - 298)\text{K}$$

ΔH = 2,21 kJ

- Lemak

$$\Delta H = \frac{4{,}55}{593}\text{kmol}.2{,}85\frac{\text{kJ}}{\text{kmol.K}}.(331{,}9 - 298)\text{K}$$

ΔH = 0,74 kJ

- $\underline{H_2O}$

$$\Delta H = \frac{1111,12}{18}\text{kmol}\left[18,2964 + \frac{47,212.10^{-2}}{2}(331,9+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.(331,9^2 + 331,9.298 + 298^2) + \frac{1314,2.10^{-9}}{4}(331,9^2 + 298^2)(331,9+298)\right]$$

$$(331,9 - 298)\ \text{kJ/kmol}$$

$$\Delta H = 157318,17\ \text{kJ}$$

$\underline{Ca_3(PO_4)_{2\,(s)}}$

$$\Delta H = \frac{1,09.10^3}{310}\text{mol}\left[18,52(331,9-298) + \frac{0,02197}{2}(331,9^2 - 298^2) + \left(\frac{156800}{331,9}\right.\right.$$

$$\left.\left. - \frac{156800}{298}\right)\right]\ \text{cal/mol}$$

$$\Delta H = 3,37\ \text{kJ}$$

$\underline{H_2O_{(l)}}$

$$\Delta H = \frac{7,58}{18}\text{kmol}\left[18,2964 + \frac{47,212.10^{-2}}{2}(331,9+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.(331,9^2 + 331,9.298 + 298^2) + \frac{1314,2.10^{-9}}{4}(331,9^2 + 298^2)(331,9+298)\right]$$

$$(331,9 - 298)\ \text{kJ/kmol}$$

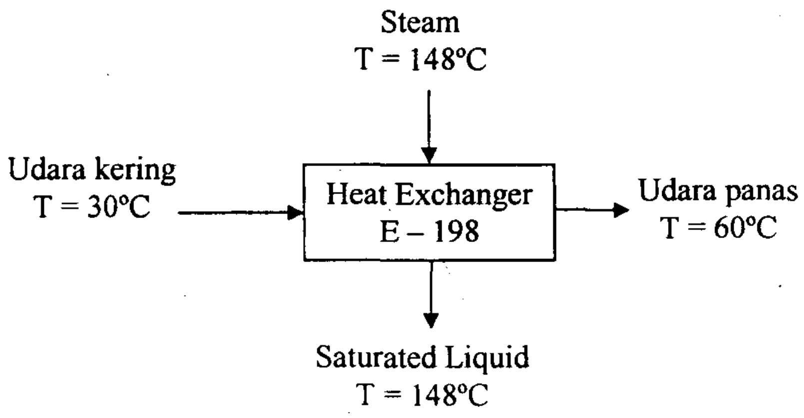
$$\Delta H = 1073,22\ \text{kJ}$$

Total entalpi keluar $= \Delta H_{gelatin} + \Delta H_{padatan\ Ca_3(PO_4)_2} + \Delta H_{air}$

$= (2,21 + 0,74 + 157318,17)$ kJ + 3,37 kJ + 1073,22 kJ

$= 157397,71$ kJ

HEAT EXCHANGER E – 198



Entalpi masuk :

- **Udara kering**

  Suhu masuk = 303 K = 30°C

  Cp udara pada 30°C = 1,0048 kJ / kg . K

  (Geankoplis, 1993, pp. 866, table A.3-3)

  $\Delta H = m . C_P . \Delta T$

  $\Delta H = 2700{,}08 \text{ kg} . 1{,}0048 \dfrac{\text{kJ}}{\text{kg.K}} . (303 - 298) \text{K}$

  $\Delta H = 13565{,}20 \text{ kJ}$

Entalpi keluar :

- **Udara kering**

  Suhu masuk = 333 K = 60°C

  Cp udara pada 60°C = 1,0087 kJ / kg . K

  (Geankoplis, 1993, pp. 866, table A.3-3)

$$\Delta H = m.C_p.\Delta T$$

$$\Delta H = 2700{,}08\ kg.1{,}0087\ \frac{kJ}{kg.K}.(333 - 298)K$$

$$\Delta H = 95324{,}97\ kJ$$

$$\text{Entalpi masuk} + Q_{suplai} = \text{Entalpi keluar} + Q_{loss}$$

$$13565{,}20\ kJ + Q_{suplai} = 95324{,}97\ kJ + 10\%.Q_{suplai}$$

$$Q_{suplai} = \frac{95324{,}97\ kJ - 13565{,}20\ kJ}{0{,}9}$$

$$Q_{suplai} = 90844{,}19\ kJ$$

APPENDIX C

PERHITUNGAN SPESIFIKASI ALAT

APPENDIX C

PERHITUNGAN SPESIFIKASI PERALATAN

Data massa jenis zat :

Zat	Sg	Massa Jenis (kg / lt)	Massa Jenis (lb / ft^3)
$Ca_3(PO_4)_2$	3,04	3,04	189,8346
$CaCO_3$	2,93	2,93	182,9656
$CaCl_2$	2,152	2,152	134,3829
$Ca(OH)_2$	2,2	2,2	137,3803
$Mg_3(PO_4)_2$	2,84	2,84	177,3455
$MgCO_3$	2,16	2,16	134,8825
$MgCl_2$	2,325	2,325	145,1860
HCl	1,46	1,46	91,1706
H_3PO_4	1,834	1,834	114,5252
CO_2	1,53	1,53	95,5418
Protein	-	0,8955 *	55,9200
Lemak	-	0,9290 **	58,0120

* www.ccp4.ac.uk

** www.usd.edu.biol/courses/cellthies/cpa3answers.html

(Perry, 1999)

Tulang :

Massa $Ca_3(PO_4)_2$ dalam tulang = 262,63 kg

Massa tulang = 505,05 kg

$$\text{Fraksi } Ca_3(PO_4)_2 = \frac{\text{massa } Ca_3(PO_4)_2}{\text{massa tulang}} = \frac{262{,}23 \text{ kg}}{505{,}05 \text{ kg}} = 0{,}52$$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi
$Ca_3PO_4)_2$	262,63	0,52
Protein	146,46	0,29
$CaCO_3$	18,18	0,036
$MgCO_3$	18,18	0,036
$Mg_3(PO_4)_2$	24,25	0,048
Lemak	5,05	0,01
H_2O	30,3	0,06
	505,05	1

ρ H_2O pada 30°C = 0,99568 kg / lt = 62,1758 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Sehingga :

$$\rho_{tulang} = \frac{1}{\left(\frac{X_{Ca_3(PO_4)_2}}{\rho_{Ca_3(PO_4)_2}} + \frac{X_{protein}}{\rho_{protein}} + \frac{X_{CaCO_3}}{\rho_{CaCO_3}} + \frac{X_{MgCO_3}}{\rho_{MgCO_3}} + \frac{X_{Mg_3(PO_4)_2}}{\rho_{Mg_3(PO_4)_2}} + \frac{X_{lemak}}{\rho_{lemak}} + \frac{X_{H_2O}}{\rho_{H_2O}}\right) lt/kg}$$

$$\rho_{tulang} = \frac{1}{\left(\frac{0,52}{3,04} + \frac{0,29}{0,8955} + \frac{0,036}{2,93} + \frac{0,036}{2,16} + \frac{0,048}{2,84} + \frac{0,01}{0,9290} + \frac{0,06}{0,99568}\right) lt/kg}$$

ρ_{tulang} = 1,6346 kg / lt = 102,0751 lb / ft^3

1. Belt Conveyor (J – 111)

Fungsi : memindahkan tulang dari penampung F – 110 menuju ke Jaw Crusher C – 120

Tipe : belt conveyor dengan kemiringan 20° (Perry, 1999, 21-8)

Dasar pemilihan : dapat digunakan untuk kapasitas besar, ekonomis, cocok untuk material berukuran besar

Kondisi operasi : suhu = 30°C

tekanan = 1 atm

Jumlah : 1 buah

Perhitungan :

Waktu pemindahan = 1 jam

Kapasitas = 505,05 kg / jam = 0,5051 ton / jam

Power :

$$hp = \frac{F(L + L_0)(T + 0{,}03.W.S) + T.\Delta Z}{990}$$

Dimana : hp : power yang dibutuhkan

F : faktor friksi, F = 0,05

L : panjang conveyor, ft

L_0 = 100

S : kecepatan belt, fpm

T : massa bahan, ton / jam

ΔZ : tinggi belt conveyor secara vertikal, ft

W : massa bagian yang bergerak termasuk belt dan idler, lb / ft

(Brown, 1961, pp. 57)

Data :

L = 10 m = 32,808 ft

T = 0,5051 ton / jam

S = 100 fpm (Brown, 1961, pp. 58, tabel 16)

Dengan sudut kemiringan 20°, dapat diperoleh :

$\Delta Z = \sin 20^\circ . L = \sin 20^\circ . 32,808\ ft = 11,2253\ ft$

W = 1 lb / in = 12 lb / ft (Brown, 1961, pp. 58, table 16A)

$$hp = \frac{0,05(32,808\,ft + 100)\left(0,5051\,\frac{ton}{jam} + 0,03.12\,\frac{lb}{ft}.100\,fpm\right) + 0,5051\,\frac{ton}{jam}.11,2253\,ft}{990}$$

hp = 0,2506 hp

Efisiensi motor = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$Power = \frac{100\%}{80\%} 0,2506\ hp = 0,3132\ hp$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,3132 hp × 2 = 0,6264 hp → dipilih motor 1 hp

Lebar belt = 14 in

Belt plies = 3

(Perry, 1999, pp.21-11, tabel 21-7)

$\rho_{tulang} = 1,6346\ kg / lt = 102,0751\ lb / ft^3$

$$Kecepatan\ belt = \frac{0,5051\ ton/jam}{32\ ton/jam}\ \frac{\frac{1}{102,0751\ lb/ft^3}}{\frac{1}{100\ lb/ft^3}}\ 100\ fpm = 1,5463\ fpm$$

Bahan konstruksi : carbon steel

2. Jaw Crusher (C – 120)

Fungsi	: mengecilkan ukuran tulang yang akan dimasukkan ke dalam Screen H – 122
Tipe	: Dodge jaw crusher
Dasar pemilihan	: ukuran hasil pengecilan lebih seragam, dapat digunakan untuk material berukuran besar, serta dapat digunakan untuk kapasitas besar
Jumlah	: 1 buah
Kapasitas bahan	: 631,31 kg / jam
Ukuran feed opening	: 15 × 11 in
Discharge setting	: ¾ in
Kapasitas alat	: 2 ton / jam
Tinggi	: 5 m
Kecepatan	: 200 rpm
Power	: 15 hp
Bahan konstruksi	: carbon steel

(Brown, 1961, pp. 27, table 7)

3. Belt Conveyor (J – 121)

Fungsi	: memindahkan tulang dari Jaw Crusher C – 120 menuju ke Screen H – 122
Tipe	: belt conveyor dengan kemiringan 20° (Perry, 1999, 21-8)

Dasar pemilihan : dapat digunakan untuk kapasitas besar, ekonomis, cocok untuk material berukuran besar

Kondisi operasi : suhu = 30°C

tekanan = 1 atm

Jumlah : 1 buah

Perhitungan :

Waktu pemindahan = 1 jam

Kapasitas = 631,31 kg / jam = 0,6313 ton / jam

Power :

$$hp = \frac{F(L + L_0)(T + 0{,}03 . W . S) + T . \Delta Z}{990}$$

Dimana : hp : power yang dibutuhkan

F : faktor friksi, F = 0,05

L : panjang conveyor, ft

L_0 = 100

S : kecepatan belt, fpm

T : massa bahan, ton / jam

ΔZ : tinggi belt conveyor secara vertikal, ft

W : massa bagian yang bergerak termasuk belt dan idler, lb / ft

(Brown, 1961, pp. 57)

Data :

L = 10 m = 32,808 ft

T = 0,6313 ton / jam

S = 100 fpm (Brown, 1961, pp. 58, tabel 16)

Dengan sudut kemiringan 20°, dapat diperoleh :

$\Delta Z = \sin 20° . L = \sin 20° . 32{,}808 \text{ ft} = 11{,}2253 \text{ ft}$

W = 1 lb / in = 12 lb / ft (Brown, 1961, pp. 58, table 16A)

$$hp = \frac{0{,}05(32{,}808\,\text{ft} + 100)\left(0{,}6313\frac{\text{ton}}{\text{jam}} + 0{,}03.12\frac{\text{lb}}{\text{ft}}.100\,\text{fpm}\right) + 0{,}6313\frac{\text{ton}}{\text{jam}}.11{,}2253\,\text{ft}}{990}$$

hp = 0,2529 hp

Efisiensi motor = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$\text{Power} = \frac{100\%}{80\%} 0{,}2529 \text{ hp} = 0{,}3161 \text{ hp}$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,3161 hp × 2 = 0,6322 hp → dipilih motor 1 hp

Lebar belt = 14 in

Belt plies = 3

(Perry, 1999, pp.21-11, tabel 21-7)

$\rho_{tulang} = 1{,}6346 \text{ kg / lt} = 102{,}0751 \text{ lb / ft}^3$

$$\text{Kecepatan belt} = \frac{0{,}6313 \text{ ton / jam}}{32 \text{ ton / jam}} \frac{\frac{1}{102{,}0751 \text{ lb/ft}^3}}{\frac{1}{100 \text{ lb/ft}^3}} 100 \text{ fpm} = 1{,}9327 \text{ fpm}$$

Bahan konstruksi : carbon steel

4. Screen (H – 122)

Fungsi : untuk memisahkan serpihan tulang yang berukuran tidak sama

Tipe : Vibrating screen

Dasar pemilihan : kapasitas besar, efisiensi pemisahan tinggi

Jumlah : 1 buah

Perhitungan :

Kapasitas = 631,31 kg / jam = 0,6313 ton / jam

Data-data :

Kapasitas aktual screen = 0,2 – 0,8 ton / ft^2. h . mm. mesh size

(Mc. Cabe, 1985, pp.1001)

Diameter partikel = 50 – 50000 μm

Panjang Screen (L) = 2 – 5 m

Lebar Screen (D) = 0,5 – 1,5 m

Luas area (A) = 1 – 7,5 m^2

(Ulrich, 1984, pp. 223, table 4-23)

Dari data di atas diambil :

Kapasitas aktual screen = 0,2 ton / ft^2. jam . mm mesh size

Diameter partikel = 500 μm = 0,5 mm

Panjang screen (L) = 2 m

Lebar screen (D) = 0,5 m ; maka :

Ukuran ayakan = 28 mesh → (Diameter lubang screen = 589 μm)

(Brown, 1961, pp. 17, table 4)

$$\text{Luas screen yang dibutuhkan (A)} = \frac{0{,}6313 \text{ ton / jam}}{0{,}2 \dfrac{\text{ton}}{\text{ft}^2\text{.jam.mm}} .0{,}589 \text{ mm}}$$

$$= 5{,}3592 \text{ ft}^2$$

Luas area (A) = L . D

= 2 m . 0,5 m

= 1 m² = 10,7636 ft²

$$ms = 631{,}31 \text{ kg / jam} = \frac{631{,}31 \text{ kg/jam}}{3600 \dfrac{\text{s}}{\text{jam}} .1 \text{ m}^2} = 0{,}1754 \frac{\text{kg}}{\text{m}^2\text{.s}}$$

$$\text{Power} = 1600 \frac{ms}{Dp} = 1600 \frac{0{,}1754 \dfrac{\text{kg}}{\text{m}^2\text{.s}}}{589 \ \mu\text{m}} = 0{,}4764 \text{ hp} \rightarrow \text{power} < 2 \text{ hp}$$

(Ulrich, 1984, pp. 223, table 4-23)

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,4764 hp × 2 = 0,9527 hp → dipilih motor 1 hp

Bahan konstruksi : carbon steel

5. Belt Conveyor (J – 131)

Fungsi : memindahkan tulang dari Screen H – 122 menuju ke Tumbling Mill C – 130

Tipe : belt conveyor dengan kemiringan 20° (Perry, 1999, 21-8)

Dasar pemilihan : dapat digunakan untuk kapasitas besar, ekonomis, cocok untuk material berukuran besar

Kondisi operasi : suhu = 30°C

tekanan = 1 atm

Jumlah : 1 buah

Perhitungan :

Waktu pemindahan = 1 jam

Kapasitas = 631,31 kg / jam = 0,6313 ton / jam

Power :

$$hp = \frac{F(L + L_0)(T + 0{,}03.W.S) + T.\Delta Z}{990}$$

Dimana : hp : power yang dibutuhkan

F : faktor friksi, F = 0,05

L : panjang conveyor, ft

L_0 = 100

S : kecepatan belt, fpm

T : massa bahan, ton / jam

ΔZ : tinggi belt conveyor secara vertikal, ft

W : massa bagian yang bergerak termasuk belt dan idler, lb / ft

(Brown, 1961, pp. 57)

Data :

L = 10 m = 32,808 ft

T = 0,6313 ton / jam

S = 100 fpm (Brown, 1961, pp. 58, tabel 16)

Dengan sudut kemiringan 20°, dapat diperoleh :

$\Delta Z = \sin 20^\circ \cdot L = \sin 20^\circ \cdot 32,808 \text{ ft} = 11,2253 \text{ ft}$

W = 1 lb / in = 12 lb / ft (Brown, 1961, pp. 58, table 16A)

$$hp = \frac{0,05(32,808\,\text{ft} + 100)\left(0,6313\,\frac{\text{ton}}{\text{jam}} + 0,03 . 12\,\frac{\text{lb}}{\text{ft}} . 100\,\text{fpm}\right) + 0,6313\,\frac{\text{ton}}{\text{jam}} . 11,2253\,\text{ft}}{990}$$

hp = 0,2529 hp

Efisiensi motor = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$\text{Power} = \frac{100\%}{80\%} 0,2529 \text{ hp} = 0,3161 \text{ hp}$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,3161 hp × 2 = 0,6322 hp → dipilih motor 1 hp

Lebar belt = 14 in

Belt plies = 3

(Perry, 1999, pp.21-11, tabel 21-7)

$\rho_{\text{tulang}} = 1.6346 \text{ kg / lt} = 102.0751 \text{ lb / ft}^3$

$$\text{Kecepatan belt} = \frac{0,6313 \text{ ton/jam}}{32 \text{ ton/jam}} \frac{\dfrac{1}{102,0751 \text{ lb/ft}^3}}{\dfrac{1}{100 \text{ lb/ft}^3}} 100 \text{ fpm} = 1,9327 \text{ fpm}$$

Bahan konstruksi : carbon steel

6. **Screw Conveyor (J – 123)**

Fungsi : mengangkut tulang dari Screen H – 122 ke Jaw Crusher C-120

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dan dapat dipasang vertikal, miring ataupun mendatar

Jumlah : 1 buah

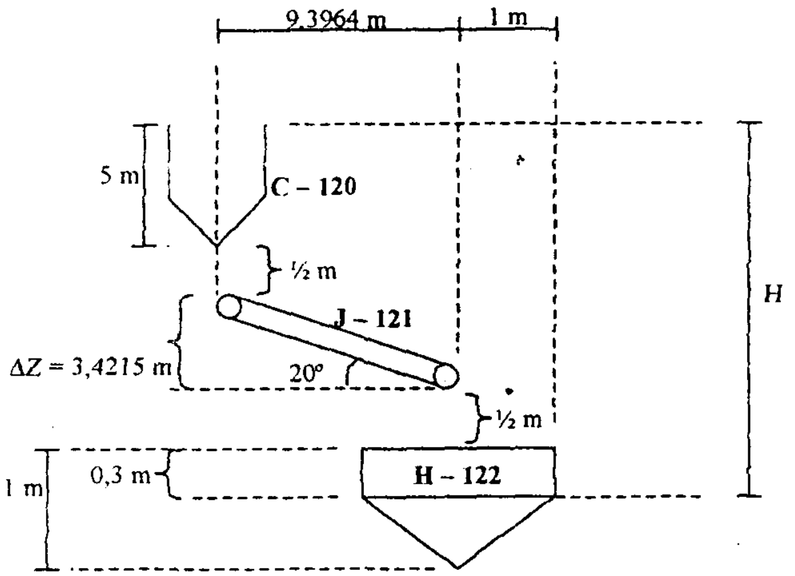
Perhitungan :

Kapasitas = 126,26 kg / jam

Jarak screen ke Jaw Crusher = ½ panjang screen + cos 20° . panjang Belt Conveyor J – 121

= ½ . 2 m + cos 20° . 10 m

= 10,3964 = 34,1087 ft



H = tinggi Jaw Crusher C – 120 + jarak Jaw Crusher ke Belt Conveyor J – 121 + tinggi Belt Conveyor J – 121 + jarak Belt Conveyor ke Screen H – 122 + tinggi Screen

H = 5 m + ½ m + 3,4215 m + ½ m + 0,3 m

H = 9,7215 m = 31,8944 ft

Panjang Screw Conveyor J – 123 = $\sqrt{34{,}1087^2 + 31{,}8944^2}$ ft = 46,6974 ft ≈ 50 ft

Sudut Screw Conveyor J – 123 :

$$\tan x = \frac{31{,}8944 \text{ ft}}{34{,}1087 \text{ ft}} = 0{,}9351$$

$$x = 43{,}1^{\circ}$$

ρ_{tulang} = 1,6346 kg / lt = 102,0751 lb / ft^3

Massa yang dipindahkan $= 126{,}26\ \frac{kg}{jam} . 2{,}205\ \frac{lb}{kg} . \frac{1\ jam}{60\ menit} = 4{,}6401\ lb/menit$

Volume yang dipindahkan $= \frac{126{,}26\ kg/jam}{1{,}6346\ kg/lt} = 77{,}2410\ lt/jam = 2{,}7274\ ft^3/jam$

Maka kapasitas Screw Conveyor J – 123 = 2,7274 ft^3 / jam

Waktu pemindahan = 60 menit

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

Power :

$hp = \frac{Co . Ca . L}{33000}$, dimana : Co : koefisien (untuk tulang Co = 1,3)

Ca : kapasitas Screw Conveyor (= 4,6401 lb/menit)

L : panjang Screw Conveyor (= 50 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3 . 4{,}6401\ lb/menit . 50\ ft}{33000} = 0{,}0091\ hp$$

Efisiensi motor = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$hp = \frac{0{,}0091}{0{,}8} = 0{,}0114$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0114 hp × 2 = 0,0228 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

7. **Tumbling Mill (C – 130)**

Fungsi : mengecilkan ukuran tulang dari Belt Conveyor J – 131

Dasar pemilihan : cocok untuk material keras dan abrasif, dapat memberikan hasil dengan ukuran merata

Jumlah : 1 buah

Kapasitas bahan : 631,31 kg / jam = 0,1754 kg / s

Kapasitas alat maksimum : 15 kg / s

Reduction ratio(R) : 20

(Ulrich, 1984, pp. 77, table 4-5)

Tinggi : 2 m

Perhitungan :

$D_P = 500\ \mu m = 5\ .10^{-4}\ m$

$$Power = 0{,}008\ \frac{m}{D_P} = 0{,}008\ \frac{0{,}1754\ kg/s}{5.10^{-4}\ m} = 2{,}8058\ kW = 3{,}76\ hp$$

(Ulrich, 1984, pp. 77, table 4-5)

Maka dipilih motor 4 hp

Bahan konstruksi = carbon steel

8. **Belt Conveyor (J – 132)**

Fungsi : memindahkan tulang dari Tumbling Mill C – 130 menuju ke Screen H – 133

Tipe : belt conveyor dengan kemiringan 20° (Perry, 1999, 21-8)

Dasar pemilihan : dapat digunakan untuk kapasitas besar, ekonomis, cocok untuk material berukuran besar

Kondisi operasi : suhu = 30°C

tekanan = 1 atm

Jumlah : 1 buah

Perhitungan :

Waktu pemindahan = 1 jam

Kapasitas = 631,31 kg / jam = 0,6313 ton / jam

Power :

$$hp = \frac{F(L + L_0)(T + 0{,}03 . W . S) + T . \Delta Z}{990}$$

Dimana : hp : power yang dibutuhkan

F : faktor friksi, F = 0,05

L : panjang conveyor, ft

L_0 = 100

S : kecepatan belt, fpm

T : massa bahan, ton / jam

ΔZ : tinggi belt conveyor secara vertikal, ft

W : massa bagian yang bergerak termasuk belt dan idler, lb / ft

(Brown, 1961, pp. 57)

Data :

L = 10 m = 32,808 ft

T = 0.6313 ton / jam

S = 100 fpm (Brown, 1961, pp. 58, tabel 16)

Dengan sudut kemiringan 20°, dapat diperoleh :

$\Delta Z = \sin 20° \cdot L = \sin 20° \cdot 32{,}808 \text{ ft} = 11{,}2253 \text{ ft}$

W = 1 lb / in = 12 lb / ft (Brown, 1961, pp. 58, table 16A)

$$hp = \frac{0{,}05(32{,}808\,ft + 100)\left(0{,}6313\frac{ton}{jam} + 0{,}03.12\frac{lb}{ft}.100\,fpm\right) + 0{,}6313\frac{ton}{jam}.11{,}2253\,ft}{990}$$

hp = 0,2529 hp

Efisiensi motor = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$Power = \frac{100\%}{80\%} 0{,}2529 \text{ hp} = 0{,}3161 \text{ hp}$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,3161 hp × 2 = 0,6322 hp → dipilih motor 1 hp

Lebar belt = 14 in

Belt plies = 3

(Perry, 1999, pp.21-11, tabel 21-7)

ρ_{bulk} = 1,6346 kg / lt = 102,0751 lb / ft³

$$Kecepatan\ belt = \frac{0{,}6313\ ton/jam}{32\ ton/jam}\ \frac{\frac{1}{102{,}0751\ lb/ft^3}}{\frac{1}{100\ lb/ft^3}}\ 100\ fpm = 1{,}9327\ fpm$$

Bahan konstruksi : carbon steel

9. **Screen (H – 133)**

Fungsi : untuk memisahkan bahan yang berukuran tidak sama

Tipe : Vibrating screen

Dasar pemilihan : kapasitas besar, efisiensi tinggi

Jumlah : 1 buah

Perhitungan :

Kapasitas = 631,31 kg / jam = 0,6313 ton / jam

Data-data :

Kapasitas aktual screen = 0,2 – 0,8 ton / ft^2. h . mm mesh size

(Mc. Cabe, 1985, pp.1001)

Diameter partikel = 50 – 50000 μm

Panjang Screen (L) = 2 – 5 m

Lebar Screen (D) = 0,5 – 1,5 m

Luas area (A) = 1 – 7,5 m^2

(Ulrich, 1984, pp. 223, table 4-23)

Dari data di atas diambil :

Kapasitas aktual screen = 0,2 ton / ft^2. jam . mm mesh size

Diameter partikel = 50 μm = 5.10^{-2} mm

Panjang screen (L) = 4 m

Lebar screen (D) = 1,5 m ; maka :

Ukuran ayakan = 270 mesh → (Diameter lubang screen = 53 μm)

(Brown, 1961, pp. 17, tabel 4)

$$\text{Luas screen yang dibutuhkan (A)} = \frac{0{,}6313\ \text{ton/jam}}{0{,}2\ \dfrac{\text{ton}}{\text{ft}^2.\text{jam.mm}}.0{,}053\,\text{mm}}$$

$$= 59{,}5575\ \text{ft}^2$$

Luas area (A) = L . D

= 4 m . 1,5 m

= 6 m^2 = 64,5819 ft^2

$$ms = 631{,}31\ \text{kg/jam} = \frac{631{,}31\ \text{kg/jam}}{3600\ \dfrac{\text{s}}{\text{jam}}.6\ \text{m}^2} = 0{,}0292\ \frac{\text{kg}}{\text{m}^2.\text{s}}$$

$$\text{Power} = 1600\ \frac{ms}{Dp} = 1600\ \frac{0{,}0292\ \dfrac{\text{kg}}{\text{m}^2.\text{s}}}{53\ \mu\text{m}} = 0{,}8823\ \text{hp}$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,8823 hp × 2 = 1,7647 hp → dipilih motor 2 hp

Bahan konstruksi = carbon steel

10. Screw Conveyor (J – 134)

Fungsi : mengangkut tulang dari Screen H – 133 ke Tumbling Mill C – 130

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

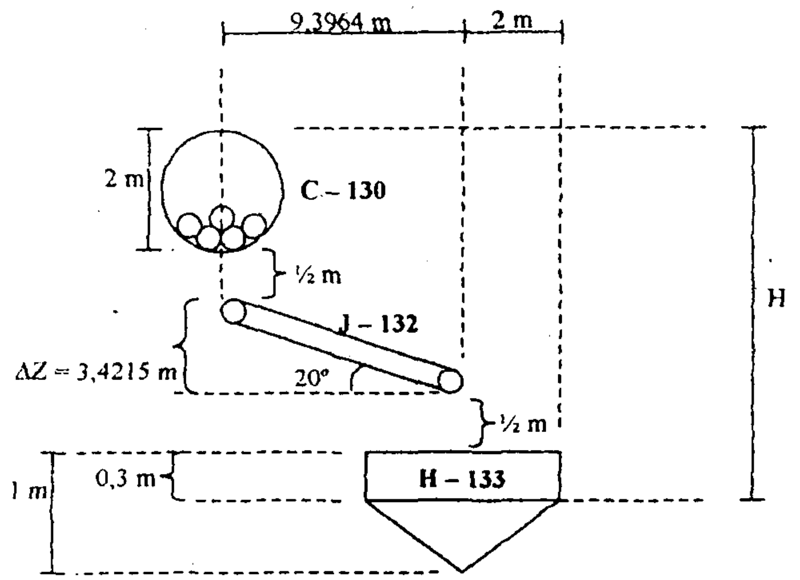
Perhitungan :

Kapasitas = 126,26 kg / jam

Jarak screen ke Tumbling Mill = ½ panjang screen + cos 20° . panjang Belt Conveyor J – 132

= ½ . 4 m + cos 20° . 10 m

= 11,3964 m = 37,3895 ft



H = tinggi Tumbling Mill C – 130 + jarak Tumbling Mill ke Belt Conveyor J – 132 + tinggi Belt Conveyor J – 132 + jarak Belt Conveyor ke Screen H – 133 + tinggi Screen

H = 2 m + ½ m + 3,4215 m + ½ m + 0,3 m

H = 6,7215 m = 22,0250 ft

Panjang Screw Conveyor J – 134 = $\sqrt{37{,}3895^2 + 22{,}0250^2}$ ft = 43,4081 ft ≈ 45 ft

Sudut Screw Conveyor J – 134 :

$$\tan x = \frac{22{,}0250\ \text{ft}}{37{,}3895\ \text{ft}} = 0{,}5898$$

$$x = 30{,}53^\circ$$

ρ_{tulang} = 1,6346 kg / lt = 102,0751 lb / ft^3

$$\text{Massa yang dipindahkan} = 126{,}26\ \frac{\text{kg}}{\text{jam}} .\ 2{,}205\ \frac{\text{lb}}{\text{kg}} . \frac{1\ \text{jam}}{60\ \text{menit}} = 4{,}6401\ \text{lb/menit}$$

$$\text{Volume yang dipindahkan} = \frac{126{,}26\ \text{kg/jam}}{1{,}6346\ \text{kg/lt}} = 77{,}2410\ \text{lt/jam} = 2{,}7274\ \text{ft}^3\ /\ \text{jam}$$

Maka kapasitas Screw Conveyor J – 134 = 2,7274 ft^3 / jam

Waktu pemindahan = 60 menit

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

Power :

$$hp = \frac{Co . Ca . L}{33000}$$, dimana :

Co : koefisien (untuk tulang Co = 1,3)

Ca : kapasitas Screw Conveyor (= 4,6401 lb/menit)

L : panjang Screw Conveyor (= 45 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3\ .4{,}6401\ lb/menit.45\ ft}{33000} = 0{,}0082\ hp$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{0{,}0082\ hp}{0{,}8} = 0{,}0103$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0103 hp × 2 = 0,0206 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

11. Tangki Penampung Larutan HCl (F – 143)

Fungsi : Untuk tempat penampungan larutan HCl

Tipe : Tangki silinder dengan bagian bawah berbentuk datar (flat-bottomed) dan tutup atas berbentuk torispherical dished head

Dasar pemilihan : cocok digunakan untuk menampung bahan yang berbentuk liquid

Jumlah : 1 buah

Perhitungan :

Suhu = 30°C

Jumlah = 1 buah

Tangki dirancang untuk menyimpan larutan HCl selama 7 hari.

Volume larutan HCl total = 695,3555 lt / jam . 7 hari . 24 jam / hari

= 116819,7240 lt = 4124,9903 ft^3

Asumsi : Ruang kosong = 20 % volume tangki

$$\text{Volume tangki} = \frac{100\%}{80\%} 4124{,}9903 \text{ ft}^3$$

$$= 5156{,}2378 \text{ ft}^3$$

$\frac{H}{D} = 1$, sehingga : Volume tangki $= \frac{\pi}{4} . D^2 . H$

$$5156{,}2378 \text{ ft}^3 = \frac{\pi}{4} . D^2 . D$$

$$D^3 = 6562{,}4845 \text{ ft}^3$$

$$D = 18{,}7222 \text{ ft} \approx 18{,}8 \text{ ft} = 5{,}7317 \text{ m}$$

$$H = 18{,}8 \text{ ft} = 5{,}7317 \text{ m}$$

ρ larutan HCl 35% = 1,16775 kg / lt = 72,9208 lb / ft^3 (Perry, 1999, 2-101)

Bahan konstruksi : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}\ in$

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$$4124{,}9903 \text{ ft}^3 = \frac{\pi}{4} . D^2 . H_l$$

$$4124{,}9903\ ft^3 = \frac{\pi}{4}.(18{,}8\ ft)^2.H_l$$

$$H_l = 14{,}8540\ ft$$

$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

$$t_S = \frac{72{,}9208\ lb/ft^3 . (14{,}8540\ ft).(12.18{,}8)\ in}{2.18750\ lb/in^2 .0{,}80.(144\ in^2/ft^2)} + \frac{1}{8}\ in$$

$t_S = 0{,}1816\ in$ → diambil $t_S\ \frac{3}{16}\ in$

Tutup bawah berbentuk datar

Tebal tutup flat-bottomed = tebal shell = $\frac{3}{16}$ in

Penentuan tebal head (t_h) :

Head berbentuk torispherical dished head

Rc = D–0,5 = (18,8–0,5) ft = 18,3 ft

sf = 2 in

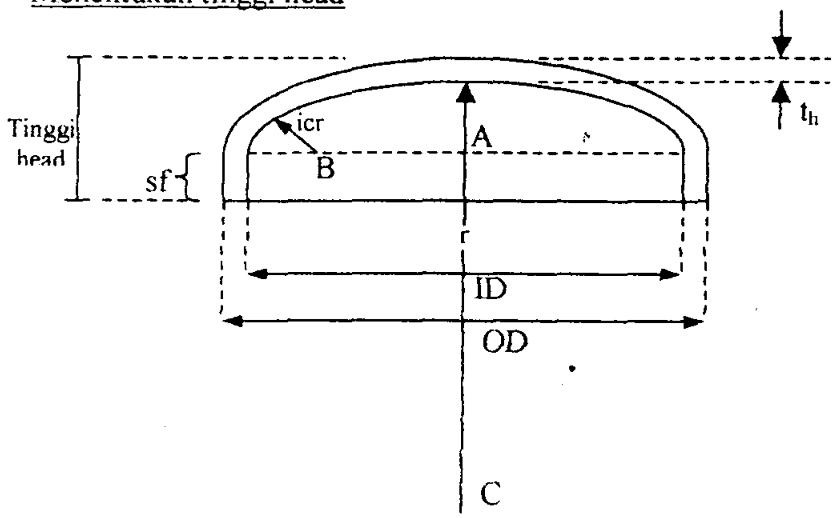
$$P_{hidrostatis} = \frac{\rho.H}{144} = \frac{72{,}9208\ lb/ft^3 .14{,}8540\ ft}{144\ in^2/ft^2} = 7{,}5520\ lb/in^2$$

$$t_h = \frac{0{,}885.P.rc}{f.E - 0{,}1.P} + C$$ (Brownell & Young, 1959, pp. 258, pers.13.12)

$$= \frac{0{,}885.7{,}5520\ lb/in^2 .18{,}3\ ft.12\ in/ft}{18750\ lb/in^2 .0{,}8 - 0{,}1.7{,}5520\ lb/in^2} + \frac{1}{8}\ in$$

$= 0{,}2225\ in$ → *diambil* $t_h = \frac{4}{16}\ in = 0{,}0208\ ft$

Menentukan tinggi head



ID = 18,8 ft = 225,6 in

OD = ID + 2 t_s

$= 225{,}6 \text{ in} + 2 \cdot \frac{3}{16} \text{ in}$

= 225,975 in

r = 180 in

icr = 13,75 in

(Brownell & Young, 1959, pp. 91, table 5.7)

$$\text{Tinggi head} = t_h + sf + \left(r - \sqrt{(BC)^2 - (AB)^2} \right)$$

$$= \frac{4}{16} \text{ in} + 2 \text{ in} + \left(180 - \sqrt{(180 - 13{,}75)^2 - \left(\frac{225{,}6}{2} - 13{,}75 \right)^2} \right)$$

= 48,7279 in = 4,0607 ft

Jarak untuk pemasangan pipa & perawatan = 3 ft

H total = tinggi head + tinggi tangki + tebal tutup flat-bottomed + pemasangan pipa

$= 4{,}0607 \text{ ft} + 18{,}8 \text{ ft} + \dfrac{4}{16.12} \text{ ft} + 3 \text{ ft}$

$= 25{,}8815 \text{ ft} \approx 26 \text{ ft}$

12. Tangki Pengencer (F – 142)

Fungsi : mengencerkan larutan HCl dari Tangki Penampung HCl F – 143

Tipe : tangki silinder dengan bagian bawah berbentuk konis yang dilengkapi dengan baffle dan pengaduk tipe flat six-blade turbine with disk

Dasar pemilihan : cocok digunakan untuk tempat pengenceran bahan yang berupa liquida

Jumlah : 1 buah

Perhitungan :

Massa larutan HCl = 730 kg = 1609,65 lb

Massa H_2O = 4870,07 kg = 10738,5044 lb

$\rho_{\text{larutan HCl 35\%}}$ pada 30°C = 1,16775 kg / lt = 72,9208 lb / ft^3 (Perry, 1999, 2-101)

ρ H_2O pada 30°C = 0,99568 kg / lt = 62,1758 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

$$\text{Volume larutan HCl} = \frac{1609{,}65 \text{ lb}}{72{,}9208 \text{ lb/ft}^3} = 22{,}0739 \text{ ft}^3$$

$$\text{Volume } H_2O = \frac{10738{,}5044 \text{ lb}}{62{,}1758 \text{ lb/ft}^3} = 172{,}7119 \text{ ft}^3$$

$$\text{Volume total} = 22{,}0739 \text{ ft}^3 + 172{,}7119 \text{ ft}^3 = 194{,}7858 \text{ ft}^3$$

Asumsi : Ruang kosong = 20% volume tangki

$$\text{Volume tangki} = \frac{194{,}7858 \text{ ft}^3}{80\%} = 243{,}4822 \text{ ft}^3$$

$$\frac{H_1}{D} = 2 \rightarrow H_1 = 2D$$

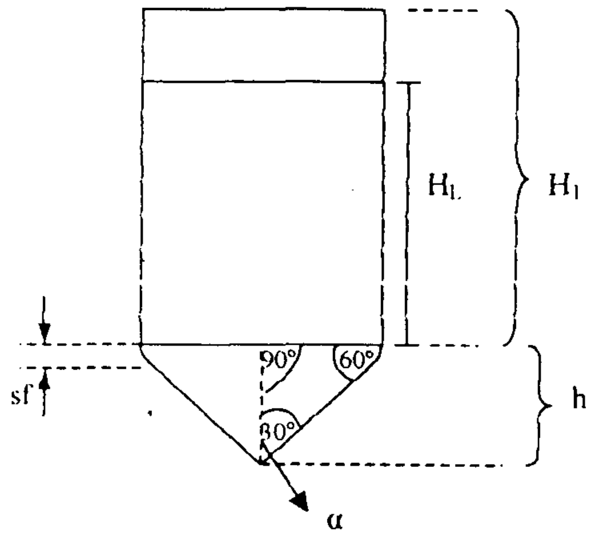
$$\text{Volume tangki} = \frac{\pi}{4} . D^2 . H_1$$

$$243{,}4822 \text{ ft}^3 = \frac{\pi}{4} . D^2 . 2D$$

$$D^3 = 154{,}9432 \text{ ft}^3$$

$$D = 5{,}3710 \text{ ft} = 5{,}4 \text{ ft}$$

$$H_1 = 10{,}8 \text{ ft}$$



Perancangan konis

sf = 2 in

(Brownell & Young, 1959, pp. 87, table 5.4)

Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$$\tan 60° = \frac{h - sf}{0{,}5.D} \rightarrow h = \tan 60°.0{,}5.D + sf$$

$$h = \tan 60° . 0{,}5 . 5{,}4 \text{ ft} + (2 / 12) \text{ ft}$$

$$h = 4{,}8478 \text{ ft}$$

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(5{,}4 \text{ ft})^2.4{,}8478 \text{ ft}$$

$$= 37{,}0230 \text{ ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$194{,}7858 \text{ ft}^3 - 37{,}023 \text{ ft}^3 = \frac{1}{4}.\pi.(5{,}4 \text{ ft})^2.H_L$$

$$H_L = 6{,}8858 \text{ ft}$$

Tinggi liquid total (H)

$$H = H_L + h$$

$$H = 6{,}8858 \text{ ft} + 4{,}8478 \text{ ft}$$

$$H = 11{,}7335 \text{ ft} \approx 11{,}8 \text{ ft}$$

Penentuan tebal shell (t_S)

$$\text{Volume total} = \frac{1}{4}.\pi.D^2.H'$$

$$194{,}7858\ ft^3 = \frac{1}{4}.\pi.(5{,}4\ ft)^2.H'$$

$$H' = 8{,}5017\ ft$$

Dari Appendix A dapat diketahui bahwa :

Larutan HCl masuk = 730 kg, yang terdiri dari : HCl = 255,5 kg

H_2O = 474,5 kg

H_2O masuk dari WD = 4870,07 kg

Sehingga massa total bahan masuk = 730 kg + 4870,07 kg

= 5600,07 kmol

$$X\ \text{larutan HCl} = \frac{\text{massa larutan HCl}}{\text{massa total bahan masuk}} = \frac{730\ kg}{5600{,}07\ kg} = 0{,}1304$$

$$X\ H_2O = \frac{\text{massa } H_2O}{\text{massa total bahan masuk}} = \frac{4870{,}07\ kg}{5600{,}07\ kg} = 0{,}8696$$

$$\rho_{campuran} = \frac{1}{X_{larutan\ HCl}\dfrac{1}{\rho_{larutan\ HCl}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry,1999)

$$\rho_{campuran} = \frac{1}{0{,}1304\dfrac{1}{72{,}9208\ lb/ft^3} + 0{,}8696\dfrac{1}{62{,}1758\ lb/ft^3}}$$

$$\rho_{campuran} = 63{,}3935\ lb/ft^3 = 1015{,}1797\ kg/m^3$$

Bahan konstruksi :

Stainless steel SA – 240 Grade M tipe 316

$F_{allowable}$ (T = -20°C – 100°C) = 18750 lb/ in^2

(Brownell & Young, 1959, pp. 342, App. D, item 4)

Pengelasan menggunakan double welded butt joint → efisiensi = 80%

(Brownell & Young, 1959, pp. 254, table 13.2)

$$C = \frac{1}{8}$$

Mencari tebal shell (t_S)

$$t_S = \frac{\rho.H'.12D}{2.f.E.144} + C$$

(Brownell & Young, 1959, pp. 46, eq. 3.18)

$$t_S = \frac{63{,}3935\ lb/ft^3.8{,}5017\ ft.12.5{,}4\ in}{2.18750\ lb/in^2.0{,}80.144} + \frac{1}{8}$$

$$t_S = 0{,}1331\ in \quad \rightarrow \quad \text{diambil } t_S = \frac{3}{16}\ in$$

Mencari tebal konis (t_K)

$$P_{hidrostatik} = \frac{\rho.H}{144} = \frac{63{,}3935\ lb/ft^3.11{,}8\ ft}{144} = 5{,}1655\ lb/in^2$$

Sudut konis = 60° → α = 30°

Untuk α ≤ 30° dapat dipakai rumus

$$t_k = \frac{P.D}{2.\cos\alpha.(f.E - 0{,}6.P)} + C$$

(Brownell & Young, 1959, pp. 118, eq. 6.154)

$$t_k = \frac{5{,}1655\ lb/in^2 .5{,}4\ ft}{2.\cos 30°.\left(18750\ lb/in^2 .0{,}80 - 0{,}6.5{,}1655\ lb/in^2\right)} + \frac{1}{8}$$

$t_k = 0{,}1379$ in → diambil $t_k = \frac{3}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + jarak pemasangan pipa

= 10,8 ft + 4,8478 ft + 3 ft

= 18,6478 ft

Perancangan Pengaduk

$$\frac{H_{liquid}}{D_{tangki}} = \frac{11{,}8\ ft}{5{,}4\ ft} = 2{,}1852$$

μ $_{larutan\ HCl\ 35\%}$ pada 30°C = 1,8 cp

(Geankoplis, 1993, pp.876 A.3-13, pp.878, Fig. A.3-4)

μ H_2O pada 30°C = 0,8007 cp (Geankoplis, 1993, pp.855, A.2-4)

$$\mu_{campuran}^{1/3} = X_{larutan\ HCl} \cdot \left(\mu_{larutan\ HCl}\right)^{1/3} + X_{H_2O} \cdot \left(\mu_{H_2O}\right)^{1/3}$$ (Perry, 1999)

$$\mu_{campuran}^{1/3} = 0{,}1304.\left(1{,}8\ cp\right)^{1/3} + 0{,}8696.\left(0{,}8007\ cp\right)^{1/3}$$

$$\mu_{campuran} = 0{,}9017\ cp$$

$\mu_{campuran} = 0{,}9017$ cp

$\frac{H_{liquid}}{D_{tangki}} = 2{,}1852$

} Walas, 1990, pp.288 diperoleh :

Jumlah impeller = 2

Letak impeller 1 = D_t /3

Letak impeller 2 = (2/3) H

Letak impeller 1 = $\frac{D_t}{3} = \frac{5{,}4 \text{ ft}}{3} = 1{,}8 \text{ ft}$

Letak impeller 2 = $\frac{2}{3} H = \frac{2}{3} 11{,}8 \text{ ft} = 7{,}8667 \text{ ft}$

Ukuran impeller

$\frac{d}{D_t} = 0{,}3 - 0{,}6$; dimana : d : diameter impeller

D_t : diameter tangki

(Walas, 1990, pp. 287)

Dipilih $\frac{d}{D_t} = 0{,}5$, sehingga : d = 0,5 . 5,4 ft

d = 2,7 ft

Ukuran baffle

$W = \frac{D_t}{12}$ Dimana : W : lebar baffle

$\text{Offset} = \frac{d}{2}$ D_t : diameter tangki

d : diameter impeller

(Walas, 1990, pp. 287)

Sehingga : $W = \frac{5,4\ ft}{12} = 0,45\ ft$

$$Offset = \frac{2,7\ ft}{2} = 1,35\ ft$$

Jumlah baffle = 4 buah (Walas, 1990, pp. 287)

<u>Perhitungan power pengaduk</u>

$d = D_a = 2,7\ ft = 0,8230\ m$

$N = 110\ rpm = 1,8333\ rps$

$$N_{Re} = \frac{D_a^2 . N . \rho}{\mu} = \frac{(0,8230\,m)^2 . 1,8333\ rps . 1015,1797\ kg/m^3}{0,9017.10^{-3}\ kg/m.s} = 1397882,1693$$

(Walas, 1990, pp. 290)

Untuk flat six-blade turbine with disk (Walas, 1990, pp. 292, Fig. 10.6) :

$N_P = 5$

$P = N_P . \rho . N^3 . D_a$ (Walas, 1990, pp. 292, Fig. 10.6)

$P = 5 . 1015,1797\ kg/m^3 . 1,8333\ rps . 0,8230\ m$

$P = 25740,7523\ Watt = 34,5050\ hp$

Efisiensi motor = 85% (Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$Power = \frac{34,5050\ hp}{0,85} = 40,5942\ hp \approx 41\ hp$$

13. Reaktor (R – 140)

<u>Fungsi</u> : untuk tempat pembuatan wet ossein

Tipe : tangki silinder dengan bagian bawah berbentuk konis dan tutup atas berbentuk flat head yang dilengkapi dengan baffle dan pengaduk tipe flat six-blade turbine with disk

Dasar pemilihan : cocok digunakan untuk menampung dan mereaksikan bahan yang berbentuk slurry, cocok untuk operasi pada tekanan rendah

Jumlah : 1 buah

Perhitungan :

Suhu operasi = 37,6°C (App. B)

Tekanan (P_0) = 6,5218 kPa (Geankoplis, 1993, pp.857, A.2-9)

= 0,9459 psia

Mencari volume total masuk reaktor

Massa tulang dari Screw Conveyor J – 135 = 505,05 kg

ρ_{tulang} = 1,6346 kg / lt = 102,0751 lb / ft^3

$$\text{Volume tulang masuk} = \frac{\text{Massa tulang masuk}}{\rho_{tulang}}$$

$$= \frac{505{,}05 \text{ kg}}{1{,}6346 \text{ kg / lt}} = 308{,}9701 \text{ lt} = 10{,}91 \text{ ft}^3$$

Volume larutan HCl dari Tangki Pengencer F – 142 = 194,7858 ft^3

Volume total masuk Reaktor R – 140 = 10,91 ft^3 + 194,7858 ft^3

= 205,6958 ft^3

Mencari dimensi tangki

Asumsi ruang kosong = 20% volume tangki

$$\text{Volume tangki} = \frac{205{,}6958\ ft^3}{80\%} = 257{,}1197\ ft^3$$

$$\frac{H}{D} = 2 \quad \Rightarrow \quad H = 2\ D$$

$$\text{Volume tangki} = \frac{\pi}{4}.D^2.H$$

$$257{,}1197\ ft^3 = \frac{\pi}{4}.D^2.2\ D$$

$$D^3 = 163{,}6216\ ft^3$$

$$D = 5{,}4695\ ft \quad \approx \quad 5{,}5\ ft$$

$$H = 11\ ft$$

Diketahui bahwa :

Massa tulang masuk = 505,05 kg

Massa larutan HCl masuk = 5600,07 kg yang terdiri dari :

HCl = 255,5 kg

H_2O = 5344,75 kg

$$\text{Sehingga : } X_{HCl} = \frac{\text{Massa HCl}}{\text{Massa larutan HCl}} = \frac{255{,}5\ kg}{5600{,}07\ kg} = 0{,}0456$$

$$X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa larutan HCl}} = \frac{5344{,}75\ kg}{5600{,}07\ kg} = 0{,}9544$$

$$\rho_{HCl} = 1{,}46\ kg/lt = 91{,}1706\ lb/ft^3$$ (Perry, 1999)

$$\rho_{\text{larutan HCl}} = \frac{1}{X_{HCl}\dfrac{1}{\rho_{HCl}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{\text{larutan HCl}} = \frac{1}{0{,}0456\dfrac{1}{91{,}1706\ lb/ft^3} + 0{,}9544\dfrac{1}{62{,}1758\ lb/ft^3}}$$

$$\rho_{\text{larutan HCl}} = 63{,}0913\ lb/ft^3 = 1010{,}3398\ kg/m^3$$

Massa bahan masuk total = massa tulang + massa larutan HCl

= 505,05 kg + 5600,07 kg

= 6105,12 kg

Sehingga : $X_{tulang} = \dfrac{\text{Massa tulang}}{\text{Massa total bahan masuk}} = \dfrac{505{,}05\ kg}{6105{,}12\ kg} = 0{,}0827$

$$X_{\text{larutan HCl}} = \frac{\text{Massa larutan HCl}}{\text{Massa total bahan masuk}} = \frac{5600{,}07\ kg}{6105{,}12\ kg} = 0{,}9173$$

$\rho_{tulang} = 1{,}6346\ kg/lt = 102{,}0751\ lb/ft^3$

$$\rho_{\text{bahan masuk}} = \frac{1}{X_{\text{larutan HCl}}\dfrac{1}{\rho_{\text{larutan HCl}}} + X_{tulang}\dfrac{1}{\rho_{tulang}}}$$ (Perry, 1999)

$$\rho_{\text{bahan masuk}} = \frac{1}{0{,}9173\dfrac{1}{62{,}6340\ lb/ft^3} + 0{,}0827\dfrac{1}{102{,}0751\ lb/ft^3}}$$

$$\rho_{\text{bahan masuk}} = 65{,}1496\ lb/ft^3 = 1043{,}3019\ kg/m^3$$

Tinggi bahan pada shell (H_b)

$$\text{Volume total} = \frac{1}{4}.\pi.D^2.H_b$$

$$205,6958\ ft^3 = \frac{1}{4}.\pi.(5,5\ ft)^2.H_b$$

$$H_b = 8,6544\ ft$$

$$P_{hidrostatis} = \frac{\rho.H_b}{144} = \frac{65,1496\ lb/ft^3.8,6544\ ft}{144} = 3,9155\ psia$$

$P_{operasi} = P_0 + P_{hidrostatis} = 0,9459$ psia + 3,9155 psia = 4,8614 psia

$P_{design} = 1,5 . P_{operasi}$

= 1,5 . 4,8614 psia

= 7,2921 psia

Bahan konstruksi :

Stainless steel SA – 240 Grade M tipe 316

$F_{allowable}$ (T = -20°C – 100°C) = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342, App. D, item 4)

Pengelasan menggunakan double welded butt joint → efisiensi = 80%

(Brownell & Young, 1959, pp. 254, table 13.2)

$$C = \frac{1}{8}$$

Mencari tebal shell (t_S)

$$t_S = \frac{P.r_i}{f.E - 0,6.P} + C$$ (Brownell & Young, 1959, pp.254, eq. 13.1)

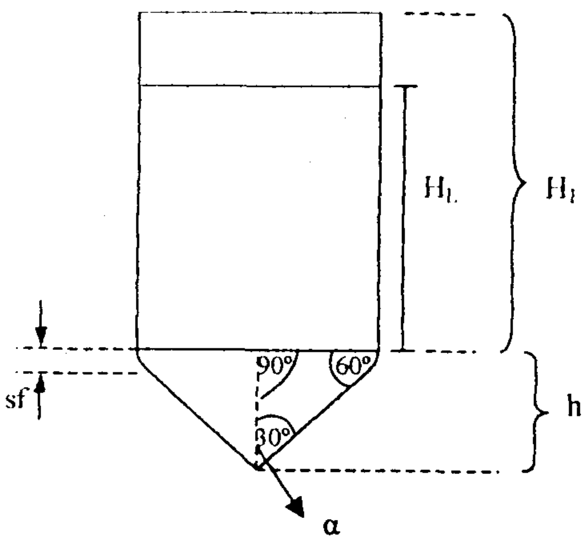
$$t_S = \frac{7{,}2921\ \text{lb/in}^2 . \frac{1}{2} . 5{,}5 . 12\ \text{in}}{18750\ \text{lb/in}^2 . 0{,}80 - 0{,}6 . 7{,}2921\ \text{lb/in}^2} + \frac{1}{8}$$

$t_S = 0{,}1410$ in $\rightarrow$ diambil $t_S = \frac{3}{16}$ in

Penentuan tebal head (t_h)

Tutup atas berbentuk datar (flat-head) dengan tebal = tebal shell = $\frac{3}{16}$ in

Penentuan tebal konis (t_k)



$\tan x = \frac{h - sf}{0{,}5 . D}$; h : tinggi konis, ft

$h = \tan 60^\circ . 0{,}5 . 5{,}5\ \text{ft} + \frac{2}{12}\ \text{ft}$

$h = 4{,}9344$ ft

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(5{,}5\ ft)^2.4{,}9344\ ft$$

$$= 12{,}4389\ ft^3$$

<u>Mencari tinggi liquida pada shell (H_L)</u>

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$205{,}6958\ ft^3 - 12{,}4389\ ft^3 = \frac{1}{4}.\pi.(5{,}5\ ft)^2.H_L$$

$$H_L = 8{,}1310\ ft$$

<u>Tinggi liquid total (H)</u>

$H = H_L + h$

$H = 8{,}1310\ ft + 4{,}9344\ ft$

$H = 13{,}0655\ ft \approx 13{,}1\ ft$

$$P_{hidrostatis} = \frac{\rho.H}{144} = \frac{65{,}1496\ lb/ft^3.13{,}1\ ft}{144\ in^2/ft^2} = 5{,}9268\ psia$$

$$t_k = \frac{P.D}{2.\cos\alpha(f.E - 0{,}6.P)} + C$$ (Brownell & Young, 1959, pp.254, eq. 13.1)

$$t_k = \frac{5,9268\ lb/in^2 .5,5.12\ in}{2.\cos 30^\circ \left(18750\ lb/in^2 .0,8 - 0,6.5,9268\ lb/in^2\right)} + \frac{1}{8}\ in$$

$t_k = 0,1401\ in$ $\rightarrow$ diambil $t_k = \frac{3}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + jarak pemasangan pipa

= 11 ft + 4,9344 ft + 3 ft

= 18,9344 ft

Perancangan pengaduk

$$\frac{H_{liquid}}{D_{tangki}} = \frac{13,1\ ft}{5,6\ ft} = 2,3818$$

$\mu_{\text{larutan HCl dari tangki pengencer}} = 0,9017$ cp

μ tulang = 7000 cp (www.norlandprod.com/twchrpts/fishgelrpt.html)

$$\mu_{campuran}^{1/3} = X_{larutan\ HCl} \cdot \left(\mu_{larutan\ HCl}\right)^{1/3} + X_{tulang} \cdot \left(\mu_{tulang}\right)^{1/3}$$

$$\mu_{campuran}^{1/3} = 0,9173.(0,9017\ cp)^{1/3} + 0,0827.(7000\ cp)^{1/3}$$

$$\mu_{campuran} = 15,0450\ cp$$

$\mu_{campuran} = 15,0450$ cp

$\frac{H_{liquid}}{D_{tangki}} = 2,3818$

} Walas, 1990, pp.288 diperoleh :

Jumlah impeller = 2

Letak impeller 1 = D_t /3

Letak impeller 2 = (2/3) H

Letak impeller 1 = $\frac{D_t}{3} = \frac{5,5 \text{ ft}}{3} = 1,8333$ ft

Letak impeller 2 = $\frac{2}{3}$ H = $\frac{2}{3}$ 13,1 ft = 8,7333 ft

Ukuran impeller

$\frac{d}{D_t} = 0,3 - 0,6$; dimana : d : diameter impeller

D_t : diameter tangki

(Walas, 1990, pp. 287)

Dipilih $\frac{d}{D_t} = 0,5$, sehingga : d = 0,5 . 5,5 ft

d = 2,75 ft

Ukuran baffle

$W = \frac{D_t}{12}$ Dimana : W : lebar baffle

$\text{Offset} = \frac{d}{2}$ D_t : diameter tangki

d : diameter impeller

(Walas, 1990, pp. 287)

Sehingga : $W = \frac{5,5 \text{ ft}}{12} = 0,4583$ ft

$\text{Offset} = \frac{2,75 \text{ ft}}{2} = 1,375$ ft

Jumlah baffle = 4 buah (Walas, 1990, pp. 287)

Perhitungan power pengaduk

$d = D_a = 2{,}75\ ft = 0{,}8382\ m$

$N = 110\ rpm = 1{,}8333\ rps$

$$N_{Re} = \frac{D_a^{\ 2}.N.\rho}{\mu} = \frac{(0{,}8382\,m)^2.1{,}8333\ rps.1043{,}3019\,kg/m^3}{15{,}0450.10^{-3}\ kg/m.s} = 89323{,}5711$$

(Walas, 1990, pp. 290)

Untuk Flat six blade turbine with disk (Walas, 1990, pp. 292, Fig. 10.6) :

$N_P = 5$

$P = N_P\ .\ \rho\ .\ N^3\ .\ D_a$ (Walas, 1990, pp. 292, Fig. 10.6)

$P = 5\ .\ 1043{,}3019\ kg/m^3\ .\ 1{,}8333\ rps\ .\ 0{,}8382\ m$

$P = 26943{,}7014\ Watt = 36{,}1176\ hp$

Efisiensi motor = 84% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$Power = \frac{36{,}1176\ hp}{0{,}84} = 42{,}9971\ hp \approx 43\ hp$$

14. Centrifugal Separator (H – 150)

Fungsi : untuk memisahkan wet ossein dari garam-garam mineral yang terdapat dalam filtrat

Tipe : Centrifuge sedimentation

Jumlah : 1 buah

Dasar pemilih : dapat digunakan untuk memisahkan fase solid dan liquid, design sederhana, dapat digunakan untuk kapasitas besar, serta dapat digunakan untuk liquid yang viskos

Perhitungan :

ρ H_2O pada 37,6°C = 0,9934 kg / lt = 62,0335 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft^3 (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft^3

(www.usd.edu/biol/courses/cellthies/cpa3answers.html)

Wet ossein

Protein = 146,46 kg → $X_{protein} = \dfrac{\text{Massa protein}}{\text{Massa wet ossein}} = \dfrac{146{,}46\ \text{kg}}{1262{,}63\ \text{kg}} = 0{,}1160$

Lemak = 5,05 kg → $X_{lemak} = \dfrac{\text{Massa lemak}}{\text{Massa wet ossein}} = \dfrac{5{,}05\ \text{kg}}{1262{,}63\ \text{kg}} = 3{,}9996.10^{-3}$

H_2O = 1111,12 kg → $X_{H_2O} = \dfrac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \dfrac{1111{,}12\ \text{kg}}{1262{,}63\ \text{kg}} = 0{,}8800$

Wet ossein = 1262,63 kg

$$\rho_{wet\ ossein} = \frac{1}{X_{protein}\dfrac{1}{\rho_{protein}} + X_{lemak}\dfrac{1}{\rho_{lemak}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}} \quad \text{(Perry, 1999)}$$

$$\rho_{wet\ ossein} = \frac{1}{0{,}1160\dfrac{1}{0{,}8955\ \text{kg/lt}} + 3{,}9996.10^{-3}\dfrac{1}{0{,}9290\ \text{kg/lt}} + 0{,}88\dfrac{1}{0{,}9934\ \text{kg/lt}}}$$

$\rho_{wet\ ossein}$ = 0,9807 kg / lt = 61,2399 lb/ ft^3 = 980,6918 kg / m^3

$$\text{Wet ossein} = 1262{,}63\ \text{kg} \rightarrow X_{\text{wet ossein}} = \frac{\text{Massa wet ossein}}{\text{Massa bahan masuk}} = \frac{1262{,}63\ \text{kg}}{6105{,}12\ \text{kg}} = 0{,}2068$$

$$MgCl_2 = 46{,}95\ \text{kg} \rightarrow X_{MgCl_2} = \frac{\text{Massa}\ MgCl_2}{\text{Massa bahan masuk}} = \frac{46{,}95\ \text{kg}}{6105{,}12\ \text{kg}} = 0{,}0077$$

$$CaCl_2 = 302{,}30\ \text{kg} \rightarrow X_{CaCl_2} = \frac{\text{Massa}\ CaCl_2}{\text{Massa bahan masuk}} = \frac{302{,}3\ \text{kg}}{6105{,}12\ \text{kg}} = 0{,}0495$$

$$H_3PO_4 = 184{,}2\ \text{kg} \rightarrow X_{H_3PO_4} = \frac{\text{Massa}\ H_3PO_4}{\text{Massa bahan masuk}} = \frac{184{,}2\ \text{kg}}{6105{,}12\ \text{kg}} = 0{,}0302$$

$$HCl = 20{,}62\ \text{kg} \rightarrow X_{HCl} = \frac{\text{Massa}\ HCl}{\text{Massa bahan masuk}} = \frac{20{,}62\ \text{kg}}{6105{,}12\ \text{kg}} = 0{,}0034$$

$$CO_2 = 17{,}52\ \text{kg} \rightarrow X_{CO_2} = \frac{\text{Massa}\ CO_2}{\text{Massa bahan masuk}} = \frac{175{,}52\ \text{kg}}{6105{,}12\ \text{kg}} = 0{,}0029$$

$$H_2O = 4270{,}9\ \text{kg} \rightarrow X_{H_2O} = \frac{\text{Massa}\ H_2O}{\text{Massa bahan masuk}} = \frac{4270{,}9\ \text{kg}}{6105{,}12\ \text{kg}} = 0{,}6996$$

Bahan masuk = 6105,12 kg

$$\rho_{\text{bahan masuk}} = \frac{1}{\frac{X_{\text{wet ossein}}}{\rho_{\text{wet ossein}}} + \frac{X_{MgCl_2}}{\rho_{MgCl_2}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{H_3PO_4}}{\rho_{H_3PO_4}} + \frac{X_{HCl}}{\rho_{HCl}} + \frac{X_{CO_2}}{\rho_{CO_2}} + \frac{X_{H_2O}}{\rho_{H_2O}}} \quad \text{(Perry, 1999)}$$

$$\rho_{\text{bahan masuk}} = \frac{1}{\frac{0{,}2068}{0{,}9807} + \frac{0{,}0077}{2{,}325} + \frac{0{,}0495}{2{,}152} + \frac{0{,}0302}{1{,}834} + \frac{0{,}0034}{2{,}2} + \frac{0{,}0029}{1{,}53} + \frac{0{,}6996}{0{,}9934}}\ \text{kg/lt}$$

$$\rho_{\text{bahan masuk}} = 1{,}0403\ \text{kg/lt} = 64{,}9613\ \text{lb/ft}^3 = 1040{,}2864\ \text{kg/m}^3$$

$$\text{Kapasitas} = 6105{,}12\ \text{kg/jam}$$

$$= \frac{6105{,}12\ \text{kg/jam}}{1040{,}2864\ \text{kg}/m^3} \cdot \frac{1\ \text{jam}}{3600\ \text{s}}$$

$$= 1{,}6302 \cdot 10^{-3}\ \text{m}^3/\text{dt}$$

Power = 1000 . kapasitas (Ulrich, 1984, pp. 220, table 4-23)

= 1000 . 1,6302.10^{-3} m^3 / dt

= 1,6302 kW = 2,1861 hp ≈ 3 hp

Bahan konstruksi : carbon steel

15. Mixer (M – 160)

Fungsi : untuk melarutkan sisa-sisa garam mineral yang masih terdapat dalam wet ossein

Tipe : tangki silinder dengan bagian bawah berbentuk konis dan dilengkapi dengan baffle dan pengaduk tipe flat six-blade turbine with disk

Dasar pemilihan : cocok digunakan untuk mencampur dan menampung bahan yang berbentuk slurry

Jumlah : 1 buah

Perhitungan :

Massa wet ossein = 1262,63 kg = 2784,0992 lb

Massa Protein = 146,46 kg

Massa lemak = 5,05 kg

Massa H_2O = 1111,12 kg

Sehingga : $X_{protein} = \frac{\text{Massa protein}}{\text{Massa wet ossein}} = \frac{146,46 \text{ kg}}{1262,63 \text{ kg}} = 0,1160$

$$X_{lemak} = \frac{\text{Massa lemak}}{\text{Massa wet ossein}} = \frac{5,05 \text{ kg}}{1262,63 \text{ kg}} = 0,0040$$

$$X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \frac{1111,12 \text{ kg}}{1262,63 \text{ kg}} = 0,8800$$

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft³ (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft³

(www.usd.edu/biol/courses/cellthics/cpa3answers.html)

ρ H_2O pada 35,2°C = 0,9939 kg / lt = 62,0647 lb / ft³

(Geankoplis, 1993, pp.855, A.2-3)

$$\rho_{wet\ ossein} = \frac{1}{X_{protein}\frac{1}{\rho_{protein}} + X_{lemak}\frac{1}{\rho_{lemak}} + X_{H_2O}\frac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{wet\ ossein} = \frac{1}{0,1160\frac{1}{55,92\,lb/ft^3} + 0,0040\frac{1}{58,012\,lb/ft^3} + 0,8800\frac{1}{62,0647\,lb/ft^3}}$$

$$\rho_{wet\ ossein} = 61,2667\ lb/ft^3 = 981,1205\ kg/m^3$$

Massa H_2O dari WD = 1262,63 kg = 2784,0992 lb

Massa total bahan masuk = 1262,63 kg + 1262,63 kg = 2525,26 kg

$$\text{Sehingga : } X_{wet\ ossein} = \frac{\text{Massa wet ossein}}{\text{Massa total bahan masuk}} = \frac{1262,63 \text{ kg}}{2525,26 \text{ kg}} = 0,5$$

$$X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa total bahan masuk}} = \frac{1262,63 \text{ kg}}{2525,26 \text{ kg}} = 0,5$$

$$\rho_{\text{bahan masuk}} = \frac{1}{X_{\text{wet ossein}}\dfrac{1}{\rho_{\text{wet ossein}}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{\text{bahan masuk}} = \frac{1}{0{,}5\dfrac{1}{61{,}2667\ \text{lb/ft}^3} + 0{,}5\dfrac{1}{62{,}1758\ \text{lb/ft}^3}}$$

$$\rho_{\text{bahan masuk}} = 61{,}6631\ \text{lb/ft}^3 = 987{,}4689\ \text{kg/m}^3$$

$$\text{Volume wet ossein} = \frac{2784{,}0992\ \text{lb}}{61{,}2667\ \text{lb/ft}^3} = 45{,}4423\ \text{ft}^3$$

$$\text{Volume } H_2O = \frac{2784{,}0992\ \text{lb}}{62{,}1758\ \text{lb/ft}^3} = 44{,}7778\ \text{ft}^3$$

Volume total = $45{,}4423\ \text{ft}^3 + 44{,}7778\ \text{ft}^3 = 90{,}2202\ \text{ft}^3$

Asumsi : ruang kosong = 20% volume tangki

$$\text{Volume tangki} = \frac{90{,}2202\ \text{ft}^3}{80\%} = 112{,}7752\ \text{ft}^3$$

$$\frac{H_1}{D} = 1{,}5 \quad \rightarrow H_1 = 1{,}5\ D$$

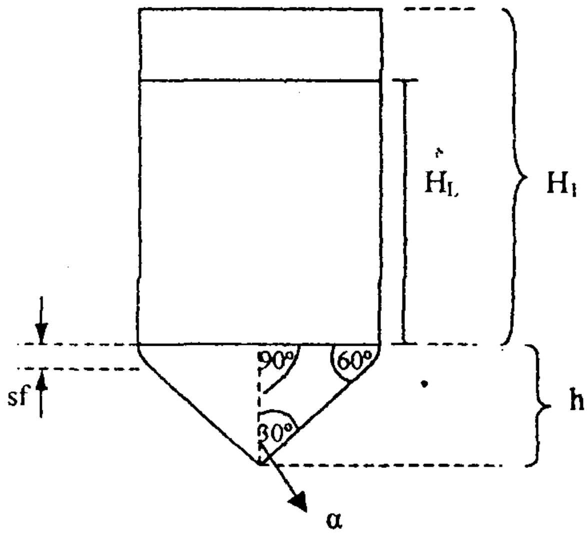
$$\text{Volume tangki} = \frac{\pi}{4}.D^2.H_1$$

$$112{,}7752\ \text{ft}^3 = \frac{\pi}{4}.D^2.1{,}5D$$

$$D^3 = 95{,}6880\ \text{ft}^3$$

$$D = 4{,}5739\ \text{ft} \approx 4{,}6\ \text{ft} = 1{,}4021\ \text{m}$$

$$H_1 = 6{,}9\ \text{ft} = 2{,}1031\ \text{m}$$



Perancangan konis

sf = 2 in (Brownell & Young, 1959, pp. 87, table 5.4)

Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$$\tan 60° = \frac{h - sf}{0{,}5.D} \rightarrow h = \tan 60°.0{,}5.D + sf$$

$$h = \tan 60° \,.\, 0{,}5 \,.\, 4{,}6 \text{ ft} + (2 / 12) \text{ ft}$$

$$h = 4{,}1543 \text{ ft}$$

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(4{,}6 \text{ ft})^2.4{,}1543 \text{ ft}$$

$$= 7{,}3254 \text{ ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$90{,}2202\ ft^3 - 7{,}3254\ ft^3 = \frac{1}{4}.\pi.(4{,}6\ ft)^2.H_L$$

$$H_L = 4{,}9859\ ft$$

Tinggi liquid total (H)

$H = H_L + h$

$H = 4{,}9859\ ft + 4{,}1543\ ft$

$H = 9{,}1402\ ft \approx 9{,}2\ ft$

Penentuan tebal shell (t_S)

$$\text{Volume total} = \frac{1}{4}.\pi.D^2.H'$$

$$90{,}2202\ ft^3 = \frac{1}{4}.\pi.(4{,}6\ ft)^2.H'$$

$$H' = 5{,}4265\ ft$$

Bahan konstruksi :

Stainless steel SA – 240 Grade M tipe 316

$F_{allowable}$ (T = -20°C – 100°C) = 18750 lb / in^2 (T = 31,7°C)

(Brownell & Young, 1959, pp. 342, App. D, item 4)

Pengelasan menggunakan double welded butt joint → efisiensi = 80%

(Brownell & Young, 1959, pp. 254, table 13.2)

$$C = \frac{1}{8}$$

Mencari tebal shell (t_S)

$$t_S = \frac{\rho . H' . 12 D}{2 . f . E . 144} + C$$ (Brownell & Young, 1959, pp. 46, eq. 3.18)

$$t_S = \frac{61,6631 \text{ lb/ft}^3 . 5,4265 \text{ ft} . 12 . 4,6 \text{ in}}{2 . 18750 \text{ lb/in}^2 . 0,80 . 144 \text{ in}^2/\text{ft}^2} + \frac{1}{8}$$

$t_S = 0,1293$ in $\rightarrow$ diambil $t_S = \frac{3}{16}$ in

Mencari tebal konis (t_K)

$$P_{hidrostatik} = \frac{\rho . H}{144} = \frac{61,6631 \text{ lb/ft}^3 . 9,2 \text{ ft}}{144 \text{ in}^2/\text{ft}^2} = 3,9396 \text{ lb/in}^2$$

Sudut konis = 60° → $\alpha = 30°$

Untuk $\alpha \leq 30°$ dapat dipakai rumus :

$$t_k = \frac{P . D}{2 . \cos\alpha . (f . E - 0,6 . P)} + C$$

(Brownell & Young, 1959, pp. 118, eq. 6.154)

$$t_k = \frac{3,9396 \text{ lb/in}^2 . 4,6 \text{ ft} . 12 \text{ in/ft}}{2 . \cos 30° . (18750 \text{ lb/in}^2 . 0,80 - 0,6 . 3,9396 \text{ lb/in}^2)} + \frac{1}{8}$$

$t_k = 0,2564$ in $\rightarrow$ diambil $t_k = \frac{5}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + jarak pemasangan pipa

= 6,9 ft + 4,1543 ft + 3 ft

= 14,0543 ft

Perancangan Pengaduk

$$\frac{H_{bahan}}{D_{tangki}} = \frac{4{,}9859 \text{ ft}}{4{,}6 \text{ ft}} = 1{,}0839$$

μ wet ossein = 7500 cp (www.norlandprod.com/twchrpts/fishgelrpt.html)

μ H_2O pada 30°C = 0,8007 cp (Geankoplis, 1993, pp.855, A.2-4)

$$\mu_{campuran}{}^{1/3} = X_{wet\ ossein} \cdot (\mu_{wet\ ossein})^{1/3} + X_{H_2O} \cdot (\mu_{H_2O})^{1/3}$$

$$\mu_{campuran}{}^{1/3} = 0{,}5.(7500 \text{ cp})^{1/3} + 0{,}5.(0{,}8007 \text{ cp})^{1/3}$$

$$\mu_{campuran} = 1077{,}3519 \text{ cp}$$

$\mu_{campuran} = 1077{,}3519 \text{ cp}$

$\frac{H_{liquid}}{D_{tangki}} = 1{,}0839$

} Walas, 1990, pp.288 diperoleh :

Jumlah impeller = 2

Letak impeller 1 = D_t /3

Letak impeller 2 = (2/3) H

$$\text{Letak impeller 1} = \frac{D_t}{3} = \frac{4{,}6 \text{ ft}}{3} = 1{,}5333 \text{ ft}$$

$$\text{Letak impeller 2} = \frac{2}{3} H = \frac{2}{3} 9{,}2 \text{ ft} = 6{,}1333 \text{ ft}$$

Ukuran impeller

$\frac{d}{D_t} = 0,3 - 0,6$; dimana : d : diameter impeller

D_t : diameter tangki

(Walas, 1990, pp. 287)

Dipilih $\frac{d}{D_t} = 0,5$, sehingga : $d = 0,5 \cdot 4,6$ ft

$d = 2,3$ ft

Ukuran baffle

$W = \frac{D_t}{12}$ Dimana : W : lebar baffle

$\text{Offset} = \frac{d}{2}$ D_t : diameter tangki

d : diameter impeller

(Walas, 1990, pp. 287)

Sehingga : $W = \frac{4,6 \text{ ft}}{12} = 0,3833$ ft

$\text{Offset} = \frac{2,3 \text{ ft}}{2} = 1,15$ ft

Jumlah baffle = 4 buah (Walas, 1990, pp. 287)

Perhitungan power pengaduk

$d = D_a = 2,3$ ft $= 0,7010$ m

N = 110 rpm = 1,8333 rps

$$N_{Re} = \frac{D_a^{\,2}.N.\rho}{\mu} = \frac{(0{,}7010\,m)^2.1{,}8333\ rps.987{,}4689\ kg/m^3}{1077{,}3519.10^{-3}\ kg/m.s} = 825{,}8543$$

(Walas, 1990, pp. 290)

Untuk Flat six blade turbine with disk (Walas, 1990, pp. 292, Fig. 10.6) :

$N_P = 5$

$P = N_P \,.\, \rho \,.\, N^3 \,.\, D_a$ (Walas, 1990, pp. 292, Fig. 10.6)

$P = 5 \,.\, 987{,}4689\ kg/m^3 \,.\, 1{,}8333\ rps \,.\, 0{,}7010\ m$

$P = 21328{,}7708$ Watt = 28,5908 hp

Efisiensi motor = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$Power = \frac{28{,}5908\ hp}{0{,}80} = 35{,}7386\ hp \approx 36\ hp$$

16. Screw Conveyor (J – 151)

Fungsi : mengangkut wet ossein dari Centrifugal Separator H – 150 ke Mixer M – 160

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

Perhitungan :

Kapasitas = 1262,63 kg / jam

Jarak Centrifugal Separator ke Mixer = panjang Centrifugal Separator + ½ m

= 1 m + ½ m

= 1,5 m = 4,9212 ft

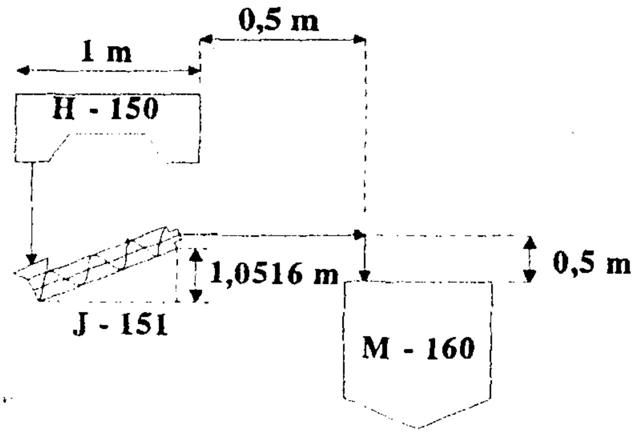
H = tinggi Screw Conveyor + ½ m

H = 0,5 . tinggi shell Mixer + ½ m

H = 0,5 . 2,1031 m + ½ m

H = 1,0516 m + ½ m

H = 1,5516 m = 5,0904 ft



Panjang Screw Conveyor J – 151 = $\sqrt{5{,}0904^2 + 4{,}9212^2}$ ft = 7,0803 ft ≈ 10 ft

Sudut Screw Conveyor J – 151 :

$$\tan x = \frac{5{,}0904 \text{ ft}}{4{,}9212 \text{ ft}} = 1{,}0344$$

$$x = 45{,}97^\circ$$

$\rho_{wet\ ossein} = 61{,}2667 \text{ lb/ft}^3 = 981{,}1205 \text{ kg/m}^3$

$$\text{Massa yang dipindahkan} = 1262{,}63\frac{kg}{jam}.2{,}205\frac{lb}{kg}.\frac{1\ jam}{60\ menit} = 46{,}4017\ lb/menit$$

$$\text{Volume yang dipindahkan} = \frac{1262{,}63\ kg/jam}{0{,}9811\ kg/lt} \doteq 1286{,}9265\ lt/jam = 45{,}4423\ ft^3/jam$$

Maka kapasitas Screw Conveyor J – 151 = 45,4423 ft^3 / jam

Waktu pemindahan = 60 menit

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

Power :

$$hp = \frac{Co\,.Ca.L}{33000}$$, dimana :

Co : koefisien (untuk tulang Co = 1,3)

Ca : kapasitas Screw Conveyor (= 44,6801 lb/menit)

L : panjang Screw Conveyor (= 10 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3\,.46{,}4017\ lb/menit.10\ ft}{33000} = 0{,}0183\ hp$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{0{,}0183\ hp}{0{,}8} = 0{,}0228$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0228 hp × 2 = 0,0457 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

17. Filter Press (. . - 162)

Fungsi : memisahkan kembali garam mineral yang masih terdapat dalam wet ossein

Tipe : plate and frame filter press

Dasar pemilihan : sederhana, biaya ekonomis, dapat digunakan pada tekanan tinggi, kapasitas dapat disesuaikan dengan menambah atau mengurangi jumlah plate dan frame, serta dapat dengan mudah dibersihkan.

Jumlah : 3 buah (1 buah untuk cadangan)

Perhitungan :

ρ H_2O pada 31°C = 0,995337 kg / lt = 62,1544 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Waktu operasi = 3 jam (8 proses per hari)

Massa cake = massa wet ossein masuk = 1262,63 kg / jam

= 2784,0992 lb / jam

= 66818,3796 lb / hari

$$= \frac{66818,3796 \text{ lb/hari}}{2 \text{ alat}}$$

= 33409,1898 lb / hari / alat

$\rho_{wet\ ossein}$ = 61,2667 lb/ ft^3 = 981,1205 kg / m^3

$$\text{Volume cake} = \frac{\text{massa cake}}{\rho_{cake}\ .8\ \text{proses/hari}}$$

$$= \frac{33409{,}1898\ \text{lb/hari/alat}}{61{,}2667\ \text{lb/ft}^3\ .8\ \text{proses/hari}}$$

$$= 68{,}1635\ \text{ft}^3\ /\ \text{proses}$$

Ukuran plate & frame = 48 in

Luas efektif = 28,8 ft^2

Kapasitas total = 1,20 ft^3 / in tebal

Tebal frame berkisar antara 0,125 in – 8 in

Diambil tebal plate & frame = 2 in

(Perry, 1973, pp. 19-67, table 19-17)

$$\text{Volume tiap frame} = \text{luas} \times \text{tebal}$$

$$= \frac{28{,}8\ \text{in}}{2} \cdot \frac{2\ \text{in}}{12\ in/ft}$$

$$= 2{,}4\ \text{ft}^3$$

$$\text{Jumlah frame} = \frac{\text{volume cake}}{\text{volume frame}}$$

$$= \frac{68{,}1635\ \text{ft}^3\ /\ \text{proses}}{2{,}4\ \text{ft}^3}$$

$$= 28{,}4014\ \text{buah / proses} \approx 29\ \text{buah / proses}$$

Panjang alat berkisar antara 0,5 – 20 m (Ulrich, 1984, pp. 223)

Diambil panjang Filter Press = 4 m

Jumlah plate & frame = (29 . 2) + 1

= 59 buah

Tebal total plate & frame = $59 \cdot \dfrac{2 \text{ in}}{12 \text{ in/ft}}$

= 9,8333 ft = 2,9972 m

Bahan konstruksi : carbon steel

18. Ekstraktor (H – 170)

Fungsi : untuk mengekstrak gelatin

Tipe : tangki silinder dengan bagian bawah berbentuk konis dan tutup atas berbentuk datar (flat-head) yang dilengkapi dengan baffle dan pengaduk tipe flat six-blade turbine with disk, jaket pemanas, dan koil.

Dasar pemilihan : panas yang disuplai jaket pemanas dan koil untuk menaikkan suhu operasi sampai 75°C, cocok digunakan untuk mencampur dan menampung bahan yang berbentuk slurry.

Jumlah : 1 buah

Perhitungan :

Perancangan bejana

Mencari ρ campuran

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft^3 (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft^3

(www.usd.edu/biol/courses/cellthics/cpa3answers.html)

ρ H_2O pada 30°C = 0,99568 kg / lt = 62,1758 lb / ft^3

ρ H_2O pada 30,4°C = 0,9938 kg / lt = 62,0584 lb / ft^3

ρ H_2O pada 65°C = 0,9808 kg / lt = 61,2466 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Dari J – 163

Protein = 146,46 kg → $X_{protein} = \dfrac{\text{Massa protein}}{\text{Massa wet ossein}} = \dfrac{146{,}46\ kg}{1262{,}63\ kg} = 0{,}1160$

Lemak = 5,05 kg → $X_{lemak} = \dfrac{\text{Massa lemak}}{\text{Massa wet ossein}} = \dfrac{5{,}05\ kg}{1262{,}63\ kg} = 3{,}9996.10^{-3}$

H_2O = 1111,12 kg → $X_{H_2O} = \dfrac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \dfrac{1111{,}12\ kg}{1262{,}63\ kg} = 0{,}8800$

Wet ossein = 1262,63 kg

$$\rho_{wet\ ossein} = \frac{1}{X_{protein}\dfrac{1}{\rho_{protein}} + X_{lemak}\dfrac{1}{\rho_{lemak}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{wet\ ossein} = \frac{1}{0{,}1160\dfrac{1}{0{,}8955\ kg/lt} + 3{,}9996.10^{-3}\dfrac{1}{0{,}9290\ kg/lt} + 0{,}88\dfrac{1}{0{,}9938\ kg/lt}}$$

$\rho_{wet\ ossein}$ = 0,9810 kg / lt = 61,2613 lb / ft^3 = 981,0348 kg / m^3

Dari WD

H_2O = 1262,63 kg

ρ H_2O pada 30°C = 0,99568 kg / lt = 62,1758 lb / ft³

Dari F – 176

H_3PO_4 = 0,68 kg → $X_{H_3PO_4} = \frac{\text{Massa } H_3PO_4}{\text{Massa lar} H_3PO_4} = \frac{0{,}68 \text{ kg}}{0{,}8 \text{ kg}} = 0{,}85$

H_2O = 0,12 kg → $X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa lar} H_3PO_4} = \frac{0{,}12 \text{ kg}}{0{,}8 \text{ kg}} = 0{,}15$

Larutan H_3PO_4 = 0,80 kg

$$\rho_{lar.H_3PO_4} = \frac{1}{X_{H_3PO_4}\frac{1}{\rho_{H_3PO_4}} + X_{H_2O}\frac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{lar.H_3PO_4} = \frac{1}{0{,}85\frac{1}{1{,}8340 \text{ kg/lt}} + 0{,}85\frac{1}{0{,}99568 \text{ kg/lt}}}$$

$$\rho_{lar.H_3PO_4} = 1{,}6283 \text{ kg/lt} = 101{,}6833 \text{ lb/ft}^3 = 162{,}8350 \text{ kg/m}^3$$

Dari J – 175

<u>Wet ossein</u>

Protein = 16,28 kg → $X_{protein} = \frac{\text{Massa protein}}{\text{Massa wet ossein}} = \frac{16{,}28 \text{ kg}}{140{,}3 \text{ kg}} = 0{,}1160$

Lemak = 0,56 kg → $X_{lemak} = \frac{\text{Massa lemak}}{\text{Massa wet ossein}} = \frac{0{,}56 \text{ kg}}{140{,}3 \text{ kg}} = 3{,}9914.10^{-3}$

H_2O = 123,46 kg → $X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \frac{123{,}46 \text{ kg}}{140{,}3 \text{ kg}} = 0{,}8800$

Wet ossein = 140,3 kg

$$\rho_{wet\ ossein} = \frac{1}{X_{protein}\frac{1}{\rho_{protein}} + X_{lemak}\frac{1}{\rho_{lemak}} + X_{H_2O}\frac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{wet\ ossein} = \frac{1}{0{,}1160\frac{1}{0{,}8955\,kg/lt} + 3{,}9914.10^{-3}\frac{1}{0{,}9290\,kg/lt} + 0{,}88\frac{1}{0{,}9808\,kg/lt}}$$

$$\rho_{wet\ ossein} = 0{,}9699\,kg/lt = 60{,}5638\ lb/ft^3 = 969{,}8642\ kg/m^3$$

<u>Larutan H_3PO_4</u>

H_3PO_4 = 0,08 kg → $X_{H_3PO_4} = \frac{Massa\ H_3PO_4}{Massa\ lar\ H_3PO_4} = \frac{0{,}08\,kg}{140{,}38\ kg} = 5{,}6988.10^{-4}$

H_2O = 140,3 kg → $X_{H_2O} = \frac{Massa\ H_2O}{Massa\ lar\ H_3PO_4} = \frac{140{,}3\,kg}{140{,}38\ kg} = 0{,}9994$

Larutan H_3PO_4 = 140,38 kg

$$\rho_{lar.H_3PO_4} = \frac{1}{X_{H_3PO_4}\frac{1}{\rho_{H_3PO_4}} + X_{H_2O}\frac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{lar.H_3PO_4} = \frac{1}{5{,}6988.10^{-4}\frac{1}{1{,}8340\ kg/lt} + 0{,}9994\frac{1}{0{,}9808\,kg/lt}}$$

$$\rho_{lar.H_3PO_4} = 0{,}9881\,kg/lt = 61{,}2629\,lb/ft^3 = 981{,}0601\ kg/m^3$$

Massa total J – 175 = 140,3 kg + 140,38 kg = 280,68 kg

$$X_{wet\ ossein} = \frac{Massa\ wet\ ossein}{Massa\ total\ J-175} = \frac{140{,}3\,kg}{280{,}68\ kg} = 0{,}4999$$

$$X_{lar.H_3PO_4} = \frac{Massa\ lar.H_3PO_4}{Massa\ total\ J-175} = \frac{140{,}38\,kg}{280{,}68\ kg} = 0{,}5001$$

$$\rho_{total\,J-175} = \frac{1}{X_{wet\ ossein}\dfrac{1}{\rho_{wet\ ossein}} + X_{lar.H_3PO_4}\dfrac{1}{\rho_{lar.H_3PO_4}}}$$ (Perry, 1999)

$$\rho_{total\,J-175} = \frac{1}{0{,}4999\dfrac{1}{0{,}9699\ kg/lt} + 0{,}5001\dfrac{1}{0{,}9881\,kg/lt}}$$

$$\rho_{total\,J-175} = 0{,}9754\,kg/lt = 60{,}9114\ lb/ft^3 = 975{,}4316\ kg/m^3$$

Massa total bahan masuk = (1262,63 + 1262,63 + 0,8 + 280,68) kg = 2806,74 kg

Sehingga fraksi dari masing-masing aliran adalah :

Dari J – 163

$$X_{wet\ ossein} = \frac{\text{Massa wet ossein}}{\text{Massa total bahan masuk}} = \frac{1262{,}63\ kg}{2806{,}74\ kg} = 0{,}4499$$

Dari WD

$$X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa total bahan masuk}} = \frac{1262{,}63\ kg}{2806{,}74\ kg} = 0{,}4499$$

Dari F – 176

$$X_{larutan\,H_3PO_4} = \frac{\text{Massa larutan } H_3PO_4}{\text{Massa total bahan masuk}} = \frac{0{,}80\ kg}{2806{,}74\ kg} = 2{,}8503.10^{-4}$$

Dari J – 175

$$X_{total\,J-175} = \frac{\text{Massa total J} - 175}{\text{Massa total bahan masuk}} = \frac{280{,}68\ kg}{2806{,}74\ kg} = 0{,}1000$$

$$\rho_{campuran} = \frac{1}{X_{wet\ ossein}\frac{1}{\rho_{wet\ ossein}} + X_{H_2O}\frac{1}{\rho_{H_2O}} + X_{lar.H_3PO_4}\frac{1}{\rho_{lar.H_3PO_4}} + X_{total\,J-175}\frac{1}{\rho_{total\,J-175}}}$$

(Perry, 1999)

$$\rho_{campuran} = \frac{1}{0{,}4499\frac{1}{0{,}9810\,kg/lt} + 0{,}4499\frac{1}{0{,}99568\,kg/lt} + 2{,}8503.10^{-4}\frac{1}{1{,}6283\,kg/lt} + 0{,}1\frac{1}{0{,}9754\,kg/lt}}$$

$$\rho_{campuran} = 0{,}9871\,kg/lt = 61{,}6407\ lb/ft^3 = 987{,}1111\ kg/m^3$$

$$\text{Volume total} = \frac{\text{massa total bahan masuk}}{\rho_{campuran}} = \frac{2806{,}74\,kg}{0{,}9871\,kg/lt} = 2843{,}388\,lt = 100{,}4021\,ft^3$$

Asumsi : Ruang kosong = 20% volume tangki

$$\text{Volume tangki} = \frac{100{,}4021\ ft^3}{80\%} = 125{,}5026\ ft^3$$

$$\frac{H_1}{D} = 1{,}5 \rightarrow H_1 = 1{,}5\ D$$

$$\text{Volume tangki} = \frac{\pi}{4}.D^2.H_1$$

$$125{,}5026\ ft^3 = \frac{\pi}{4}.D^2.1{,}5\,D$$

$$D^3 = 106{,}4871\ ft^3$$

$$D = 4{,}7399\ ft \approx 4{,}8\ ft = 1{,}4631\ m$$

$$H_1 = 7{,}2\ ft = 2{,}1946\ m$$

Tinggi bahan pada shell (H_b)

$$\text{Volume total} = \frac{1}{4}.\pi.D^2.H_b$$

$$100{,}4021\ ft^3 = \frac{1}{4}.\pi.(4{,}8\ ft)^2.H_b$$

$$H_b = 5{,}5462\ ft$$

Suhu operasi = 75°C (App. B)

Tekanan (P_0) = 38,58 kPa (Geankoplis, 1993, pp.857, A.2-9)

= 5,5956 psia

$$P_{hidrostatis} = \frac{\rho . H_b}{144} = \frac{61{,}6407\ lb/ft^3 . 5{,}5462\ ft}{144} = 2{,}3741\ psia$$

$P_{operasi} = P_0 + P_{hidrostatis}$ = 5,5956 psia + 2,3741 psia = 7,9697 psia

P_{design} = 1,5 . $P_{operasi}$

= 1,5 . 7,9697 psia

= 11,9545 psia

Bahan konstruksi :

Stainless steel SA – 240 Grade M tipe 316

$F_{allowable}$ (T = -20°C – 100°C) = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342, App. D, item 4)

Pengelasan menggunakan double welded butt joint → efisiensi = 80%

(Brownell & Young, 1959, pp. 254, table 13.2)

$$C = \frac{1}{8}$$

Mencari tebal shell (t_S)

$$t_S = \frac{P.r_i}{f.E - 0{,}6.P} + C$$ (Brownell & Young, 1959, pp.254, eq. 13.1)

$$t_S = \frac{11,9545\ lb/in^2 . \frac{1}{2} . 4,8.12 in}{18750\ lb/in^2 . 0,80 - 0,6.11,9545\ lb/in^2} + \frac{1}{8}$$

$t_S = 0,1480\ in$ $\rightarrow$ diambil $t_S = \frac{3}{16}\ in$

Penentuan tebal head (t_h)

Rc = D – 0,5 = (4,8 – 0,5) ft = 4,3 ft

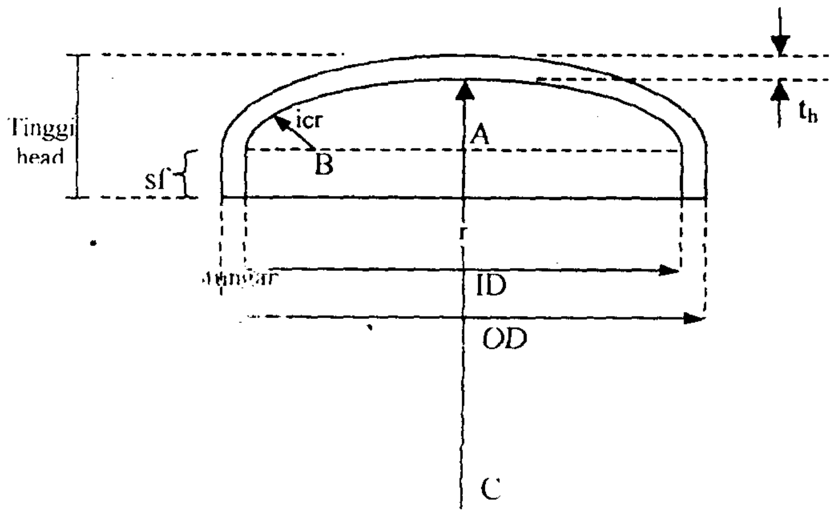
sf = 2 in

$$t_h = \frac{0,885 . P . rc}{f E - 0,1 . P} + C$$ (Brownell & Young, 1959, pp. 258, pers.13.12)

$$= \frac{0,885 . 11,9545\ lb/in^2 . 4,3 ft . 12\ in/ft}{18750\ lb/in^2 . 0,8 - 0,1 . 11,9545\ lb/in^2} + \frac{1}{8}\ in$$

$= 0,1614$ in $\rightarrow$ diambil $t_h = \frac{3}{16}$ in = 0,0156 ft

Menentukan tinggi head



ID = 4,8 ft = 57,6 in

OD $= ID + 2$

$= 57{,}6 \text{ in} + 2 \cdot \dfrac{3}{16} \text{ in}$

$= 57{,}9750 \text{ in}$

r $= 60 \text{ in}$

icr $= 3\dfrac{5}{8} \text{ in}$

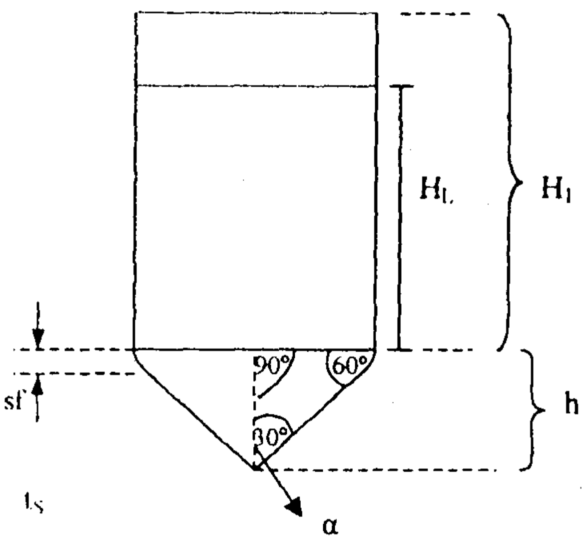
(Brownell & Young, 1959, pp. 91, table 5.7)

$$\text{Tinggi head} = t_h + sf + \left(r - \sqrt{(BC)^2 - (AB)^2} \right)$$

$$= \frac{3}{16} \text{ in} + 2 \text{ in} + \left(60 - \sqrt{\left(60 - 3\frac{5}{8}\right)^2 - \left(\frac{57{,}6}{2} - 3\frac{5}{8}\right)^2} \right)$$

$$= 11{,}7459 \text{ in} = 0{,}9788 \text{ ft}$$

Penentuan tebal konis (t_k)



t_s

$\alpha = ?$

$\tan x = \frac{h - sf}{0{,}5.D}$; h : tinggi konis, ft

$h = \tan 60°.0{,}5.4{,}8\,ft + \frac{2}{12}\,ft$

h = 4,3276 ft

$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.H$

$= \frac{1}{3}.\frac{1}{4}.\pi.(4{,}8\ ft)^2.4{,}3276\ ft$

$= 26{,}1142\ ft^3$

<u>Mencari tinggi liquida pada shell (H_L)</u>

$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$

$100{,}4021\ ft^3 - 26{,}1142\ ft^3 = \frac{1}{4}.\pi.(4{,}8ft)^2.H_L$

$H_L = 4{,}1037\ ft$

<u>Tinggi liquid total (H)</u>

$H = H_L + h$

$H = 4{,}1037\ ft + 4{,}3276\ ft$

$H = 8{,}4313\ ft \approx 8{,}5\ ft$

$P_{hidrostatis} = \frac{\rho.H}{144} = \frac{61{,}6407\ lb/ft^3.8{,}5\ ft}{144\ in^2/ft^2} = 3{,}6385\ psia$

$t_k = \frac{P.D}{2.\cos\alpha(f.E - 0{,}6.P)} + C$ (Brownell & Young, 1959, pp.254, eq. 13.1)

$$t_k = \frac{3{,}6385\ lb/in^2 . 4{,}8 . 12\ in}{2.\cos 30^o \left(18750\ lb/in^2 . 0{,}8 - 0{,}6 . 3{,}6385\ lb/in^2\right)} + \frac{1}{8}\ in$$

$t_k = 0{,}1331\ in$ $\rightarrow$ diambil $t_k = \frac{3}{16}\ in$

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi head + tinggi silinder + tinggi konis + jarak pemasangan pipa

= 0,9788 ft + 7,2 ft + 4,3276 ft + 3 ft

= 26,2735 ft

Perancangan pengaduk

$$\frac{H_{liquid}}{D_{tangki}} = \frac{8{,}5\ ft}{4{,}8\ ft} = 1{,}7708$$

μ wet ossein = 7500 cp (www.norlandprod.com/twchrpts/fishgelrpt.html)

μ H_2O pada 30°C = 0,8007 cp

μ H_2O pada 30,4°C = 0,8136 cp

μ H_2O pada 65°C = 0,4027 cp

(Geankoplis, 1993, pp.855, A.2-4)

$\mu_{H_3PO_4}$ = 41,2 cp (Perry, 1999, pp. 2-105)

Menghitung μ campuran

Dari J – 163

$X_{wet\ ossein}$ = 0,4499

Dari WD

$X_{H_2O} = 0,4499$

Dari F – 176

$X_{H_3PO_4} = 0,85$

$X_{H_2O} = 0,15$

$\mu_{larutan\ H_3PO_4}{}^{1/3} = X_{H_3PO_4} \cdot (\mu_{H_3PO_4})^{1/3} + X_{H_2O} \cdot (\mu_{H_2O})^{1/3}$

$\mu_{larutan\ H_3PO_4}{}^{1/3} = 0,85.(41,2\ cp)^{1/3} + 0,15.(0,8007\ cp)^{1/3}$

$\mu_{larutan\ H_3PO_4} = 29,0980\ cp$

$X_{larutan\ H_3PO_4} = 2,8503.10^{-4}$

Dari J – 175

$X_{wet\ ossein} = 0,4999$

$X_{H_3PO_4} = 5,6988.10^{-4}$

$X_{H_2O} = 0,9994$

$\mu_{larutan\ H_3PO_4}{}^{1/3} = X_{H_3PO_4} \cdot (\mu_{H_3PO_4})^{1/3} + X_{H_2O} \cdot (\mu_{H_2O})^{1/3}$

$\mu_{larutan\ H_3PO_4}{}^{1/3} = 5,6988.10^{-4}.(41,2\ cp)^{1/3} + 0,9994.(0,8007\ cp)^{1/3}$

$\mu_{larutan\ H_3PO_4} = 0,4052\ cp$

$X_{larutan\ H_3PO_4} = 0,5001$

$$\mu_{total\,J-175}{}^{1/3} = X_{wet\,ossein}\cdot(\mu_{wet\,ossein})^{1/3} + X_{larutan\,H_3PO_4}\cdot(\mu_{larutan\,H_3PO_4})^{1/3}$$

$$\mu_{total\,J-175}{}^{1/3} = 0{,}4999.(7500\ cp)^{1/3} + 0{,}5001.(0{,}4052\ cp)^{1/3}$$

$$\mu_{total\,J-175} = 1047{,}0664\ cp$$

$$X_{total\,J-175} = \ldots$$

$$\mu_{campuran}{}^{1/3} = X_{wet\,ossein}\cdot(\mu_{wet\,ossein})^{1/3} + X_{H_2O}\cdot(\mu_{H_2O})^{1/3} + X_{larutan\,H_3PO_4}\cdot(\mu_{larutan\,H_3PO_4})^{1/3} + X_{total\,J-175}\cdot(\mu_{total\,J-175})^{1/3}$$

$$\mu_{campuran}{}^{1/3} = 0{,}4499.(7500\ cp)^{1/3} + 0{,}4499.(0{,}8007\ cp)^{1/3} + 2{,}8503.10^{-4}.(29{,}0980\ cp)^{1/3} + 0{,}1.(1047{,}0664\ cp)^{1/3}$$

$$\mu_{campuran} = 1074{,}3559\ cp$$

$$\left.\begin{aligned}\mu_{campuran} &= 1074{,}3559\,cp\\ \frac{H_{liquid}}{D_{tangki}} &= 2{,}4\end{aligned}\right\}$$ Walas, 1990, pp.288 diperoleh :

Jumlah impeller = 2

Letak impeller 1 = $D_t/3$

Letak impeller 2 = (2/3) H

$$\text{Letak impeller 1} = \frac{D_t}{3} = \frac{4{,}8\ ft}{3} = 1{,}6\ ft$$

$$\text{Letak impeller 2} = \frac{2}{3}\ H = \frac{2}{3}\ 8{,}5\ ft = 5{,}6667\ ft$$

Ukuran impeller

$\frac{d}{D_t} = 0{,}3 - 0{,}6$; dimana : d : diameter impeller

D_t : diameter tangki

(Walas, 1990, pp. 287)

Dipilih $\frac{d}{D_t} = 0{,}5$, sehingga : $d = 0{,}5 \cdot 4{,}8$ ft

$d = 2{,}4$ ft

Ukuran baffle

$W = \frac{D_t}{12}$ Dimana : W : lebar baffle

$\text{Offset} = \frac{d}{2}$ D_t : diameter tangki

d : diameter impeller

(Walas, 1990, pp. 287)

Sehingga : $W = \frac{4{,}8 \text{ ft}}{12} = 0{,}4 \text{ ft}$

$\text{Offset} = \frac{2{,}4 \text{ ft}}{2} = 1{,}2 \text{ ft}$

Jumlah baffle = 4 buah (Walas, 1990, pp. 287)

Perhitungan power pengaduk

$d = D_a = 2{,}4$ ft = 0,7315 m

N = 110 rpm = 1,8333 rps

$$N_{Re} = \frac{D_a^{\,2}.N.\rho}{\mu} = \frac{(0{,}7315\,m)^2.1{,}8333\ rps.987{,}1111\,kg/m^3}{1074{,}3559.10^{-3}\ kg/m.s} = 901{,}4098$$

(Walas, 1990, pp. 290)

Untuk Flat six-blade turbine with disk (Walas, 1990, pp. 292, Fig. 10.6) :

$N_P = 5$

$P = N_P \cdot \rho \cdot N^3 \cdot D_a$ (Walas, 1990, pp. 292, Fig. 10.6)

$P = 5 \cdot 987{,}1111\ kg/m^3 \cdot 1{,}8333\ rps \cdot 0{,}7315\ m$

P = 6619,2530 Watt = 8,8730 hp

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$Power = \frac{8{,}8730\ hp}{0{,}85} = 10{,}4388\ hp \approx 11\ hp$$

Perancangan jaket pemanas dan koil

L = d = 2,4 ft

N = 110 rpm = 6600 rph

$\rho_{campuran} = 61{,}6407\ lb/ft^3$

μ_{steam} pada 148°C = 1,4762 cp

$$T_{masuk\ campuran} = X_{wet\ ossein} \cdot (T_{wet\ ossein}) + X_{H_2O} \cdot (T_{H_2O}) + X_{larutan\ H_3PO_4} \cdot (T_{larutan\ H_3PO_4}) + X_{campuran\ bahan\ masuk\ J-175} \cdot (T_{campuran\ bahan\ masuk\ J-175})$$

$$T_{masuk\ campuran} = 0{,}4499 . 30{,}4°C + 0{,}4499 . 30°C + 2{,}8503.10^{-4} . 30°C + 0{,}1 . 65°C$$

$$T_{masuk\ campuran} = 33{,}7°C = 92{,}6°F$$

Diambil k = k untuk air karena komponen terbesar adalah air pada T = 33,7°C = 92,6°F, maka :

$$k = 0{,}3588 \frac{\text{Btu}}{\text{jam.ft}^2 . \frac{°F}{ft}}$$ (Kern, 1965, pp. 800)

Cp protein = 3,18 kJ / kmol . K = $4{,}4544.10^{-4}$ kJ / kg . K

Cp lemak = 2,85 kJ / kmol . K = $5{,}2876.10^{-3}$ kJ / kg . K

(Geankoplis, 1993, pp. 889, A.4-1)

Cp H_2O (T = 30°C) = 4,181 kJ / kg . K

€p H_2O (T = 30,4°C)= 4,1816 kJ / kg . K

Cp H_2O (T = 65°C) = 4,1903 kJ / kg . K

(Geankoplis, 1993, pp. 856, A.2-5)

Cp H_3PO_4 = 232,9133 kJ / kmol . K = 2,3767 kJ / kg . K

(Perry, 1999)

Menghitung Cp campuran

Dari J – 163

$X_{protein}$ = 0,1160

$X_{lemak} = 3{,}9996.10^{-3}$

X_{H_2O} = 0,8800

$$Cp_{wet\ ossein} = X_{protein} \cdot (Cp_{protein}) + X_{lemak} \cdot (Cp_{lemak}) + X_{H_2O} \cdot (Cp_{H_2O})$$

$$Cp_{wet\ ossein} = 01160.4{,}4544.10^{-4} \frac{kJ}{kg.K} + 3{,}9996.10^{-3}.5{,}2876.10^{-3} \frac{kJ}{kg.K}$$

$$+ 0{,}8800.4{,}1816 \frac{kJ}{kg.K}$$

$$Cp_{wet\ ossein} = 3{,}6799 \frac{kJ}{kg.K}$$

$$X_{wet\ ossein} = 0{,}4499$$

Dari WD

$$X_{H_2O} = 0{,}4499$$

Dari F – 176

$$X_{H_3PO_4} = 0{,}85$$

$$X_{H_2O} = 0{,}15$$

$$Cp_{larutan\ H_3PO_4} = X_{H_3PO_4} \cdot (Cp_{H_3PO_4}) + X_{H_2O} \cdot (Cp_{H_2O})$$

$$Cp_{larutan\ H_3PO_4} = 0{,}85.2{,}3767.10^{-4} \frac{kJ}{kg.K} + 0{,}15.4{,}181 \frac{kJ}{kg.K}$$

$$Cp_{larutan\ H_3PO_4} = 2{,}6473 \frac{kJ}{kg.K}$$

$$X_{larutan\ H_3PO_4} = 2{,}8503.10^{-4}$$

Dari J – 175

$$X_{protein} = 0{,}1160$$

$$X_{lemak} = 3{,}9914.10^{-3}$$

$X_{H_2O} = 0{,}8800$

$Cp_{wet\ ossein} = X_{protein} \cdot (Cp_{protein}) + X_{lemak} \cdot (Cp_{lemak}) + X_{H_2O} \cdot (Cp_{H_2O})$

$$Cp_{wet\ ossein} = 0{,}1160 . 4{,}4544 . 10^{-4} \frac{kJ}{kg.K} + 3{,}9914 . 10^{-3} . 5{,}2876 . 10^{-3} \frac{kJ}{kg.K} + 0{,}88 . 4{,}1903 \frac{kJ}{kg.K}$$

$Cp_{wet\ ossein} = 3{,}6874 \frac{kJ}{kg.K}$

$X_{wet\ ossein} = 0{,}4999$

$X_{H_3PO_4} = 5{,}6988 . 10^{-4}$

$X_{H_2O} = 0{,}9994$

$Cp_{larutan\ H_3PO_4} = X_{H_3PO_4} \cdot (Cp_{H_3PO_4}) + X_{H_2O} \cdot (Cp_{H_2O})$

$$Cp_{larutan\ H_3PO_4} = 5{,}6988 . 10^{-4} . 2{,}3767 \frac{kJ}{kg.K} + 0{,}9994 . 4{,}1903 \frac{kJ}{kg.K}$$

$Cp_{larutan\ H_3PO_4} = 4{,}3206 \frac{kJ}{kg.K}$

$X_{larutan\ H_3PO_4} = 0{,}5001$

$Cp_{total\ J-175} = X_{wet\ ossein} \cdot (Cp_{wet\ ossein}) + X_{larutan\ H_3PO_4} \cdot (Cp_{larutan\ H_3PO_4})$

$$Cp_{total\ J-175} = 0{,}4999 . 3{,}6874 \frac{kJ}{kg.K} + 0{,}5001 . 4{,}3206 \frac{kJ}{kg.K}$$

$Cp_{total\ J-175} = 4{,}0041 \frac{kJ}{kg.K}$

$X_{total\ J-175} = 0{,}1000$

$$Cp_{campuran} = X_{wet\ ossein} \cdot \left(Cp_{wet\ ossein}\right) + X_{H_2O} \cdot \left(Cp_{H_2O}\right) + X_{larutan\ H_3PO_4} \cdot \left(Cp_{larutan\ H_3PO_4}\right)$$
$$+ X_{total\ J-175} \cdot \left(Cp_{total\ J-175}\right)$$

$$Cp_{campuran} = 0,4499.3,6799 \frac{kJ}{kg.K} + 0,4499.4,181 \frac{kJ}{kg.K} + 2,8503.10^{-4}.2,6473 \frac{kJ}{kg.K}$$
$$+ 0,1.4,0041 \frac{kJ}{kg.K}$$

$$Cp_{campuran} = 3,9375 \frac{kJ}{kg.K} = 0,9404 \frac{Btu}{lb.^\circ F}$$

Dari Perhitungan Neraca Panas Appendix B diperoleh data sebagai berikut :

- Q_{suplai} = 533759,20 kJ = 505904,1167 Btu
- Suhu bahan keluar ke Centrifugal Separator H – 172 = 75°C = 167°F

$$N_{Re} = \frac{L^2 . N . \rho_{campuran}}{\mu_{campuran}} = \frac{(2,4\ ft)^2 . 6600\ rph . 61,6407\ lb/ft^3}{1074,3559\ cp . 2,4191 \frac{lb}{ft.h.cp}} = 901,6382$$

<u>Asumsi</u> : $\mu = \mu_W = \mu_{steam}$ = 1,4762 cp (T = 148°C)

(Geankoplis, 1993, pp. 862, A.2-11)

J untuk jaket = 48

J untuk koil = 80

(Kern, 1965, pp. 718, Fig. 20.2)

$$\left(\frac{C_P.\mu}{k}\right)^{1/3} = \left(\frac{0{,}9404\,\frac{Btu}{lb.^\circ F}\,.\,1{,}4762\ cp\,.\,2{,}4191\,\frac{lb}{ft.jam.cp}}{0{,}3588\,\frac{Btu}{jam.ft^2\,\frac{^\circ F}{ft}}}\right)^{1/3} = 2{,}1075$$

$$\left(\frac{\mu_{campuran}}{\mu_W}\right)^{0,14} = 1$$

Steam → h_{oi} = 1500 Btu / (jam) (ft^2) (°F) (Kern, 1965, pp. 719)

Jaket pemanas

$$h_{i\,jaket} = J_{jaket}\,.\frac{k}{D_i}.\left(\frac{C_P.\mu}{k}\right)^{1/3}.\left(\frac{\mu}{\mu_W}\right)^{0,14}$$ (Kern, 1965, pp. 112, eq. 6.15b)

$$h_{i\,jaket} = 48.\frac{0{,}3588\,\frac{Btu}{jam.ft^2.\frac{^\circ F}{ft}}}{4{,}8\,ft}.2{,}1075.1$$

$$h_{i\,jaket} = 7{,}5616\,\frac{Btu}{jam.ft^2.^\circ F}$$

$$U_C = \frac{h_i.h_{oi}}{h_i + h_{oi}} = \frac{7{,}5616\,\frac{Btu}{jam.ft^2.^\circ F}.1500\,\frac{Btu}{jam.ft^2.^\circ F}}{(7{,}5616+1500)\,\frac{Btu}{jam.ft^2.^\circ F}} = 7{,}5236\,\frac{Btu}{jam.ft^2.^\circ F}$$

(Kern, 1965, pp. 121, eq. 6.38)

Rd = 0,001 (Kern, 1965, pp. 845, table 12)

$$h_d = \frac{1}{0{,}001} = 1000$$

$$U_D = \frac{U_C . h_d}{U_C + h_d} = \frac{7{,}5236 \frac{Btu}{jam.ft^2.^\circ F}.1000}{7{,}5236 \frac{Btu}{jam.ft^2.^\circ F} + 1000} = 7{,}4675$$

(Kern, 1965, pp. 107, eq. 6.10)

A = luas sisi liquida + luas kerucut

$$= \pi \,.\, D_{tangki} \,.\, H_L + \pi \,.\, \left[\left(\frac{1}{2} D_{tangki}\right)^2 + h^2\right]$$

$$= \pi \,.\, 4{,}8 \text{ ft} \,.\, 4{,}1037 \text{ ft} + \pi \,.\, \left[(2{,}4 \text{ ft})^2 + (4{,}3267 \text{ ft})^2\right]$$

$= 138{,}8703 \text{ ft}^2$

Q $= U_D \,.\, A \,.\, \Delta T$

$= 7{,}4675 \,.\, 138{,}8703 \,.\, (298{,}4 - 167)$

= 136263,0070 Btu

$Q_{sisa} = Q_{suplai} - Q$ = 505904,1167 Btu – 136263,0070 Btu = 369641,1098 Btu

Koil

Trial ukuran pipa coil = 1/4 in, sch. 40

Do = 0,540 in

Di = 0,364 in = 0,0303 ft

a" = $0{,}141 \text{ ft}^2/\text{ft}$

(Kern, 1965, pp. 844, table 11)

$$h_{i\,koil} = J_{koil} \cdot \frac{k}{D_i} \cdot \left(\frac{C_P . \mu}{k}\right)^{1/3} \cdot \left(\frac{\mu}{\mu_W}\right)^{0,14}$$ (Kern, 1965, pp. 112, eq. 6.15b)

$$h_{ikoil} = 80.\frac{0,3588\dfrac{Btu}{jam.ft^2.\dfrac{°F}{ft}}}{0,0303\ ft}.2,1075.1$$

$$h_{ikoil} = 1994,2617\frac{Btu}{jam.ft^2.°F}$$

$$U_C = \frac{h_i.h_{oi}}{h_i + h_{oi}} = \frac{1994,2617\dfrac{Btu}{jam.ft^2.°F}.1500\dfrac{Btu}{jam.ft^2.°F}}{(1994,2617+1500)\dfrac{Btu}{jam.ft^2.°F}} = 856,0871\frac{Btu}{jam.ft^2.°F}$$

(Kern, 1965, pp. 121, eq. 6.38)

Rd = 0,0005 (Kern, 1965, pp. 845, table 12)

$$h_d = \frac{1}{0,0005} = 2000$$

$$U_D = \frac{U_C.h_d}{U_C + h_d} = \frac{856,0871\dfrac{Btu}{jam.ft^2.°F}.2000}{856,0871\dfrac{Btu}{jam.ft^2.°F} + 2000} = 599,4825$$

(Kern, 1965, pp. 107, eq. 6.10)

$$A = \frac{Q_{sisa}}{U_D.\Delta T} = \frac{369641,1098}{599,4825.(298,4-167)} = 6,4224\ ft^2$$

Dipakai copper OD linear dengan mean coil diameter = 3 ft

External surface / lin ft = 0,1309 ft^2 / ft (Kern, 1965, pp. 843, table 10)

Per turn = $\pi \times 3 \times 0,1309 = 1,2342\ ft^2$

$$\text{Turns} = \frac{6{,}4224\ ft^2}{1{,}2342\ ft^2} = 5{,}2037\ \text{turns} \approx 6\ \text{turns}$$

$$L = \frac{A_{coil}}{a''} = \frac{6{,}4224\ ft^2}{0{,}141\ ft^2/ft} = 60{,}5885\ ft$$

$$D_C = 0{,}65 \times D_{tangki}$$

$$D_C = 0{,}65 \times 4{,}8\ ft$$

$$D_C = 3{,}12\ ft$$

Dimana : D_C = diameter koil

$$n_c = \frac{L}{\pi . D_C} = \frac{60{,}5885\ ft}{\pi . 3{,}12\ ft} = 6{,}1789\ \text{buah} \approx 7\ \text{buah}$$

Spasi koil (sc) diambil 5 in, maka :

hc = ((nc – 1) . (sc + Do)) + Do

hc = ((7 – 1) . (5 + 0,540) in) + 0,540 in

= 33,78 in = 2,8150 ft

Pengecekan :

Tinggi liquida bagian silinder (H_L) = 4,1037 ft, dan hc < H_L (memenuhi)

19. Tangki Umpan H_3PO_4 (F – 176)

Fungsi : Untuk tempat penampungan larutan H_3PO_4

Tipe : Tangki silinder dengan bagian bawah dan tutup atas berbentuk datar (flat-bottomed dan flat-head)

Dasar pemilihan : cocok digunakan untuk menampung bahan yang berbentuk liquid, designnya sederhana dan harganya murah

Jumlah : 1 buah

Perhitungan :

Suhu = 30°C

Massa H_3PO_4 = 0,68 kg / jam

Massa H_2O = 0,12 kg / jam

Massa larutan H_3PO_4 = 0,80 kg

ρ H_3PO_4 = 1,834 kg / lt = 114,5252 lb / ft³ (Perry, 1999, 2-101)

ρ H_2O pada 30°C = 0,99568 kg / lt = 62,1758 lb / ft³

(Geankoplis, 1993, pp.855, A.2-3)

$$X \text{ larutan } H_3PO_4 = \frac{\text{Massa } H_3PO_4}{\text{Massa larutan } H_3PO_4} = \frac{0{,}68 \text{ kg}}{0{,}80 \text{ kg}} = 0{,}85$$

$$X\, H_2O = \frac{\text{Massa } H_2O}{\text{Massa larutan } H_3PO_4} = \frac{0{,}12 \text{ kg}}{0{,}80 \text{ kg}} = 0{,}15$$

$$\rho_{campuran} = \frac{1}{X_{H_3PO_4}\dfrac{1}{\rho_{H_3PO_4}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry,1999)

$$\rho_{campuran} = \frac{1}{0{,}85\dfrac{1}{114{,}5252 \text{ lb/ft}^3} + 0{,}15\dfrac{1}{62{,}1758 \text{ lb/ft}^3}}$$

$$\rho_{campuran} = 101{,}6833 \text{ lb/ft}^3 = 1{,}6283 \text{ kg/m}^3$$

Tangki dirancang untuk menyimpan larutan H_3PO_4 selama 7 hari.

Volume larutan H_3PO_4 in $= \dfrac{\text{massa total masuk}}{\rho_{campuran}}$

$= \dfrac{0,8\ kg/jam.7\,hari.24\,jam/hari}{1,6283\ kg/lt}$

$= 1,3218\ lt = 0,0467\ ft^3$

Asumsi : Ruang kosong = 20 % volume tangki

Volume tangki $= \dfrac{100\%}{80\%} 0,0467\ ft^3$

$= 0,0583\ ft^3$

$\dfrac{H}{D} = 1$, sehingga : Volume tangki $= \dfrac{\pi}{4} . D^2 . H$

$0,0583\ ft^3 = \dfrac{\pi}{4} . D^2 . D$

$D^3 = 0,0743\ ft^3$

$D = 0,4203\ ft \approx 0,5\ ft = 0,1524\ m$

$H = 0,5\ ft = 0,1524\ m$

Bahan konstruksi : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \dfrac{1}{8}\ in$

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$$0{,}0467 \text{ ft}^3 = \frac{\pi}{4} . D^2 . H_l$$

$$0{,}0467 \text{ ft}^3 = \frac{\pi}{4} . (0{,}5 \text{ ft})^2 . H_l$$

$$H_l = 0{,}2376 \text{ ft}$$

$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

$$t_S = \frac{101{,}6833 \text{ lb/ft}^3 . (0{,}2376 \text{ ft}) . (12 . 0{,}5) \text{ in}}{2 . 18750 \text{ lb/in}^2 . 0{,}80 . (144 \text{ in}^2/\text{ft}^2)} + \frac{1}{8} \text{ in}$$

$t_S = 0{,}1250$ → diambil t_S $\frac{3}{16}$ in

Tutup bawah berbentuk datar

Tebal tutup flat-bottomed = tebal shell = $\frac{3}{16}$ in

Tutup atas berbentuk datar

Tebal tutup flat-head = tebal shell = $\frac{3}{16}$ in

H total = tebal head + tinggi silinder + tebal tutup bawah + jarak pemasangan pipa

= 0,1875 ft + 0,5 ft + 0,1875 ft + 3 ft

= 3,8750 ft

20. Screw Conveyor (J – 163)

Fungsi : mengangkut wet ossein dari Filter Press H – 162 menuju ke Ekstraktor H – 170

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

Perhitungan :

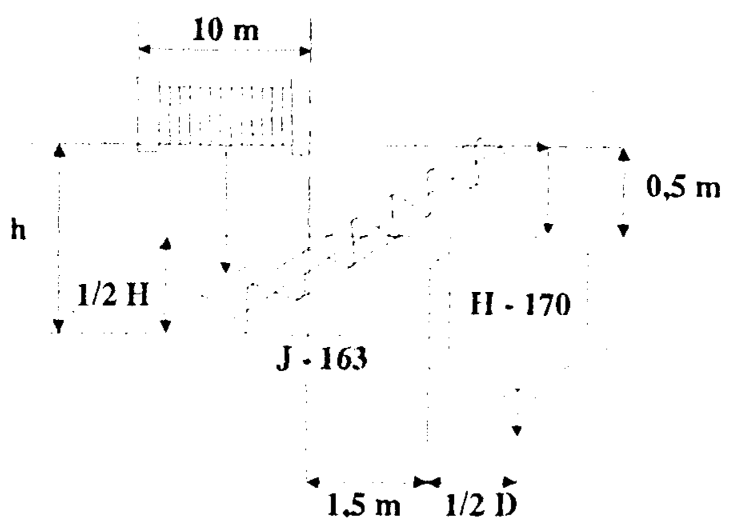
Kapasitas = 1262,63 kg / jam

Jarak Filter Press ke Ekstraktor

= ½ panjang Filter Press + 1,5 m + ½ diameter Ekstraktor H – 170

= ½ . 10 m + 1,5 m + ½ . 1,4631 m

= 7,2315 m = 23,7252 ft



h = ½ H shell + ½ m

H = 0,5 . 2,1946 + ½ m

H = 1,5973 m = 5,2404 ft

Panjang Screw Conveyor J – 163 = $\sqrt{5,2404^2 + 23,7252^2}$ ft = 24,2971 ft = 25 ft

Sudut Screw Conveyor J – 163 :

$$\tan x = \frac{5,2404 \text{ ft}}{23,7252 \text{ ft}} = 0,2209$$

x = 12,46°

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft³ (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft³

(www.usd.edu/biol/courses/cellthies/cpa3answers.html)

ρ H_2O pada 31°C = 0,9952 kg / lt = 62,1459 lb / ft³

(Geankoplis, 1993, pp.855, A.2-3)

Protein = 146,46 kg → $X_{protein} = \frac{\text{Massa protein}}{\text{Massa wet ossein}} = \frac{146,46 \text{ kg}}{1262,63 \text{ kg}} = 0,1160$

Lemak = 5,05 kg → $X_{lemak} = \frac{\text{Massa lemak}}{\text{Massa wet ossein}} = \frac{5,05 \text{ kg}}{1262,63 \text{ kg}} = 3,9996.10^{-3}$

H_2O = 1111,12 kg → $X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \frac{1111,12 \text{ kg}}{1262,63 \text{ kg}} = 0,8800$

Wet ossein = 1262,63 kg

$$\rho_{wet\ ossein} = \frac{1}{X_{protein}\dfrac{1}{\rho_{protein}} + X_{lemak}\dfrac{1}{\rho_{lemak}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{wet\ ossein} = \frac{1}{0{,}1160\dfrac{1}{0{,}8955\,kg/lt} + 3{,}9996.10^{-3}\dfrac{1}{0{,}9290\,kg/lt} + 0{,}88\dfrac{1}{0{,}9952\,kg/lt}}$$

$$\rho_{wet\ ossein} = 0{,}9892\,kg/lt = 61{,}7681\,lb/ft^3 = 989{,}1505\,kg/m^3$$

$$\text{Massa yang dipindahkan} = 1262{,}63\frac{kg}{jam}.2{,}205\frac{lb}{kg}.\frac{1\,jam}{60\,menit} = 46{,}4017\,lb/menit$$

$$\text{Volume yang dipindahkan} = \frac{1262{,}63\,kg/jam}{0{,}9892\,kg/lt} = 1276{,}4791\,lt/jam = 45{,}0734\,ft^3/jam$$

Maka kapasitas Screw Conveyor J – 163 = 45,0734 ft^3 / jam

Waktu pemindahan = 60 menit

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

Power :

$$hp = \frac{Co.Ca.L}{33000}$$, dimana : Co : koefisien (untuk wet ossein Co = 1,3)

Ca : kapasitas Screw Conveyor (= 46,4017 lb/menit)

L : panjang Screw Conveyor (= 25 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3\,.46{,}4017\,lb/menit.25\,ft}{33000} = 0{,}0457\,hp$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$hp = \frac{0{,}0457\ hp}{0{,}8} = 0{,}0571$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0571 hp × 2 = 0,1142 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

21. Tangki Umpan $Ca(OH)_2$ (F – 182)

Fungsi : Untuk tempat penampungan $Ca(OH)_2$

Tipe : Tangki silinder dengan bagian bawah konis dan tutup atas berbentuk datar (flat)

Dasar pemilihan : cocok digunakan untuk menampung bahan yang berbentuk solid

Jumlah : 1 buah

Perhitungan :

Suhu = 30°C

Massa $Ca(OH)_2$ = 0,78 kg = $1{,}0541 . 10^{-2}$ kmol

ρ $Ca(OH)_2$ = 2,2 kg / lt = 137,3803 lb / ft^3 (Perry, 1999, 2-101)

Tangki dirancang untuk menyimpan $Ca(OH)_2$ selama 7 hari.

$$\text{Volume } Ca(OH)_2 = \frac{\text{massa } Ca(OH)_2}{\rho_{Ca(OH)_2}}$$

$$= \frac{0{,}78\ kg/jam . 7\ hari . 24\ jam/hari}{2{,}2\ kg/lt}$$

$= 59{,}5636\ lt/hari = 2{,}1032\ ft^3/hari$

Asumsi : Ruang kosong = 20 % volume tangki

Volume tangki $= \frac{100\%}{80\%} 2{,}1032\ ft^3$

$= 2{,}6290\ ft^3$

$\frac{H}{D} = 1$, sehingga : *Volume tangki* $= \frac{\pi}{4} . D^2 . H$

$2{,}6290\ ft^3 = \frac{\pi}{4} . D^2 . D$

$D^3 = 3{,}3461\ ft^3$

$D = 1{,}4957\ ft \approx 1{,}5\ ft = 0{,}4572\ m$

$H = 1{,}5\ ft = 0{,}4572\ m$

Bahan konstruksi : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}\ in$

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$$2{,}1032\ ft^3 = \frac{\pi}{4}.D^2.\ H_l$$

$$2{,}1032\ ft^3 = \frac{\pi}{4}.(1{,}5\ ft)^2.\ H_l$$

$$H_l = 1{,}1897\ ft$$

$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

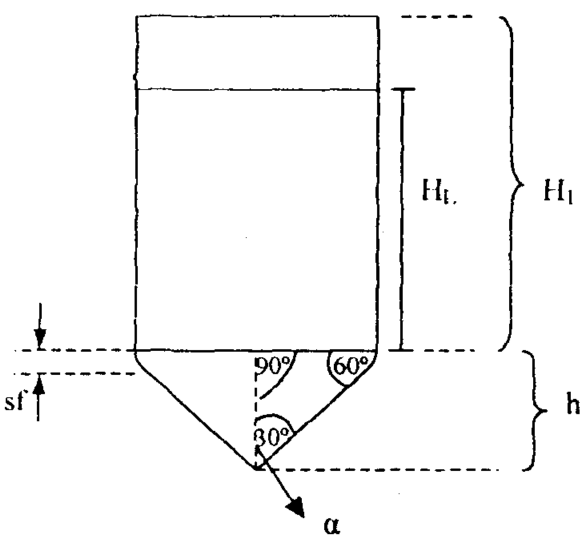
$$t_S = \frac{137{,}3803\ lb/ft^3\ .\ (1{,}1897\ ft).\ (12\ .1{,}5)\ in}{2.18750\ lb/in^2\ .0{,}80.(144\ in^2/ft^2)} + \frac{1}{8}\ in$$

t_S = 0,1257 in → diambil t_S $\frac{3}{16}$ in

Penentuan tebal head (t_h)

Tutup atas digunakan flat head (tutup atas berbentuk datar) dengan tebal diambil sama dengan tebal shell yaitu $\frac{3}{16}$ in.

Penentuan tebal konis (t_k)



sf = 2 in

$$\tan x = \frac{h - sf}{0{,}5.D} \quad ; \; h : \text{tinggi konis, ft}$$

$$h = \tan 60^{o}.0{,}5.1{,}5\,ft + \frac{2}{12}\,ft$$

h = 1,4670 ft

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.H$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(1{,}5\ ft)^2.1{,}4670\ ft$$

$$= 0{,}8645\ ft^3$$

<u>Mencari tinggi liquida pada shell (H_L)</u>

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$2{,}1032\ ft^3 - 0{,}8645\ ft^3 = \frac{1}{4}.\pi.(1{,}5\ ft)^2.H_L$$

$$H_L = 0{,}7007\ ft$$

<u>Tinggi liquid total (H)</u>

$H = H_L + h$

$H = 0{,}7007\ ft + 1{,}4670\ ft$

$H = 2{,}1677\ ft \approx 2{,}2\ ft$

$$P_{hidrostatis} = \frac{\rho.H}{144} = \frac{137{,}3803\ lb/ft^3.2{,}2\ ft}{144\ in^2/ft^2} = 2{,}0989\ psia$$

$$t_k = \frac{P.D}{2.\cos\alpha(f.E - 0{,}6.P)} + C$$ (Brownell & Young, 1959, pp.254, eq. 13.1)

$$t_k = \frac{2{,}0989\ lb/in^2.1{,}5.12\ in}{2.\cos 30^\circ(18750\ lb/in^2.0{,}8 - 0{,}6.2{,}0989\ lb/in^2)} + \frac{1}{8}\ in$$

$t_k = 0{,}1265\ in$ → diambil $t_k = \frac{3}{16}\ in$

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tebal head + tinggi silinder + tinggi konis + jarak pemasangan pipa

= 0,1875 ft + 1,5 ft + 1,4670 ft + 3 ft

= 6,1545 ft

22. Centrifugal Separator (H – 172)

Fungsi : untuk memisahkan wet ossein dan gelatin

Tipe : Centrifuge sedimentation

Jumlah : 1 buah

Dasar pemilihan : dapat digunakan untuk memisahkan fase solid dan liquid, sederhana, dapat digunakan untuk kapasitas besar, serta dapat digunakan untuk liquid yang viskos

Perhitungan :

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft^3 (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft^3

(www.usd.edu/biol courses/cellthies cpa3answers.html)

ρ H_2O pada 75°C = 0,9742 kg / lt = 60,8345 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

ρ H_3PO_4 = 1,834 kg / lt = 114,5252 lb / ft^3 (Perry, 1999, 2-101)

Wet ossein

Protein = 16,28 kg → $X_{protein} = \dfrac{\text{Massa protein}}{\text{Massa wet ossein}} = \dfrac{16,28\ \text{kg}}{140,3\ \text{kg}} = 0,1160$

Lemak = 0,56 kg → $X_{lemak} = \dfrac{\text{Massa lemak}}{\text{Massa wet ossein}} = \dfrac{0,56\ \text{kg}}{140,3\ \text{kg}} = 3,9914.10^{-3}$

H_2O = 123,46 kg → $X_{H_2O} = \dfrac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \dfrac{123,46\ \text{kg}}{140,3\ \text{kg}} = 0,8800$

Wet ossein = 140,3 kg

$$\rho_{wet\ ossein} = \frac{1}{X_{protein}\dfrac{1}{\rho_{protein}} + X_{lemak}\dfrac{1}{\rho_{lemak}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{wet\ ossein} = \frac{1}{0,1160\dfrac{1}{0,8955\ \text{kg/lt}} + 3,9914.10^{-3}\dfrac{1}{0,9290\ \text{kg/lt}} + 0,88\dfrac{1}{0,9742\ \text{kg/lt}}}$$

$\rho_{wet\ ossein} = 0,9642\ \text{kg/lt} = 60,2088\ \text{lb/ft}^3$

Gelatin

Protein = 146,46 kg → $X_{protein} = \dfrac{\text{Massa protein}}{\text{Massa wet ossein}} = \dfrac{146,46\ \text{kg}}{1262,63\ \text{kg}} = 0,1160$

Lemak = 5,05 kg → $X_{lemak} = \dfrac{\text{Massa lemak}}{\text{Massa wet ossein}} = \dfrac{5,05\ \text{kg}}{1262,63\ \text{kg}} = 3,9996.10^{-3}$

$H_2O = 1111{,}12\ kg \rightarrow X_{H_2O} = \dfrac{Massa\ H_2O}{Massa\ wet\ ossein} = \dfrac{1111{,}12\ kg}{1262{,}63\ kg} = 0{,}8800$

Gelatin = 1262,63 kg

$$\rho_{gelatin} = \frac{1}{X_{protein}\dfrac{1}{\rho_{protein}} + X_{lemak}\dfrac{1}{\rho_{lemak}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{gelatin} = \frac{1}{0{,}1160\dfrac{1}{0{,}8955\ kg/lt} + 3{,}9996.10^{-3}\dfrac{1}{0{,}9290\ kg/lt} + 0{,}88\dfrac{1}{0{,}9742\ kg/lt}}$$

$\rho_{gelatin} = 0{,}9642\ kg/lt = 60{,}2090\ lb/ft^3$

Larutan H_3PO_4

$H_3PO_4 = 0{,}76\ kg \rightarrow X_{H_3PO_4} = \dfrac{Massa\ H_3PO_4}{Massa\ lar\ H_3PO_4} = \dfrac{0{,}76\ kg}{1403{,}81\ kg} = 5{,}4138.10^{-4}$

$H_2O = 1403{,}05\ kg \rightarrow X_{H_2O} = \dfrac{Massa\ H_2O}{Massa\ lar\ H_3PO_4} = \dfrac{1403{,}05\ kg}{1403{,}81\ kg} = 0{,}9995$

Larutan H_3PO_4 = 1403,81 kg

$$\rho_{lar.H_3PO_4} = \frac{1}{X_{H_3PO_4}\dfrac{1}{\rho_{H_3PO_4}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{lar.H_3PO_4} = \frac{1}{5{,}4318.10^{-4}\dfrac{1}{1{,}8340\ kg/lt} + 0{,}9995\dfrac{1}{0{,}9742\ kg/lt}}$$

$\rho_{lar.H_3PO_4} = 0{,}9744\ kg/lt = 60{,}8499\ lb/ft^3$

$$\rho_{campuran} = \frac{1}{X_{wet\ ossein}\frac{1}{\rho_{wet\ ossein}} + X_{gelatin}\frac{1}{\rho_{gelatin}} + X_{lar.H_3PO_4}\frac{1}{\rho_{lar.H_3PO_4}}} \quad \text{(Perry, 1999)}$$

$$\rho_{campuran} = \frac{1}{0{,}05\frac{1}{60{,}2088\ lb/ft^3} + 0{,}4499\frac{1}{60{,}2090\ lb/ft^3} + 0{,}5002\frac{1}{60{,}8499\ lb/ft^3}}$$

$$\rho_{campuran} = 60{,}5279\ lb/ft^3 = 969{,}2896\ kg/m^3$$

$$\text{Kapasitas} = 2806{,}74\ kg/jam$$

$$= \frac{2806{,}74\ kg/jam}{969{,}2896\ kg/m^3}\cdot\frac{1\ jam}{3600\ s}$$

$$= 8{,}0435.10^{-4}\ m^3/s$$

Power $= 1000$. kapasitas (Ulrich, 1984, pp. 220, table 4-23)

$= 1000 . 8{,}0435.10^{-4}$

$= 0{,}8044\ kW = 1{,}0787\ hp \approx 1{,}5\ hp$

Bahan konstruksi : carbon steel

23. Mixer (M – 180)

Fungsi : untuk memisahkan H_3PO_4 dari gelatin dengan cara mereaksikan H_3PO_4 dengan $Ca(OH)_2$

Tipe : Tangki silinder dengan bagian bawah berbentuk konis, tutup atas berbentuk flat-head, dilengkapi dengan baffle dan pengaduk tipe flat six-blade turbine with disk

Dasar pemilihan : cocok digunakan untuk mencampur dan menampung bahan yang berbentuk slurry, cocok digunakan untuk operasi pada tekanan rendah

Jumlah : 1 buah

Perhitungan :

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft^3 (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft^3

(www.usd.edu/biol/courses/cellthies/cpa3answers.html)

ρ H_2O pada 35,2°C = 0,9939 kg / lt = 62,0647 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

ρ H_3PO_4 = 1,834 kg / lt = 114,5252 lb / ft^3 (Perry, 1999, 2-101)

ρ $Ca(OH)_2$ = 2,2 kg / lt = 137,3803 lb / ft^3 (Perry, 1999, 2-101)

Gelatin

Protein = 146,46 kg → $X_{protein} = \dfrac{\text{Massa protein}}{\text{Massa wet ossein}} = \dfrac{146,46\text{ kg}}{1262,63\text{ kg}} = 0,1160$

Lemak = 5,05 kg → $X_{lemak} = \dfrac{\text{Massa lemak}}{\text{Massa wet ossein}} = \dfrac{5,05\text{ kg}}{1262,63\text{ kg}} = 3,9996.10^{-3}$

H_2O = 1111,12 kg → $X_{H_2O} = \dfrac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \dfrac{1111,12\text{ kg}}{1262,63\text{ kg}} = 0,8800$

Gelatin 1262,63 kg

$$\rho_{gelatin} = \frac{1}{X_{protein}\dfrac{1}{\rho_{protein}} + X_{lemak}\dfrac{1}{\rho_{lemak}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}} \quad \text{(Perry, 1999)}$$

$$\rho_{gelatin} = \frac{1}{0{,}1160\dfrac{1}{0{,}8955\,kg/lt} + 3{,}9996.10^{-3}\dfrac{1}{0{,}9290\,kg/lt} + 0{,}88\dfrac{1}{0{,}9939\,kg/lt}}$$

$$\rho_{gelatin} = 0{,}9811\,kg/lt = 61{,}2667\ lb/ft^3$$

Larutan H_3PO_4

H_3PO_4 = 0,68 kg → $X_{H_3PO_4} = \dfrac{Massa\ H_3PO_4}{Massa\ lar\ H_3PO_4} = \dfrac{0{,}68\,kg}{1263{,}43\ kg} = 5{,}3822.10^{-4}$

H_2O = 1262,75 kg → $X_{H_2O} = \dfrac{Massa\ H_2O}{Massa\ lar\ H_3PO_4} = \dfrac{1262{,}75\,kg}{1263{,}43\ kg} = 0{,}9995$

Larutan H_3PO_4 = 1263,43 kg

$$\rho_{lar.H_3PO_4} = \frac{1}{X_{H_3PO_4}\dfrac{1}{\rho_{H_3PO_4}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}} \quad \text{(Perry, 1999)}$$

$$\rho_{lar.H_3PO_4} = \frac{1}{5{,}3822.10^{-4}\dfrac{1}{1{,}8340\ kg/lt} + 0{,}9995\dfrac{1}{0{,}9939\,kg/lt}}$$

$$\rho_{lar.H_3PO_4} = 0{,}9941\,kg/lt = 62{,}08\ lb/ft^3$$

Massa total H – 172 = 1262,63 kg + 1263,43 kg = 2526,06 kg

$$X_{gelatin} = \frac{Massa\ gelatin}{Massa\ total\ H-172} = \frac{1262{,}63\ kg}{2526{,}06\ kg} = 0{,}4998$$

$$X_{lar.H_3PO_4} = \frac{Massa\ lar.H_3PO_4}{Massa\ total\ H-172} = \frac{1263{,}43\ kg}{2526{,}06\ kg} = 0{,}5002$$

$$\rho_{total\ H-172} = \frac{1}{X_{gelatin}\dfrac{1}{\rho_{gelatin}} + X_{lar.H_3PO_4}\dfrac{1}{\rho_{lar.H_3PO_4}}}$$ (Perry, 1999)

$$\rho_{total\ H-172} = \frac{1}{0{,}4998\dfrac{1}{0{,}9811\ kg/lt} + 0{,}5002\dfrac{1}{0{,}9941\ kg/lt}}$$

$$\rho_{total\ H-172} = 0{,}9876\ kg/lt = 61{,}6708\ lb/ft^3$$

Massa $Ca(OH)_2$ dari F – 182 = 0,78 kg

$$\text{Volume total H} - 172 = \frac{2526{,}06\ kg}{0{,}9876\ kg/lt} = 2557{,}7973\ lt = 90{,}3177\ ft^3$$

$$\text{Volume } Ca(OH)_2 = \frac{0{,}78\ kg}{2{,}2\ kg/lt} = 0{,}3545\ lt = 0{,}0125\ ft^3$$

Volume total = 90,3177 ft^3 + 0,0125 ft^3 = 90,3302 ft^3

Asumsi : Ruang kosong = 20% volume tangki

$$\text{Volume tangki} = \frac{90{,}3302\ ft^3}{80\%} = 112{,}9128\ ft^3$$

$$\frac{H_1}{D} = 1{,}5 \quad \rightarrow H_1 = 1{,}5\ D$$

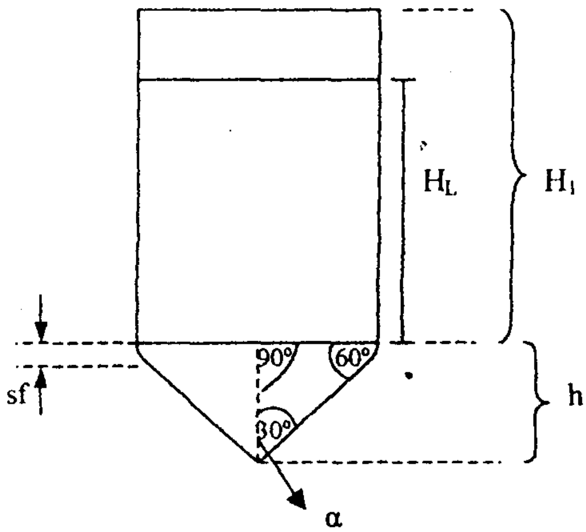
$$\text{Volume tangki} = \frac{\pi}{4}.D^2.H_1$$

$$112{,}9128\ ft^3 = \frac{\pi}{4}.D^2.1{,}5D$$

$$D^3 = 95{,}8048\ ft^3$$

$$D = 4{,}5758\ ft \approx 4{,}6\ ft = 1{,}4021\ m$$

$$H_1 = 6{,}9\ ft = 2{,}1031\ m$$



Perancangan konis

sf = 2 in (Brownell & Young, 1959, pp. 87, table 5.4)

Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$$\tan 60^\circ = \frac{h - sf}{0{,}5 . D} \rightarrow h = \tan 60^\circ . 0{,}5 . D + sf$$

$$h = \tan 60^\circ . 0{,}5 . 4{,}6 \text{ ft} + (2 / 12) \text{ ft}$$

$$h = 4{,}1543 \text{ ft}$$

$$\text{Volume konis} = \frac{1}{3} . \frac{1}{4} . \pi . D^2 . h$$

$$= \frac{1}{3} . \frac{1}{4} . \pi . (4{,}6 \text{ ft})^2 . 4{,}1543 \text{ ft}$$

$$= 7{,}3254 \text{ ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$90{,}33C \quad - 7{,}3254\ ft^3 = \frac{1}{4}.\pi.(4{,}6\ ft)^2.H_L$$

$$H_L = 4{,}9926\ ft$$

Tinggi liquid total (H)

$H = H_L + h$

$H = 4{,}9926\ ft + 4{,}1543\ ft$

$H = 9{,}1468\ ft \approx 9{,}2\ ft$

Penentuan tebal shell (t_S)

$$\text{Volume total} = \frac{1}{4}.\pi.D^2.H'$$

$$90{,}3302\ ft^3 = \frac{1}{4}.\pi.(4{,}6\ ft)^2.H'$$

$$H' = 5{,}4332\ ft$$

Bahan konstruksi :

Stainless steel SA – 240 Grade M tipe 316

$F_{allowable}$ (T = -20°C – 100°C) = 18750 lb / in^2 (T = 31,7°C)

(Brownell & Young, 1959, pp. 342, App. D, item 4)

Pengelasan menggunakan double welded butt joint → efisiensi = 80%

(Brownell & Young, 1959, pp. 254, table 13.2)

$$C = \frac{1}{8}$$

Mencari tebal shell (t_S)

$$t_S = \frac{\rho.H'.12D}{2.f.E.144} + C$$ (Brownell & Young, 1959, pp. 46, eq. 3.18)

$$t_S = \frac{61,6708 \text{ lb/ft}^3 .5,4332 \text{ ft}.12.4,6 \text{ in}}{2.18750 \text{ lb/in}^2 .0,80.144 \text{ in}^2/\text{ft}^2} + \frac{1}{8}$$

$$t_S = 0,1293 \text{ in} \quad \rightarrow \quad \text{diambil } t_S = \frac{3}{16} \text{ in}$$

Tutup atas berbentuk datar

Tebal flat-head = tebal shell = $\frac{3}{16}$ in

Mencari tebal konis (t_K)

$$P_{hidrostatik} = \frac{\rho.H}{144} = \frac{61,6708 \text{ lb/ft}^3 .9,2 \text{ ft}}{144 \text{ in}^2/\text{ft}^2} = 3,9401 \text{ lb/in}^2$$

Sudut konis = 60° → α = 30°

Untuk α ≤ 30° dapat dipakai rumus :

$$t_k = \frac{P.D}{2.\cos\alpha.(f.E - 0,6.P)} + C$$

(Brownell & Young, 1959, pp. 118, eq. 6.154)

$$t_k = \frac{3,9401 \text{ lb/in}^2 .4,6 \text{ ft}.12 \text{ in/ft}}{2.\cos 30°.(18750 \text{ lb/in}^2 .0,80 - 0,6.3,9401 \text{ lb/in}^2)} + \frac{1}{8}$$

$$t_k = 0,1334 \text{ in} \quad \rightarrow \quad \text{diambil } t_k = \frac{3}{16} \text{ in}$$

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tebal head + tinggi silinder + tinggi konis + jarak pemasangan pipa

= 0,1875 ft + 6,9 ft + 4,1543 ft + 3 ft

= 14,2418 ft

<u>Perancangan Pengaduk</u>

$$\frac{H_{bahan}}{D_{tangki}} = \frac{4,9926\ ft}{4,6\ ft} = 1,0853$$

μ wet ossein = 7500 cp (www.norlandprod.com/twchrpts/fishgelrpt.html)

μ H_2O pada 70°C = 0,4061 cp (Geankoplis, 1993, pp.855, A.2-4)

$$\mu_{lar.H_3PO_4}{}^{1/3} = X_{H_3PO_4} \cdot (\mu_{H_3PO_4})^{1/3} + X_{H_2O} \cdot (\mu_{H_2O})^{1/3}$$

$$\mu_{lar.H_3PO_4}{}^{1/3} = 5,3822.10^{-4}.(41,2\ cp)^{1/3} + 0,9995.(0,4061\ cp)^{1/3}$$

$$\mu_{lar.H_3PO_4} = 0,4085\ cp$$

$$\mu_{total\,H-172}{}^{1/3} = X_{gelatin} \cdot (\mu_{gelatin})^{1/3} + X_{lar.H_3PO_4} \cdot (\mu_{lar.H_3PO_4})^{1/3}$$

$$\mu_{total\,H-172}{}^{1/3} = 0,4998.(7500\ cp)^{1/3} + 0,5002.(0,4085\ cp)^{1/3}$$

$$\mu_{total\,H-172} = 1047,2813\ cp$$

$\mu_{campuran}$ = 1047,2813 cp

$\frac{H_{liquid}}{D_{tangki}} = 1,0853$

} Walas, 1990, pp.288 diperoleh :

Jumlah impeller = 2

Letak impeller 1 = D_t /3

Letak impeller 2 = (2/3) H

Letak impeller 1 = $\frac{D_t}{3} = \frac{4{,}6 \text{ ft}}{3} = 1{,}5333$ ft

Letak impeller 2 = $\frac{2}{3}$ H = $\frac{2}{3}$ 9,2 ft = 6,1333 ft

Ukuran impeller

$\frac{d}{D_t} = 0{,}3 - 0{,}6$; dimana : d : diameter impeller

D_t : diameter tangki

(Walas, 1990, pp. 287)

Dipilih $\frac{d}{D_t} = 0{,}5$, sehingga : d = 0,5 . 4,6 ft

d = 2,3 ft

Ukuran baffle

$W = \frac{D_t}{12}$ Dimana : W : lebar baffle

$\text{Offset} = \frac{d}{2}$ D_t : diameter tangki

d : diameter impeller

(Walas, 1990, pp. 287)

Sehingga : $W = \frac{4{,}6 \text{ ft}}{12} = 0{,}3833$ ft

$\text{Offset} = \frac{2{,}3 \text{ ft}}{2} = 1{,}15$ ft

Jumlah baffle = 4 buah (Walas, 1990, pp. 287)

Perhitungan power pengaduk

$d = D_a = 2,3 \text{ ft} = 0,7010 \text{ m}$

$N = 110 \text{ rpm} = 1,8333 \text{ rps}$

$$N_{Re} = \frac{D_a^2 . N . \rho}{\mu} = \frac{(0,7010 \text{ m})^2 . 1,8333 \text{ rps} . 987,5919 \text{ kg/m}^3}{1047,2813 . 10^{-3} \text{ kg/m.s}} = 849,6730$$

(Walas, 1990, pp. 290)

Untuk Flat six blade turbine with disk (Walas, 1990, pp. 292, Fig. 10.6) :

$N_P = 5$

$P = N_P . \rho . N^3 . D_a$ (Walas, 1990, pp. 292, Fig. 10.6)

$P = 5 . 987,5919 \text{ kg/m}^3 . (1,8333 \text{ rps})^3 . 0,7010 \text{ m}$

$P = 21331,4278 \text{ Watt} = 28,5944 \text{ hp}$

Efisiensi motor = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{28,5944 \text{ hp}}{0,80} = 35,7430 \text{ hp} \approx 36 \text{ hp}$$

24. Screw Conveyor (J – 181)

Fungsi : mengangkut $Ca(OH)_2$ dari angki Penampung F – 182 menuju ke Mixer M – 180

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

Perhitungan :

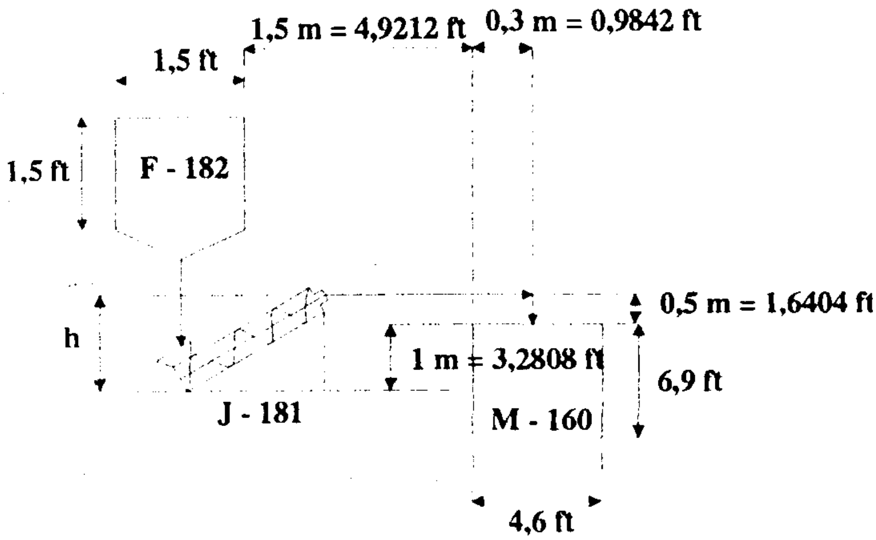
Kapasitas = 0,78 kg / jam

Jarak Tangki Umpan ke Mixer = ½ $D_{Tangki\ Umpan}$ + 1½ m + 0,3 m

= ½ . 1,5 ft + 4,9212 ft + 0,9842 ft

= 6,6554 ft

h = 3,2808 ft + 1,6404 ft = 4,9212 ft



Panjang Screw Conveyor J – 181 = $\sqrt{6{,}6554^2 + 4{,}9212^2}$ ft = 8,2773 ft ≈ 10 ft

Sudut Screw Conveyor J – 181 :

$$\tan x = \frac{4{,}9212 \text{ ft}}{6{,}6554 \text{ ft}} = 0{,}7394$$

$$x = 36{,}48^{\circ}$$

$\rho_{Ca(OH)_2} = 2,2\ kg/lt = 137,3803\ lb/ft^3$

$$\text{Massa yang dipindahkan} = 0,78\frac{kg}{jam}.2,205\frac{lb}{kg}.\frac{1\ jam}{60\ menit} = 0,0287\ lb/menit$$

$$\text{Volume yang dipindahkan} = \frac{0,78\ kg/jam}{2,2\ kg/lt} = 0,0130\ lt/jam = 0,3690\ ft^3/jam$$

Maka kapasitas Screw Conveyor J – 181 = 0,3690 ft^3 / jam

Waktu pemindahan = 60 menit

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

Power :

$hp = \frac{Co\ .Ca\ .L}{33000}$, dimana : Co : koefisien (untuk gelatin Co = 1,3)

Ca : kapasitas Screw Conveyor (= 0,0287 lb/menit)

L : panjang Screw Conveyor (= 10 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1,3\ .0,0287\ lb/menit.10\ ft}{33000} = 1,1292.10^{-5}\ hp$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{1,1292.10^{-5}\ hp}{0,8} = 1,4115.10^{-5}$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = $1{,}4115.10^{-5}$ hp × 2 = $2{,}8230.10^{-5}$ hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

25. Screw Conveyor (J – 175)

Fungsi : mengangkut wet ossein yang tidak terekstrak kembali ke Ekstraktor H – 170

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

Perhitungan :

Kapasitas = 280,68 kg / jam

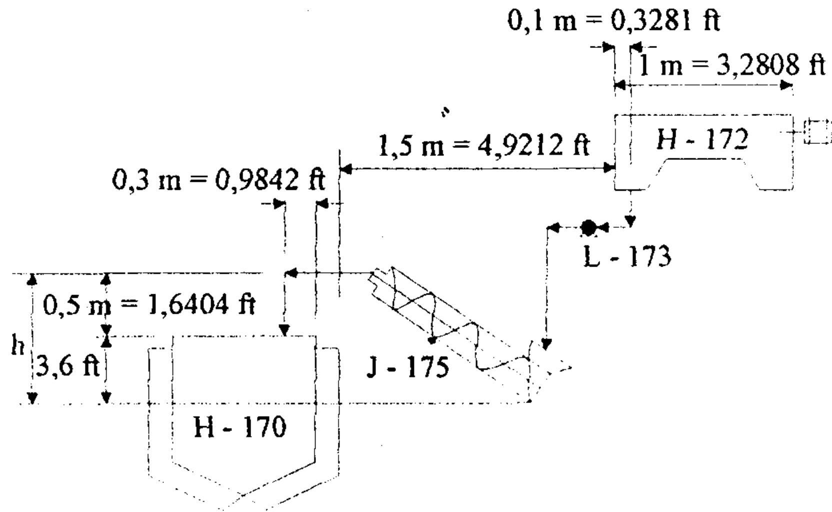
Jarak Ekstraktor ke H – 172 = 0,9842 ft + 4,9212 ft + 0,3281 ft

= 6,2335 ft

h = ½ tinggi shell Ekstraktor + 1,6404 ft

= ½ . 7,2 ft + 1,6404 ft

= 5,2404 ft



Panjang Screw Conveyor J – 175 = $\sqrt{6{,}2335^2 + 5{,}2404^2}$ ft = 8,1436 ft ≈ 10 ft

Sudut Screw Conveyor J – 175 :

$$\tan x = \frac{5{,}2404 \text{ ft}}{6{,}2335 \text{ ft}} = 0{,}8407$$

$$x = 40{,}0532°$$

Massa yang dipindahkan = $280{,}68 \frac{\text{kg}}{\text{jam}} . 2{,}205 \frac{\text{lb}}{\text{kg}} . \frac{1 \text{ jam}}{60 \text{ menit}} = 10{,}3150 \text{ lb/menit}$

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft^3 (www.cep4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft^3

(www.usd.edu/biol/courses/cellthies/cpa3answers.html)

ρ H_2O pada 70°C = 0,99781 kg / lt = 62,3088 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

$\rho\ H_3PO_4 = 1{,}834\ kg/lt = 114{,}5252\ lb/ft^3$ (Perry, 1999, 2-101)

Wet ossein

Protein $= 16{,}28\ kg \rightarrow X_{protein} = \dfrac{\text{Massa protein}}{\text{Massa wet ossein}} = \dfrac{16{,}28\ kg}{140{,}3\ kg} = 0{,}1160$

Lemak $= 0{,}56\ kg \rightarrow X_{lemak} = \dfrac{\text{Massa lemak}}{\text{Massa wet ossein}} = \dfrac{0{,}56\ kg}{140{,}3\ kg} = 3{,}9914.10^{-3}$

H_2O $= 123{,}46\ kg \rightarrow X_{H_2O} = \dfrac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \dfrac{123{,}46\ kg}{140{,}3\ kg} = 0{,}8800$

Wet ossein = 140,3 kg

$$\rho_{wet\ ossein} = \frac{1}{X_{protein}\dfrac{1}{\rho_{protein}} + X_{lemak}\dfrac{1}{\rho_{lemak}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{wet\ ossein} = \frac{1}{0{,}1160\dfrac{1}{0{,}8955\ kg/lt} + 3{,}9914.10^{-3}\dfrac{1}{0{,}9290\ kg/lt} + 0{,}88\dfrac{1}{0{,}99781\ kg/lt}}$$

$\rho_{wet\ ossein} = 0{,}9845\ kg/lt = 61{,}4757\ lb/ft^3$

Larutan H_3PO_4

H_3PO_4 = 0,08 kg $\rightarrow X_{H_3PO_4} = \dfrac{\text{Massa } H_3PO_4}{\text{Massa lar } H_3PO_4} = \dfrac{0{,}08\ kg}{140{,}38\ kg} = 5{,}6988.10^{-4}$

H_2O $= 140{,}3\ kg \rightarrow X_{H_2O} = \dfrac{\text{Massa } H_2O}{\text{Massa lar } H_3PO_4} = \dfrac{140{,}3\ kg}{140{,}38\ kg} = 0{,}9994$

Larutan H_3PO_4 = 140,38 kg

$$\rho_{lar.H_3PO_4} = \frac{1}{X_{H_3PO_4}\frac{1}{\rho_{H_3PO_4}} + X_{H_2O}\frac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{lar.H_3PO_4} = \frac{1}{5{,}6988.10^{-4}\frac{1}{1{,}8340\ kg/lt} + 0{,}9994\frac{1}{0{,}99781\,kg/lt}}$$

$$\rho_{lar.H_3PO_4} = 0{,}9981\,kg/lt = 62{,}3250\ lb/ft^3$$

$$\rho_{campuran} = \frac{1}{X_{wet\ ossein}\frac{1}{\rho_{wet\ ossein}} + X_{lar.H_3PO_4}\frac{1}{\rho_{lar.H_3PO_4}}}$$ (Perry, 1999)

$$\rho_{campuran} = \frac{1}{0{,}4999\frac{1}{0{,}9845\ kg/lt} + 0{,}5001\frac{1}{0{,}9981\ kg/lt}}$$

$$\rho_{campuran} = 0{,}9912\,kg/lt = 61{,}8976\ lb/ft^3$$

$$\text{Volume yang dipindahkan} = \frac{280{,}68\,kg/jam}{0{,}9912\,kg/lt} = 10{,}4063\,lt/jam = 294{,}7069\,ft^3/jam$$

Maka kapasitas Screw Conveyor J – 175 = 294,7069 ft^3 / jam

Waktu pemindahan = 60 menit

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

Power :

$$hp = \frac{Co\,.Ca.L}{33000}$$, dimana : Co : koefisien (untuk gelatin Co = 1,3)

Ca : kapasitas Screw Conveyor (= 10,3150 lb/menit)

L : panjang Screw Conveyor (= 10 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3\ .10{,}3 \ldots\ /\ menit.10\ ft}{33000} = 4{,}0635.10^{-3}\ hp$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{4{,}0635.10^{-3}\ hp}{0{,}8} = 5{,}0794.10^{-3}$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = $5{,}0794.10^{-3}$ hp × 2 = $1{,}0159.10^{-2}$ hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

26. Heater (E – 198)

Fungsi : memanaskan udara kering sampai menjadi udara panas untuk disuplai ke Spray Dryer B – 194

Tipe : shell and tube heat exchanger

Dasar pemilihan : designnya sederhana, luas perpindahan panasnya besar, pressure drop-nya kecil

Jumlah : 1 buah

Perhitungan :

1. **Heat Balance**

   Massa udara kering = 2700,08 kg = 5953,68 lb

   150 lb

   Cp udara kering = 1,0048 kJ / kg . K = 0,24 Btu / lb . °F

- Udara kering, $Q = m . Cp . \Delta T$

$= 2700,08 \text{ kg / jam} . 1,0048 \text{ kJ / kg . K} (333\text{-}303) \text{ K}$

$= 81391,2115 \text{ kJ/jam} = 77157,1889 \text{ Btu / jam}$

- Steam, $Q = 90844,19 \text{ kJ /jam} = 86103,3416 \text{ Btu / jam}$

Pada 148°C, $H_V = 2774,02 \text{ kJ / kg}$

$H_L = 623,572 \text{ kJ / kg}$

$\lambda = H_V - H_L = 2774,02 \text{ kJ / kg} - 623,572 \text{ kJ / kg} = 2150,448 \text{ kJ / kg}$

Massa steam yg dibutuhkan $= \frac{Q}{\lambda} = \frac{90844,19 \text{ kJ / jam}}{2150,448 \text{ kJ / kg}} = 42,24 \text{ kg / jam}$

$= 93,1487 \text{ lb / jam}$

1. **ΔT LMTD**

$\Delta T_1 = T_2 - t_1 = 148°C - 30°C = 118°C = 212,4°F$

$\Delta T_2 = T_1 - t_2 = 148°C - 60°C = 88°C = 158,4°F$

$$\Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}} = \frac{212,4°F - 158,4°F}{\ln \frac{212,4°F}{158,4°F}} = 184,1°F$$

2. **T_C dan t_C**

$F_C = 0,5$ (non minyak bumi)

$T_C = 148°C + (0,5\ (148 - 148)°C) = 148°C = 298,4°F$

$t_C = 30°C + (0,5\ (60 - 30)°C) = 45°C = 113°F$

Asumsi : $U_D = 2,3801 \text{ Btu / ft}^2 . \text{jam} . °F$

$$A = \frac{Q}{U_D \cdot \Delta T_{LMTD}} = \frac{86103{,}3416 \text{ Btu/jam}}{2{,}3801 \text{ Btu/ft}^2.\text{jam.}^\circ\text{F}.184{,}1^\circ\text{F}} = 207{,}3456 \text{ ft}^2$$

Dipilih tube dengan OD = 1 in, sehingga a" = 0,2618 ft^2 / lin ft

(Kern, 1965, pp. 843, table 10)

$$\text{Number of tubes, } N_t = \frac{A}{a''.12} = \frac{207{,}3456}{0{,}2618 .12} = 66$$

$$\left.\begin{array}{l} N_t = 66 \\ OD = 1 \text{ in on } 1\frac{1}{4} \text{ in triangular pitch} \end{array}\right\} \text{ID shell} = 13\frac{1}{4} \text{ in ; 2 passes}$$

(Kern, 1965, pp. 842, table 9)

A = 66 . 12 . 0,2618 = 207,3456 ft^2

$$U_D = \frac{Q}{A.\Delta T_{LMTD}} = \frac{86103{,}3416 \text{ Btu/jam}}{207{,}3456 \text{ ft}^2.184{,}1^\circ\text{F}} = 2{,}3801 \text{ Btu/ft}^2.\text{jam.}^\circ\text{F}$$

Shell side (Udara kering, fluida dingin)	Tube side (Steam, Fluida panas)
4. Pt = 1,25 in C' = P_t – OD = (1,25 – 1) in = 0,25 in B = 7 in $a_s = \frac{ID.C'.B}{144.P_t} = \frac{13{,}25.0{,}25.7}{144.1{,}25} = 0{,}1288 \text{ ft}^2$ (Kern, 1965, pp. 138, eq. 7.1)	4. a'_t = 0,546 in^2 (Kern, 1965, pp. 843, table 10) $a_t = \frac{N_t.a'_t}{144.n} = \frac{66.0{,}546}{144.2} = 0{,}1251$ (Kern, 1965, pp. 150, eq.7.48)
5. $G_S = \frac{W}{a_s} = \frac{5953{,}68 \text{ lb}}{0{,}1288 \text{ ft}^2} = 46217{,}2184 \text{ lb/ft}^2$	5. $G_t = \frac{W}{a_t} = \frac{93{,}1487 \text{ lb}}{0{,}1251 \text{ ft}^2} = 744{,}4452 \text{ lb/ft}^2$
6. Pada t_C = 113°F, μ = 1,94 cp = 4,68 lb/ft.h (Geankoplis, 1993, pp. 866, A.3-3) D_e = 0,72 ft (Kern, 1965, pp. 838, fig. 28) $Re_S = \frac{D_e.G_S}{\mu} = \frac{0{,}72.46217{,}2184}{4{,}68} = 7108{,}1506$	6. Pada T_C =298,4°F, μ=1,48cp=3,5701 lb/ft.h (Geankoplis, 1993, pp. 863, A.2–12) D_e = 0,834 ft (Kern, 1965, pp. 843, table 10) $Re_t = \frac{D_e.G_t}{\mu} = \frac{0{,}834.744{,}4452}{3{,}5701} = 150{,}1357$
7. j_H = 36 (Kern, 1965, pp. 838, fig. 28)	7. $\frac{h_{io}}{\Phi_t}$ = 1500 Btu / hr . ft^2 . °F
8. Pada t_C = 113°F, Cp = 0,2407 Btu / lb.°F k = 0,0159 Btu / hr . ft .°F	

$$\left(\frac{Cp.\mu}{k}\right)^{\frac{1}{3}} = \left(\frac{0,2407.4,68}{0,0159}\right)^{\frac{1}{3}} = 3,0827$$

9. $h_o = j_H.\frac{k}{D_e}.\left(\frac{Cp.\mu}{k}\right)^{\frac{1}{3}}.\Phi_S$

$$\frac{h_o}{\Phi_S} = 36.\frac{0,0159\ Btu/hr.ft.^\circ F}{0,72\ ft}.3,0827.1$$

$$\frac{h_o}{\Phi_S} = 2,4508\ Btu/hr.ft^2.^\circ F$$

10. $t_W = t_C + \frac{\frac{h_o}{\Phi_S}}{\frac{h_{io}}{\Phi_t} + \frac{h_o}{\Phi_S}}(T_C - t_C)$

(Kern, 1965, pp. 98, eq. 5.31)

$$t_W = 113 + \frac{2,4508}{1500 + 2,4508}(298,4 - 113)$$

$$t_W = 113,3^\circ F$$

11. Pada t_W = 113,3°F, μ = 1,93cp = 4,67 lb/ft.h

(Geankoplis, 1993, pp. 866, A.3-3)

$$\Phi_S = \left(\frac{\mu}{\mu_W}\right)^{0,14} = \left(\frac{4,68}{4,67}\right)^{0,14} = 1,0004$$

12. $h_o = \frac{h_o}{\Phi_S}\Phi_S = 2,4508.1,0004 = 2,4517$

(Kern, 1965, pp. 121, eq. 6.36)

11. Pada t_W = 113,3°F,μ =1,10 cp = 2,65 lb/ft.h

(Geankoplis, 1993, pp. 866, A.3-3)

$$\Phi_t = \left(\frac{\mu}{\mu_W}\right)^{0,14} = \left(\frac{3,5701}{2,65}\right)^{0,14} = 1,0425$$

12. $h_{io} = \frac{h_{io}}{\Phi_t}\Phi_S = 1500.1,0425 = 1563,74$

(Kern, 1965, pp. 121, eq. 6.36)

$$U_C = \frac{h_{io}.h_o}{h_{io} + h_o} = \frac{1563,74.2,4517}{1563,74 + 2,4517}\frac{Btu}{hr.ft^2.^\circ F} = 2,4477\frac{Btu}{hr.ft^2.^\circ F}$$

$$A = a''.L.N_t = 0,2618.12.66 = 207,3456\ ft^2 \rightarrow U_D = 2,3801$$

$$R_d = \frac{U_C - U_D}{U_C.U_D} = \frac{2,4479 - 2,3801}{2,4479.2,3801}\frac{ft^2.hr.^\circ F}{Btu} = 1,1163.10^{-2}\frac{ft^2.hr.^\circ F}{Btu}$$

Pressure Drop

Shell side	Tube side
1. Re_S = 7108,1506 f = 2,4 . 10^{-3} (Kern, 1965, pp. 839, fig. 29) 2. $N+1 = 12\frac{L}{B} = 12\frac{12}{7} = 20,5714$ 3. $D_S = \frac{ID}{12} = \frac{13,25\,in}{12} = 1,1042$ ft Sg pada suhu 298,4°F = 0,78 $\Delta P_S = \frac{f.G_S^2.D_S.(N+1)}{5,22.10^{10}.D_e.S_g.\Phi_S}$ $\Delta P_S = \frac{2,4.10^{-3}.46217,2184.1,1042.20,5714}{5,22.10^{10}.0,72.0,78.1}$ $\Delta P_S = 3,9721 . 10^{-3} < 10$ psi (memenuhi syarat)	1. Re_t = 150,1357 f = 3,3 . 10^{-3} (Kern, 1965, pp. 836, fig. 26) 2. Sg pada suhu 113°F = 0,00242 $\Delta P_t = \frac{1}{2}.\frac{f.G_t^2.L.n}{5,22.10^{10}.D.S_g.\Phi_t}$ $\Delta P_t = \frac{1}{2}.\frac{3,3.10^{-3}.744,4452.12.2}{5,22.10^{10}.0,0695.0,02242.1}$ $\Delta P_S = 2,4997 . 10^{-3} < 10$ psi (memenuhi syarat)

Bahan konstruksi : Cast iron

27. Barometric Condenser (X – 192)

Fungsi : mengembunkan uap air dari Evaporator V – 190

Tipe : direct contact condenser

Dasar pemilihan : operasinya mudah

Jumlah : 1 buah

Perhitungan :

Laju massa uap masuk = 884,18 kg / jam = 1949,62 lb / jam

Suhu uap air masuk = 70°C = 158°F

Suhu air pendingin = 30°C = 86°F

Catatan : (Ludwig, 1984, pp. 211)

Non condensable gas tidak melebihi 1% dari total uap air yang akan dikondensasi.

Jadi laju uap air yang akan dikodensasi = 99% . 1949,62 lb/jam = 1930,12 lb/jam

Non condensable gas = 1949,62 lb / jam – 1930,12 lb / jam = 19,50 lb / jam

Terminal difference = 5°F

Temperatur udara keluar kondenser = 158°F – 5°F = 153°F

Temperatur air pendingin keluar kondenser = 86°F + 5°F = 91°F

Menghitung massa air pendingin yang dibutuhkan

$$Gpm = \frac{W_S . L}{T_W . 500}$$; dimana: Gpm : massa air pendingin yang dibutuhkan (gpm)

L : panas laten penguapan pada T saturated = 158°F

(=1,6244 Btu / lb.°F)

W_S : jumlah uap yang dikondensasi (lb)

$$Gpm = \frac{1930{,}12 \text{ lb}.1{,}6244 \text{ Btu/lb.°F}}{158°\text{F}.500} = 0{,}0397 \text{ gpm}$$

Menghitung tinggi Barometric Condenser

P_a = tekanan permukaan liquid dalam kaki barometer

P_b = tekanan pada permukaan liquid

P_h = tekanan hidrostatik

Asumsi : operasi pada keadaan ideal sehingga P_a = 0

$$P_A = P_B$$

$$P_h + P_a = P_b$$

$$\rho_{air} . h_{air} . g + 0 = \rho_{Hg} . h_{Hg} . g$$

$$h_{air} = \frac{13{,}6.76}{1} = 1033{,}6 \text{ cm} = 10{,}34 \text{ m}$$

Maka diambil tinggi Barometric Condenser 11 m

Bahan konstruksi : carbon steel

28. Evaporator (V – 190)

Fungsi : untuk memekatkan gelatin

Tipe : single effect vertical forced circulation evaporator

Dasar pemilihan : dapat beroperasi secara kontinyu, forced circulation supaya koefisien perpindahan panas besar, digunakan single effect karena kapasitas kecil

Jumlah : 1 buah

Kondisi operasi :

T larutan (fluida dingin) : t_1 = 64,2°C = 147,6°F

t_2 = 70°C = 158°F

T steam (fluida panas) : T = 148°C = 298,4°F

T operasi = 70°C = 158°F

P operasi = 4 in Hg = 13,55 kPa = 0,13 atm = 1,96 psia

λ steam pada 148°C = 2150,448 kJ / kg

(Geankoplis, 1993, pp. 857, A.2-9)

Dari App. B didapat : Kebutuhan panas = 2100209,60 kJ / jam

= 1990606,79 Btu / jam

Kebutuhan steam $= \frac{2100209{,}60 \text{ kJ / jam}}{2150{,}448 \text{ kJ / kg}} \frac{100\%}{80\%}$

= 1220,80 kg = 2691,86 lb / jam

Dari App. A didapat : massa larutan = 2526,84 kg / jam = 5571,68 lb / jam

Massa uap air = 884,18 kg / jam = 1949,62 lb / jam

Perhitungan :

$\Delta T = 298,4°F - 158°F = 140,4°F$

T_d larutan = 70°C = 158°F → U_D = 510 Btu / ft² . jam . °F

(Badger, 1995, pp. 209, fig. 5-26)

$$A = \frac{Q}{U_D . \Delta T} = \frac{1990606,79\ Btu}{510\ Btu/ft^2.jam.°F.140,4°F} = 27,8002\ ft^2$$

Untuk jenis evaporator vertical forced circulation, tube ditentukan :

OD < 2 in (Kern, 1965, pp.406)

L = 48 in = 4 ft (Badger, 1995, pp. 208)

Ditentukan ukuran tube pipa diameter nominal :

1½ in sch. 40

OD = 1,9 in

ID = 1,61 in

a" = 0,498 ft² / ft

$$N_t = \frac{A}{a".L} = \frac{27,8002\ ft^2}{0,498\ ft^2/ft.4\ ft} = 13,9559 \approx 14$$

ρ_V = 0,6224 kg / lt = 622,4 kg / m³

Menghitung ρ liquid (ρ_L)

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft³ (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft³

(www.usd.edu/biol/courses/cellthies/cpa3answers.html) ρ H_2O pada 64,2°C = 0,9824 kg / lt = 61,3466 lb / ft³

(Geankoplis, 1993, pp.855, A.2-3)

Wet ossein

Protein = 146,46 kg → $X_{protein} = \frac{\text{Massa protein}}{\text{Massa wet ossein}} = \frac{146{,}46\ \text{kg}}{1262{,}63\ \text{kg}} = 0{,}1160$

Lemak = 5,05 kg → $X_{lemak} = \frac{\text{Massa lemak}}{\text{Massa wet ossein}} = \frac{5{,}05\ \text{kg}}{1262{,}63\ \text{kg}} = 3{,}9996.10^{-3}$

H_2O = 1111,12 kg → $X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \frac{1111{,}12\ \text{kg}}{1262{,}63\ \text{kg}} = 0{,}8800$

Wet ossein = 1262,63 kg

$$\rho_{wet\ ossein} = \frac{1}{X_{protein}\frac{1}{\rho_{protein}} + X_{lemak}\frac{1}{\rho_{lemak}} + X_{H_2O}\frac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{wet\ ossein} = \frac{1}{0{,}1160\frac{1}{0{,}8955\ \text{kg/lt}} + 3{,}9996.10^{-3}\frac{1}{0{,}9290\ \text{kg/lt}} + 0{,}88\frac{1}{0{,}9824\ \text{kg/lt}}}$$

$\rho_{wet\ ossein} = 0{,}9712\ \text{kg/lt} = 60{,}6499\ \text{lb/ft}^3$

Larutan $Ca_3(PO_4)_2$

$Ca_3(PO_4)_2$ = 0,03 kg → $X_{Ca_3(PO_4)_2} = \frac{\text{Massa } Ca_3(PO_4)_2}{\text{Massa lar } Ca_3(PO_4)_2} = \frac{0{,}03\ \text{kg}}{1263{,}15\ \text{kg}} = 2{,}375.10^{-5}$

H_2O = 1263,12 kg → $X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa lar } Ca_3(PO_4)_2} = \frac{1263{,}12\ \text{kg}}{1263{,}15\ \text{kg}} = 0{,}9999$

Larutan $Ca_3(PO_4)_2$ = 1263,15 kg

$$\rho_{lar.Ca_3(PO_4)_2} = \frac{1}{X_{Ca_3(PO_4)_2}\dfrac{1}{\rho_{Ca_3(PO_4)_2}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{lar.Ca_3(PO_4)_2} = \frac{1}{2{,}375.10^{-5}\dfrac{1}{3{,}04\ kg/lt} + 0{,}9999\dfrac{1}{0{,}9824\ kg/lt}}$$

$$\rho_{lar.Ca_3(PO_4)_2} = 0{,}9824\ kg/lt = 61{,}3475\ lb/ft^3$$

Padatan $Ca_3(PO_4)_2$

$Ca_3(PO_4)_2$ = 1,06 kg

Massa bahan masuk total = 1262,63 kg + 1263,15 kg + 1,06 kg = 2526,84 kg

Sehingga :

$$X_{wet\ ossein} = \frac{1262{,}63\ kg}{2526{,}84\ kg} = 0{,}4497$$

$$X_{larutan\ Ca_3(PO_4)_2} = \frac{1263{,}15\ kg}{2526{,}84\ kg} = 0{,}4999$$

$$X_{padatan\ Ca_3(PO_4)_2} = \frac{1{,}06\ kg}{2526{,}84\ kg} = 4{,}195.10^{-4}$$

$$\rho_L = \frac{1}{X_{wet\ ossein}\dfrac{1}{\rho_{wet\ ossein}} + X_{lar.Ca_3(PO_4)_2}\dfrac{1}{\rho_{lar.Ca_3(PO_4)_2}} + X_{Ca_3(PO_4)_{2\,(s)}}\dfrac{1}{\rho_{Ca_3(PO_4)_{2(s)}}}}$$

(Perry, 1999)

$$\rho_L = \frac{1}{0{,}4497\dfrac{1}{0{,}9712\ kg/lt} + 0{,}4999\dfrac{1}{0{,}9824\ kg/lt} + 4{,}195.10^{-4}\dfrac{1}{3{,}04\ kg/lt}}$$

$$\rho_L = 0{,}9771\ kg/lt = 61{,}0142\ lb/ft^3 = 977{,}0773\ kg/m^3$$

T steam = 158°F, P = 1,9105 psia → V = 81,182 ft^3 / lb

(Geankoplis, 1993, pp. 858, A.2-9)

Laju volumetrik uap = massa uap air. V

$= 1949{,}62\ \text{lb/jam} . 81{,}182\ \text{ft}^3/\text{lb}$

$= 158273{,}7992\ \text{ft}^3/\text{jam} = 1{,}2451\ \text{m}^3/\text{dt}$

$$\text{Kec. uap max.} = V_V = 0{,}035.\left(\frac{\rho_L}{\rho_V}\right)^{0,5} = 0{,}035.\left(\frac{977{,}0773\,\text{kg/m}^3}{622{,}4\,\text{kg/m}^3}\right)^{0,5} = 0{,}0439\ \text{m/dt}$$

$$A_S = \frac{Q}{V_V} = \frac{1{,}2451\ \text{m}^3/\text{dt}}{0{,}0439\ \text{m/dt}} = 28{,}3924\ \text{m}^2$$

$$A_S = \frac{\pi}{4} D_S^2$$

$$D_S = \sqrt{\frac{A_S}{\pi/4}} = \sqrt{\frac{28{,}3924\ \text{m}^2}{\pi/4}} = 6{,}0113\ \text{m} = 19{,}7219\ \text{ft}$$

Menentukan tinggi evaporator

Tinggi badan silinder = 1,5 – 2 dari panjang tube (Hugot, pp. 500)

Diambil H_S = 2 . L = 2 . 4 ft = 8 ft

Menghitung tebal shell

Asumsi : t_S = ¼ in

ID = 5,9481 ft = 71,3772 in

OD = ID + 2 . t_S = 71,3772 in + 2 . ¼ in = 71,7882 in

$$\frac{H_S}{OD} = \frac{8.12\ \text{in}}{71{,}7882\ \text{in}} = 1{,}3356$$

$$\frac{OD}{t_S} = \frac{71{,}8772\ in}{0{,}25\,in} = 287{,}5088$$

Dari fig. 8.7 dan 8.8 Brownell & Young diperoleh : A = 0,00014

B = 3900 psi

$$P_{allowable} = \frac{4.B}{3\left(\frac{OD}{t_S}\right)} = \frac{4.3900}{3.287{,}5088} = 18{,}0864\,psi\ > 14{,}7\ psi\ (memenuhi)$$

$$t_S' = t_S + C = ¼ + \frac{1}{8} = \frac{3}{8}\ in$$

Digunakan tebal plate = $\frac{3}{8}$ in

Bahan konstruksi : carbon steel

29. Ejector (X – 193)

Fungsi : untuk menurunkan tekanan pada evaporator sampai pada tekanan vakum

Tipe : single stage steam jet ejector

Dasar pemilihan : design sederhana

Jumlah : 1 buah

Perhitungan :

$P_{suction}$ = 3 – 5 in Hg (Ludwig, 1984, pp. 227), diambil $P_{operasi}$ = 4 in Hg abs

Uap yang masuk = non condensable gas = 884,18 kg / jam

$W_S = W_{S\,90}.f$; dimana : W_S = total steam (lb/jam)

W_{s90} = total steam untuk steam 90 psig

f = steam pressure factor

(Ludwig, 1984, pp. 230)

Diambil udara leakage = 10% uap masuk = 88,42 kg/jam

W_m' = total campuran = uap masuk + udara leakage

= 884,18 kg + 88,42 kg = 972,60 kg / jam = 2144,58 lb / jam

(Ludwig, 1984, pp. 227)

Dari Ludwig fig. 6-26A, pp. 230, didapat :

P suction = 4 in Hg abs

W'm = 2144,58 kg / jam

Ukuran ejector = 2 in ejector

$W_{S\,90}$ = 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 = 2144,58 lb/jam

Dari Ludwig pers. 6-7, hal 230, didapat :

$$W'm = \frac{E\ V}{t} \rightarrow t = \frac{E.V}{W'_m} = \frac{1{,}3.300}{2144{,}58} = 0{,}1819 \text{ menit}$$

Konsumsi air = $0{,}06.W_s$ = 0,06 . 316,8 = 19,008 gpm (Ludwig, hal 232)

30. Spray Dryer (B – 194)

Fungsi	: sebagai alat pengering gelatin yang masuk dari Screw Conveyor J – 191 sehingga diperoleh bubuk gelatin
Tipe	: bejana silinder dengan bagian bawah berbentuk konis dan tutup atas berbentuk torispherical dished head
Dasar pemilihan	: cocok untuk produk yang berupa padatan
Kapasitas	: 1642,66 kg / jam
Kondisi	: suhu udara masuk = 60°C
	Suhu feed masuk = 65,5°C
	Tekanan operasi = 1 atm
	Suhu operasi = 70°C
Jumlah	: 1 buah

Perhitungan :

Menghitung ukuran dryer

Feed masuk sebanyak 1642,66 kg terdiri dari :

Padatan = 152,6 kg / jam

H_2O = 1490,06 kg / jam

Kadar air awal $= \dfrac{1490{,}06\ \text{kg}}{1642{,}66\ \text{kg}}\ 100\% = 90{,}71\%$

Dari perhitungan App. A diperoleh :

Massa bahan keluar Spray Dryer = 4342,74 kg / jam

Massa udara panas keluar = 3071,44 kg / jam

H_2O yang menguap = 371,36 kg / jam

Gelatin keluar sebagai produk = massa bahan keluar – massa udara panas keluar

= 4342,74 kg / jam – 3071,44 kg / jam

= 1271,30 kg / jam

Massa H_2O dalam produk = (111,11 + 0,76 + 1000,01 + 6,82) kg / jam

= 1118,70 kg / jam

$$\text{Kadar air dalam produk} = \frac{1118{,}70\ \text{kg}}{1271{,}30\ \text{kg}}\ 100\% = 88\%$$

Laju pengeringan = air yang menguap = 371,36 kg / jam

Dari data di atas dapat diperoleh :

Volume chamber = 6000 ft^3

Diameter = 22 ft = 6,7057 m = 264 in

(Perry, 1999, pp. 20-63)

Lubang pengeluaran = 12 in (Hesse, 1945, pp. 85)

Tinggi shell = 0,4 . D (Perry, 1999, fig. 20.72)

= 0,4 . 22 ft

= 8,8 ft = 2,6823 m

$$\text{Volume silinder} = \frac{\pi}{4}.D^2.H_S$$

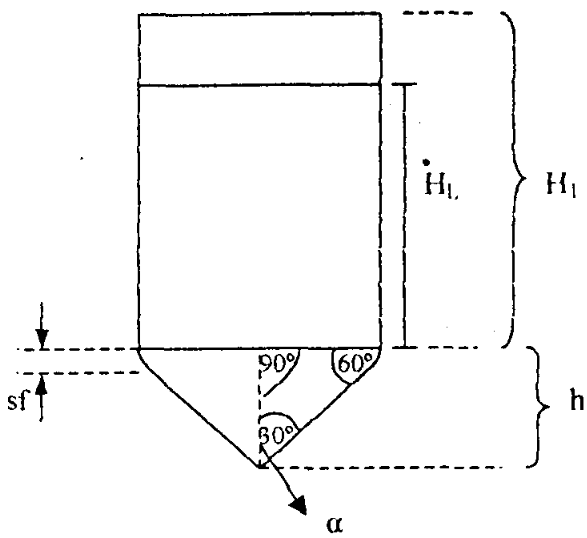
$$= \frac{\pi}{4}.(22\ \text{ft})^2.8{,}8\ \text{ft}$$

$$= 3346{,}5143\ \text{ft}^3$$

Volume konis = volume chamber – volume silinder

$= 6000\ ft^3 - 3346{,}5143\ ft^3$

$= 2653{,}4857\ ft^3$



Tinggi konis (h) $= \dfrac{0{,}5.D}{\tan 60^\circ} = \dfrac{0{,}5.22\ ft}{\tan 60^\circ} = 6{,}3447\ ft = 1{,}9339\ m$

$T = 17\dfrac{L}{S}$; dimana : T = waktu pengeringan total (detik)

L/S = perbandingan massa air terhadap solid dalam feed

(Foust, 1960, pp. 548)

$T = 17\dfrac{1490{,}06\ kg/jam}{152{,}60\ kg/jam} = 165{,}9952\ dt = 0{,}0461\ jam$

Volume udara kering yang dibutuhkan untuk pengeringan tersebut :

ρ udara kering pada suhu 60°C = 0,901 kg / m^3

(Geankoplis, 1993, pp. 866, A.3-3)

$$\text{Rate udara kering masuk} = \frac{\text{massa udara kering masuk}}{\rho \text{ udara kering}} = \frac{2700{,}08 \text{ kg/jam}}{0{,}901 \text{ kg/m}^3}$$

$$= 2432{,}7721 \text{ m}^3\text{/jam}$$

ρ steam pada suhu 60°C = 0,5507 kg / m^3

(Geankoplis, 1993, pp. 863, A.2-12)

$$\text{Rate volumetrik air yang menguap} = \frac{\text{massa air menguap}}{\rho \text{ uap air}}$$

$$= \frac{371{,}36 \text{ kg/jam}}{0{,}5507 \text{ kg/m}^3}$$

$$= 674{,}3417 \text{ m}^3\text{/jam}$$

Total aliran gas keluar = rate udara kering + rate air menguap

= 2432,7721 m^3 / jam + 674,3417 m^3 / jam

= 3107,1138 m^3 / jam

Volume = waktu tinggal . total rate keluar

= 0,0461 jam . 3107,1138 m^3 / jam

= 143,2692 m^3 / jam

Pengecekan terhadap volume chamber

Volume chamber = 6000ft^3 = 169,9 m^3 > 143,2692 m^3 (kadar air yang diinginkan dapat tercapai)

Menghitung tebal shell (t_S)

Untuk tutup bagian bawah dan atas dipilih bahan konstruksi :

Carbon steel SA – 240 Grade A tipe 410

$F_{allowable}$ (T = -20°C – 100°C) = 16250 lb / in^2

(Brownell & Young, 1959, pp. 342, App. D, item 4)

Pengelasan menggunakan double welded butt joint → efisiensi = 80%

(Brownell & Young, 1959, pp. 254, table 13.2)

$$C = \frac{1}{8}$$

R_i = 11 ft = 132 in

$P_{operasi}$ = 1 atm = 14,7 psi

P_{design} = 1,1 . $P_{operasi}$ = 1,1 . 14,7 psi = 16,17 psi

$$t_S = \frac{P.r_i}{f.E - 0{,}6.P} + C$$ (Brownell & Young, 1959, pp.254, eq. 13.1)

$$t_S = \frac{,17\ lb/in^2 .132\,in}{16250\ lb/in^2 .0{,}80 - 0{,}6.16{,}17\ lb/in^2} + \frac{1}{8}$$

$t_S = 0{,}2071$ in → diambil $t_S = \frac{4}{16}$ in

<u>Menghitung tebal konis (t_k)</u>

t_S = 4/16 in → icr = ¾ in (Brownell & Young, 1959, pp. 89, table 5.6)

D_i = D – 2 icr (1 – cos α) (Brownell & Young, 1959, pp. 260)

= 264 in – 2 . ¾ in (1 – cos 30°)

= 263,7989 in

$$L = \frac{D_i}{2 \cos \alpha} = \frac{263{,}7989\ in}{2.\cos 30°} = 152{,}3229\ in$$

(Brownell & Young, 1959, pp. 259, eq. 13.17)

$$W = \frac{1}{4}.\left(3 + \sqrt{\frac{L}{icr}}\right) = \frac{1}{4}.\left(3 + \sqrt{\frac{152,3229\ in}{0,75\ in}}\right) = 4,3128$$

(Brownell & Young, 1959, pp. 138, eq. 7.76)

$$t_k = \frac{P.L.W}{2.f.E - 0,2.P} + C$$ (Brownell & Young, 1959, pp. 138, eq. 7.77)

$$t_k = \frac{16,17\ lb/in^2.152,3229\ in}{2.16250\ lb/in^2.0,8 - 0,2.16,17\ lb/in^2}$$

$t_k = 0,5336$ in → diambil $t_k = \frac{9}{16}$ in

<u>Menghitung tebal head (t_h)</u>

R_C = ID = 22 ft = 264 in

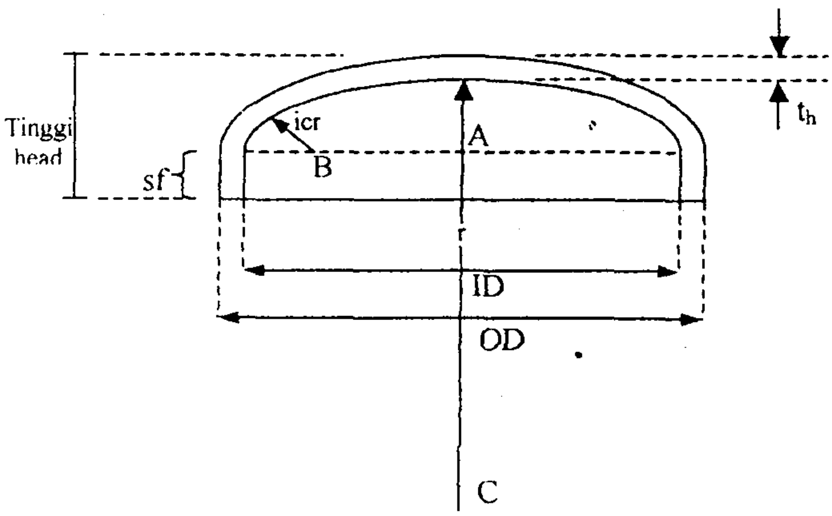
sf = 2 in

$$t_h = \frac{0,885.P.Rc}{f.E - 0,1.P} + C$$ (Brownell & Young, 1959, pp. 258, pers.13.12)

$$= \frac{0,885.16,17\ lb/in^2.264\ in/ft}{16250\ lb/in^2.0,8 - 0,1.16,17\ lb/in^2} + \frac{1}{8}\ in$$

= 0,4156 in → diambil $t_h = \frac{7}{16}$ in = 0,0365 ft

Menentukan tinggi head



ID $= 22$ ft $= 264$ in

OD $= \text{ID} + 2\ t_S$

$= 264 \text{ in} + 2 \cdot \frac{7}{16} \text{ in}$

$= 264{,}8750$ in

r $= 144$ in

icr $= 9\frac{3}{8}$ in

(Brownell & Young, 1959, pp. 91, table 5.7)

$$\text{Tinggi head} = t_h + sf + \left(r - \sqrt{(BC)^2 - (AB)^2} \right)$$

$$= \frac{7}{16} \text{ in} + 2 \text{ in} + \left(144 - \sqrt{\left(144 - 9\frac{3}{8}\right)^2 - \left(\frac{264}{2} - 9\frac{3}{8}\right)^2} \right)$$

$= 266{,}5765$ in $= 22{,}2147$ ft

Atomizer

Menentukan kecepatan atomizer

$$D_{so} = \frac{K.M^{a}}{N^{b}.D_{i}^{c}.(n.h)^{d}}.10^{-4}\ \mu m\ ;\ \text{dimana :}$$

D_{so} = median diameter, μm (= 152 μm)

K = konstanta

M = atomizer wheel feed, kg / jam (1642,66 kg / jam = 60,3678 lb/ menit)

N = kecepatan putaran, rpm

D_i = diameter roda, m (0,25 m = 0,8202 ft) (Van't Land, 1959, pp. 163)

n = banyaknya vane dalam roda (= 45)

h = tinggi vane roda atomizer, m (30 mm = 0,03 m)

(Van't Land, pp. 160, eq. 9-1)

L_W = wetted dished peripheral = π . D_i = π . 0,25 m = 0,7857 m

Vane liquid loading = r = feed masuk / L_W

= 1642,66 kg / jam / 0,7857 m

= 2090,6582 kg / jam . m

Dari tabel 8.1 Van't Land, 1959 dapat diperoleh :

a = 0,12

b = 0,8

c = 0,6

d = 0,12

K = 1,2

Sehingga :

$$152\ \mu m = \frac{1,2.(1642,66)^{0,12}}{N^{0,8}.(0,25)^{0,6}.(45.0,03)^{d}}.10^{-4}\ \mu m$$

$N^{0,8} = 4,254.10^{-7}$

$N = 1,0864.10^{-8}$ rpm ≈ 1 rpm

Menghitung power yang dibutuhkan

$P = 1,04 . 10^{-8} (r . N)^{0,8} . W$; dimana :

P : hp netto, hp

r : jari-jari roda atomizer, ft (= ½ D roda atomizer = ½ . 0,8202 ft = 0,4101 ft)

N : putaran disk, rpm

W : rate feed, lb / menit

P $= 1,04.10^{-8} . (0,4101\ ft . 1\ rpm)^{2} . 60,3678$ lb / menit

P $= 1,2463.10^{-23}$ ≈ 1 hp

31. Cyclone Separator (H – 197)

Fungsi : untuk memisahkan padatan yang terbawa oleh gas keluar Spray Dryer B – 194

Tipe : effluent dust cyclone

Jumlah : 1 buah

Perhitungan :

Kapasitas = 498,49 kg / jam

Bahan konstruksi : carbon steel

Nozzle untuk gas masuk berukuran = 15"

(Peter & Timmerhaus, 1985, pp. 458, Fig. 14-2)

Standar pipe ukuran nozzle = 15,25 in

(Peter & Timmerhaus, 1985, pp. 888, Table 13)

Luas penampang nozzle = $\frac{\pi}{4}.D_i^2 = \frac{\pi}{4}.(15,25\,in)^2 = 182,7277\ in^2 = A_c$

Dari Perry, 1999, pp. 20-82 dapat diperoleh :

$H_c = 2 . B_c$

$A_c = B_c . H_c$

$A_c = 2 . B_c^2 \quad \rightarrow B_c = \sqrt{\frac{A_c}{2}} = \sqrt{\frac{182,7277\ in^2}{2}} = 9,5584\ in$

$D_c = B_c . 4 = 9,5584\ in . 4 = 38,2338\ in$

$D_c = \frac{D_c}{2} = \frac{38,2338\ in}{2} = 19,1169\ in$

$H_c = \frac{D_c}{2} = \frac{38,2338\ in}{2} = 19,1169\ in$

$L_c = 2 . D_c = 2 . 38,2338\ in = 76,4675\ in$

$S_c = \frac{D_c}{8} = \frac{38,2338\ in}{8} = 4,7792\ in$

$Z_c = 2 . D_c = 2 . 38,2338\ in = 76,4675\ in$

$J_c = \frac{D_c}{4} = \frac{38,2338\ in}{4} = 9,5584\ in$

Dimana :

A_c : luas penampang gas masuk, in^2

B_c : panjang lubang masuk, in

D_c : diameter cyclone, in

D_e : diameter lubang pengeluaran gas, in

H_c : diameter lubang masuk, in

L_c : tinggi cyclone bagian silinder, in

Z_c : tinggi cyclone bagian kerucut, in

J_c : diameter lubang pengeluaran partikel, in

32. Pompa (L – 161)

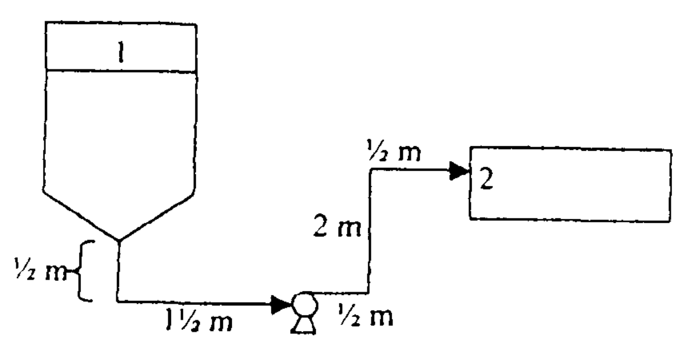
Fungsi : memompa larutan dari Mixer M – 160 ke Filter Press H - 162

Tipe : gear pump

Dasar pemilihan : dapat digunakan untuk viskositas tinggi (2,5 sampai dengan 1500 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 1½ m + ½ m +2 m +1/2 m

= 5 m = 16,404 ft ≈ 16,5 ft

Jumlah elbow = 5 buah

Jumlah valve = 2 buah (gate valve)

Tinggi feed masuk (Z_2) = 2 m = 6,5616 ft

Tinggi liquid pada Mixer M – 160 = 9,2 ft

Z_1 = ½ m + 9,2 ft = 1,6404 ft + 9,2 ft = 10,8404 ft

$\Delta Z = Z_2 - Z_1$

= 6,5616 ft – 10,8404 ft

= 4,9212 ft

Menghitung ρ campuran

ρ H_2O pada 31,7°C = 0,9953 kg / lt

(Geankoplis, 1993, pp.855, A.2-3)

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft^3 (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft^3

(www.usd.edu/biol/courses/cellthies/cpa3answers.html)

Wet ossein

Protein = 146,46 kg → $X_{protein} = \dfrac{\text{Massa protein}}{\text{Massa wet ossein}} = \dfrac{146{,}46\ \text{kg}}{1262{,}63\ \text{kg}} = 0{,}1160$

Lemak $= 5{,}05\ kg \rightarrow X_{lemak} = \dfrac{\text{Massa lemak}}{\text{Massa wet ossein}} = \dfrac{5{,}05\ kg}{1262{,}63\ kg} = 0{,}0040$

H_2O $= 1111{,}12\ kg \rightarrow X_{H_2O} = \dfrac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \dfrac{1111{,}12\ kg}{1262{,}63\ kg} = 0{,}8800$

Wet ossein = 1262,63 kg

$$\rho_{wet\ ossein} = \frac{1}{X_{protein}\dfrac{1}{\rho_{protein}} + X_{lemak}\dfrac{1}{\rho_{lemak}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{wet\ ossein} = \frac{1}{0{,}116\dfrac{1}{0{,}8955\ kg/lt} + 0{,}004\dfrac{1}{0{,}9290\ kg/lt} + 0{,}88\dfrac{1}{0{,}9953\ kg/lt}}$$

$$\rho_{wet\ ossein} = 0{,}9823\ kg/lt = 61{,}3416\ lb/ft^3$$

Wet ossein $= 1262{,}63\ kg \rightarrow X_{wet\ ossein} = \dfrac{\text{Massa wet ossein}}{\text{massa bahan ke H} - 162} = \dfrac{1262{,}63\ kg}{2525{,}26\ kg} = 0{,}5$

H_2O $= 1262{,}63\ kg \rightarrow X_{H_2O} = \dfrac{\text{Massa } H_2O}{\text{massa bahan ke H} - 162} = \dfrac{1262{,}63\ kg}{2525{,}26\ kg} = 0{,}5$

Bahan ke H – 162 = 2525,26 kg

$$\rho_{campuran} = \frac{1}{X_{wet\ ossein}\dfrac{1}{\rho_{wet\ ossein}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{campuran} = \frac{1}{0{,}5\dfrac{1}{0{,}9823\ kg/lt} + 0{,}5\dfrac{1}{0{,}9953\ kg/lt}}$$

$$\rho_{campuran} = 0{,}9888\ kg/lt = 61{,}7442\ lb/ft^3$$

$$\text{Volume bahan masuk H} - 162 = \frac{\text{massa bahan masuk H} - 162}{\rho \text{ campuran}}$$

$$= \frac{2525{,}26 \text{ kg / jam}}{988{,}8 \text{ kg/m}^3}$$

$$= 2{,}5539 \text{ m}^3 \text{ / jam} = 90{,}1817 \text{ ft}^3 \text{ / jam}$$

Menghitung μ campuran

μ wet ossein = 7500 cp (www.norlandprod.com/twchrpts/fishgelrpt.html)

μ H_2O pada 31,7°C = 0,7798 cp

(Geankoplis, 1993, pp.855, A.2-4)

$$\mu_{campuran}{}^{1/3} = X_{wet\ ossein} \cdot (\mu_{wet\ ossein})^{1/3} + X_{H_2O} \cdot (\mu_{H_2O})^{1/3}$$

$$\mu_{campuran}{}^{1/3} = 0{,}5.(7500 \text{ cp})^{1/3} + 0{,}5.(0{,}7798 \text{ cp})^{1/3}$$

$$\mu_{campuran} = 1076{,}0676 \text{ cp}$$

Waktu pemompaan = 1 jam = 60 menit = 3600 dt

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk H} - 162}{\text{waktu pemompaan}}$$

$$\text{Rate pemompaan (Q)} = \frac{90{,}1817 \text{ ft}^3 \text{ / jam}}{3600 \text{ dt / jam}} = 0{,}0251 \text{ ft}^3 \text{ / dt}$$

ID optimum $= 3{,}9 \cdot Q^{0,36} \cdot \rho^{0,18}$ (Peter & Timmerhaus, 1985, pp. 496)

$$= 3{,}9 \cdot (0{,}0251 \text{ ft}^3 \text{ / dt})^{0,36} \cdot (61{,}7442 \text{ lb / ft}^3)^{0,18}$$

$$= 2{,}1724 \text{ in}$$

Maka dipilih pipa 2½ in sch. 80 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 2,323 in = 0,1936 ft = 0,059 m

OD = 2,875 in = 0,2396 ft = 0,073 m

Luas penampang (A) = 0,02942 ft^2

Kecepatan aliran mula-mula = v_1 = 0

$$v_2 = \frac{Q}{A} = \frac{0{,}0251\ ft^3/dt}{0{,}02942\ ft^2} = 0{,}8515\ ft/dt$$

$$N_{Re} = \frac{ID \cdot v_2 \cdot \rho_{campuran}}{\mu_{campuran}} = \frac{0{,}1936\ ft . 0{,}8515\ ft/dt . 61{,}7442\ lb/ft^3}{1076{,}0676 . cp . 6{,}72 . 10^{-4}\ lb/ft.dt.cp} = 14{,}0744$$

N_{Re} < 2100 → aliran laminar → dari Geankoplis, 1993, pp. 88, fig. 2.10-3

diperoleh : f = 0,18

Elbow 90° : 5 buah → $\frac{L_e}{ID} = 35$ → $L_e = 5.35.0{,}1936$ ft = 33,8771 ft

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 2 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 2 . 9 . 0,1936 ft = 3,4845 ft

Panjang total = 16,5 ft + 33,8871 ft + 3,4845 ft = 53,8616 ft

a. **Friksi karena gesekan dalam pipa**

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0{,}18.(0{,}8515\ ft/dt)^2.53{,}86163\ ft}{32{,}1740\ lb.ft/lb_f.dt^2.0{,}1936\ ft}$$

$$f = 2{,}2571\ ft.lb_f/lb$$

b. **Friksi karena kontraksi dari tangki ke pipa**

$$f_C = \frac{K_C.v^2}{2.g_c.\alpha}$$ → untuk aliran laminar α = ½ dan K_C = 0,55

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0{,}55.(0{,}8515\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2.1/2}$$

$$f_C = 0{,}0124\ ft.lb_f/lb$$

c. **Friksi karena perluasan (enlargement)**

$$f_e = \frac{(v_1 - v_2)^2}{2.g_c.\alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 0{,}8515\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2.1/2}$$

$$f_e = 0{,}0225\ ft.lb_f/lb$$

$\Sigma F = f + f_C + f_e$ = (2,2571 + 0,0124 + 0,0225) ft . lb_f/ lb = 2,2921 ft . lb_f/ lb

Asumsi : ΔP = 5 atm = 73,5 lb / in^2 = 10584,22 lb / ft^2

$$\Delta Z + \frac{\Delta v^2}{2 . g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$4{,}9212 \text{ ft} + \frac{0^2 - (0{,}8515 \text{ ft/dt})^2}{2.32{,}1740 \text{ lb.ft/lb}_f.\text{dt}^2} - \frac{10584{,}22 \text{ lb/ft}^2}{61{,}7442 \text{ lb/ft}^3} - 2{,}2921 \text{ ft.lb}_f/\text{lb} = W_S$$

$$W_S = -168{,}8026 \text{ ft.lb}_f/\text{lb}$$

$$m_1 = \frac{2525{,}26 \text{ kg}}{3600 \text{ dt}} = 0{,}7015 \text{ kg/dt} = 1{,}5467 \text{ lb/dt}$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S . m_1}{\eta . 550} = \frac{168{,}8026 \text{ ft.lb}_f/\text{lb}.1{,}5467 \text{ lb/dt}}{0{,}20.550} = 2{,}3736 \text{ ft.lb}_f/\text{dt}$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

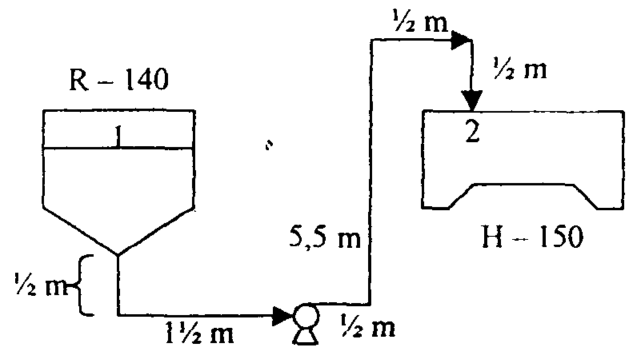
$$\text{Power} = \frac{100\%}{85\%} 2{,}3736 \text{ hp} = 2{,}8257 \text{ hp}$$ → dipilih motor 3 hp

Bahan konstruksi : carbon steel

33. Pompa (L – 141)

Fungsi	: memompa wet ossein dari Reaktor R – 140 menuju ke Centrifugal Separator H – 150
Tipe	: gear pump
Dasar pemilihan	: cocok digunakan untuk bahan berviskositas tinggi (2,5 – 1500 cp)
Jumlah	: 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 1½ m + ½ m + 5,5 m + ½ m + ½ m

= 9 m = 29,5272 ft ≈ 30 ft

Jumlah elbow = 6 buah

Jumlah valve = 2 buah (gate valve)

Tinggi feed masuk (Z_2) = 5 m = 16,404 ft

Dari perancangan Reaktor R – 140 diperoleh H_{liquid} = 13,1 ft

Z_1 = ½ m + 13,1 ft = 1,6404 ft + 13,1 ft = 14,7404 ft

$\Delta Z = Z_2 - Z_1$

$= 16,404 \text{ ft} - 14,7404 \text{ ft}$

$= 1,6636 \text{ ft}$

Menghitung volume bahan masuk H – 150

$\rho_{bahan\ masuk} = 1,0403 \text{ kg/lt} = 64,9613 \text{ lb/ft}^3 = 1040,2864 \text{ kg/m}^3$

$$\text{Volume bahan masuk H} - 150 = \frac{\text{massa bahan masuk H} - 150}{\rho \text{ campuran}}$$

$$= \frac{6105{,}12 \text{ kg/jam}}{1040{,}2864 \text{ kg/m}^3}$$

$$= 5{,}8687 \text{ m}^3/\text{jam} = 207{,}2278 \text{ ft}^3/\text{jam}$$

Menghitung μ campuran

Asumsi : Dianggap $\mu_{campuran}$ hanya terdiri dari μ wet ossein, μ H_3PO_4, μ H_2O

μ wet ossein = 7500 cp (www.norlandprod.com/twchrpts/fishgelrpt.html)

μ H_2O pada 37,6°C = 0,6854 cp

(Geankoplis, 1993, pp.855, A.2-4)

$\mu_{H_3PO_4}$ = 41,2 cp (Perry, 1999, pp. 2-105)

$$\mu_{campuran}^{1/3} = X_{wet\,ossein} \cdot (\mu_{wet\,ossein})^{1/3} + X_{H_2O} \cdot (\mu_{H_2O})^{1/3} + X_{H_3PO_4} \cdot (\mu_{H_3PO_4})^{1/3}$$

$$\mu_{campuran}^{1/3} = 0{,}2068.(7500 \text{ cp})^{1/3} + 0{,}7630.(0{,}6854 \text{ cp})^{1/3} + 0{,}0302.(41{,}2 \text{ cp})^{1/3}$$

$$\mu_{campuran} = 112{,}3369 \text{ cp}$$

Waktu pemompaan = 1 jam = 60 menit = 3600 dt

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk H} - 150}{\text{waktu pemompaan}}$$

$$\text{Rate pemompaan (Q)} = \frac{207{,}2278 \text{ ft}^3/\text{jam}}{3600 \text{ dt/jam}} = 0{,}0576 \text{ ft}^3/\text{dt}$$

ID optimum $= 3{,}9 \,.\, Q^{0,45} \,.\, \rho^{0,13}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9 \,.\, (0{,}0576 \text{ ft}^3/\text{dt})^{0,45} \,.\, (64{,}9613 \text{ lb/ft}^3)^{0,13}$

$= 1{,}8568$ in

Maka dipilih pipa 2 in sch. 80 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 1,939 in = 0,1616 ft = 0,0493 m

OD = 2,375 in = 0,1979 ft = 0,0603 m

Luas penampang (A) = 0,0205 ft^2

Kecepatan aliran mula-mula = v_1 = 0

$$v_2 = \frac{Q}{A} = \frac{0,0576\ ft^3/dt}{0,0205\ ft^2} = 2,8080\ ft/dt$$

$$N_{Re} = \frac{ID.v_2.\rho_{campuran}}{\mu_{campuran}} = \frac{0,1616\ ft.2,8080\ ft/dt.64,9613\ lb/ft^3}{112,3369.cp.\ 6,72.10^{-4} lb/ft.dt.cp} = 390,4372$$

N_{Re} < 2100 → aliran laminar → dari Geankoplis, 1993, pp. 88, fig. 2.10-3

diperoleh : f = 0,18

Elbow 90°: 6 buah → $\frac{L_e}{ID} = 35$ → $L_e = 6.35.0,1616\ ft = 33,9325\ ft$

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 2 buah → $\frac{L_e}{ID} = 9$ (pada keadaan *wide open*)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 2 . 9 . 0,1616 ft = 2,9085 ft

Panjang total = 30 ft + 33,9325 ft + 2,9085 ft = 66,8410 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0,18.(2,8080\ ft/dt)^2.66,8410\ ft}{32,1740\ lb.ft/lb_f.dt^2.0,1616\ ft}$$

$$f = 36,4945\ ft.lb_f/lb$$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C.v^2}{2.g_c.\alpha}$$ → untuk aliran laminar α = ½ dan K_C = 0,55

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0,55.(2,8080\ ft/dt)^2}{2.32,1740\ lb.ft/lb_f.dt^2.1/2}$$

$$f_C = 0,1348\ ft.lb_f/lb$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2.g_c.\alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 2,8080\ ft/dt)^2}{2.32,1740\ lb.ft/lb_f.dt^2.1/2}$$

$$f_e = 0,2451\ ft.lb_f/lb$$

$\Sigma F = f + f_C + f_e$ = (36,4945 + 0,1348 + 0,2451) ft . lb_f/ lb = 36,8743 ft . lb_f/ lb

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$1,6636\ ft + \frac{0^2 - (2,8080\ ft/dt)^2}{2.32,1740\ lb.ft/lb_f.dt^2} + 0 - 36,8743\ ft.lb_f/lb = W_S$$

$$W_S = -35,3333\ ft.lb_f/lb$$

$$m_1 = \frac{6105{,}12\ kg}{3600\ dt} = 1{,}6959\ kg/dt = 3{,}7394\ lb/dt$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S \cdot m_1}{\eta \cdot 550} = \frac{35{,}3333\ ft.lb_f/lb.3{,}7394\ lb/dt}{0{,}20.550} = 1{,}2011\ ft.lb_f/dt$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%} 1{,}2011\ hp = 1{,}4131\ hp$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 1,4131 hp × 2 = 2,8262 hp → dipilih motor 3 hp

Bahan konstruksi : carbon steel

34. Pompa (L – 145)

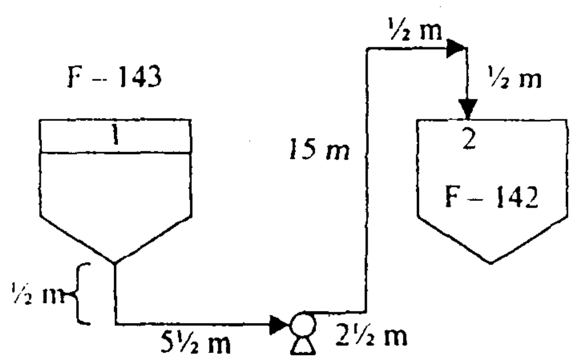
Fungsi : memompa larutan HCl 35% dari Tangki Penampung F – 143 ke Tangki Pengencer F – 142

Tipe : centrifugal pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas rendah (< 2,5 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 5½ m + 2½ m + 15 m + ½ m + ½ m

= 24½ m = 80,3796 ft ≈ 81 ft

Jumlah elbow = 6 buah

Jumlah valve = 2 buah (gate valve)

Tinggi feed masuk (Z_2) = 14,5 m = 47,5716 ft

Dari perancangan Tangki Penampung HCl F – 143 diperoleh bahwa :

volume lartutan HCl yang ditampung = 4124,9903 ft³,

diameter Tangki Penampung F – 143 = 18,8 ft, sehingga :

$$\text{Volume larutan HCl} = \frac{\pi}{4}\left(D_{\text{tangki}}\right)^2 . H_{\text{larutan}}$$

$$4124{,}9903\ \text{ft}^3 = \frac{\pi}{4}\left(18{,}8\ \text{ft}\right) H_{\text{larutan}}$$

$$H_{\text{larutan}} = 14{,}8540\ \text{ft}$$

Z_1 = ½ m + 14,8540 ft = 16,4944 ft

$\Delta Z = Z_2 - Z_1$

= 47,5716 ft – 16,4944 ft

= 31,0772 ft

Menghitung volume bahan masuk F – 142

ρ larutan HCl 35% = 1,16775 kg / lt = 72,9208 lb / ft³ (Perry, 1999, 2-101)

$$\text{Volume bahan masuk F} - 142 = \frac{\text{massa bahan masuk F} - 142}{\rho\ \text{larutan HCl}} = \frac{730\ \text{kg / jam}}{1167{,}75\ \text{kg / m}^3}$$

$= 0{,}6251\ \text{m}^3 / \text{jam} = 22{,}0739\ \text{ft}^3 / \text{jam}$

μ larutan HCl 35% pada 30°C = 1,8 cp

(Geankoplis, 1993, pp.876 A.3-13, pp.878, Fig. A.3-4)

Waktu pemompaan = 1 jam = 60 menit = 3600 dt

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk F} - 142}{\text{waktu pemompaan}}$$

$$\text{Rate pemompaan (Q)} = \frac{22{,}0739\ ft^3/jam}{3600\ dt/jam} = 0{,}0061\ ft^3/dt$$

ID optimum $= 3{,}9 \,.\, Q^{0,45} \,.\, \rho^{0,13}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9 \,.\, (0{,}0061\ ft^3/dt)^{0,45} \,.\, (72{,}9208\ lb/ft^3)^{0,13}$

$= 0{,}6881$ in

Maka dipilih pipa ¾ in sch. 80 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 0,742 in = 0,0618 ft = 0,0188 m

OD = 1,050 in = 0,0875 ft = 0,0267 m

Luas penampang (A) = 0,003 ft^2

Kecepatan aliran mula-mula = $v_1 = 0$

$$v_2 = \frac{Q}{A} = \frac{0{,}0061\ ft^3/dt}{0{,}003\ ft^2} = 2{,}0439\ ft/dt$$

$$N_{Re} = \frac{ID \,.\, v_2 \,.\, \rho_{campuran}}{\mu_{campuran}} = \frac{0{,}0618\ ft \,.\, 2{,}0439\ ft/dt \,.\, 72{,}9208\ lb/ft^3}{1{,}8\ cp \,.\, 6{,}72 \,.\, 10^{-4}\ lb/ft\,.\,dt\,.\,cp} = 7618{,}8352$$

$N_{Re} > 2100$ → aliran turbulen → dari Geankoplis, 1993, pp. 88, fig. 2.10-3 diperoleh :

Digunakan pipa commercial steel, e = 4,6 .10^{-5} → $\frac{e}{ID} = \frac{4,6.10^{-5}\,m}{0,0188\,m} = 0,0024$

Sehingga : f = 0,09

<u>Elbow 90°</u> : 6 buah → $\frac{L_e}{ID} = 35$ → $L_e = 6.35.0,0618$ ft = 12,9850 ft

(Geankoplis, 1993, pp. 93, table 2.10-1)

<u>Gate valve</u> : 2 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 2 . 9 . 0,0618 ft = 1,1130 ft

Panjang total = 81 ft + 12,9850 ft + 1,1130 ft = 95,0980 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0,09.(2,0439\ ft/dt)^2.95,0980\ ft}{32,1740\,lb.ft/lb_f.dt^2.0,0618\ ft}$$

$$f = 35,9441\ ft.lb_f/lb$$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C.v^2}{2.g_c.\alpha}$$ → untuk aliran turbulen α = 1 dan K_C = 0,55

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0,55.(2,0439\ ft/dt)^2}{2.32,1740\,lb.ft/lb_f.dt^2.1}$$

$$f_C = 0,0357\ ft.lb_f/lb$$

c. **Friksi karena perluasan (enlargement)**

$$f_e = \frac{(v_1 - v_2)^2}{2.g_c.\alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 2{,}0439\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2.1}$$

$$f_e = 0{,}0649\ ft.lb_f/lb$$

$\Sigma F = f + f_C + f_e = (35{,}9441 + 0{,}0357 + 0{,}0649)\ ft.lb_f/lb = 36{,}0448\ ft.lb_f/lb$

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$31{,}0772\ ft + \frac{0^2 - (2{,}0439\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2} + 0 - 36{,}0448\ ft.lb_f/lb = W_S$$

$$W_S = -5{,}0325\ ft.lb_f/lb$$

$$m_1 = \frac{730\ kg}{3600\ dt} = 0{,}2028\ kg/dt = 0{,}4471\ lb/dt$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S.m_1}{\eta.550} = \frac{5{,}0325\ ft.lb_f/lb.0{,}4471\ lb/dt}{0{,}20.550} = 0{,}0205\ ft.lb_f/dt$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%} 0{,}0205\ hp = 0{,}0241\ hp$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0241 hp × 2 = 0,0481 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

35. Pompa (L – 144)

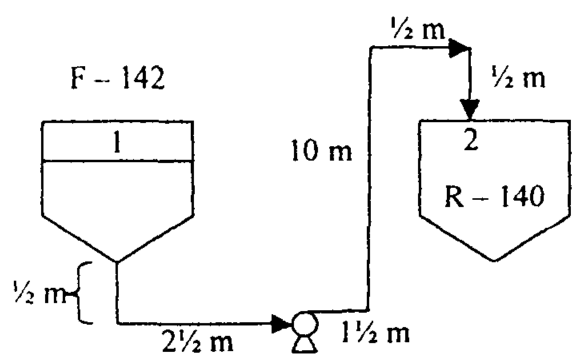
Fungsi : memompa larutan HCl dari Tangki Pengencer F – 142 menuju ke Reaktor R – 140

Tipe : gear pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas tinggi (2,5 – 1500 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 2½ m + 1½ m + 10 m + ½ m + ½ m

= 15½ m = 50,8524 ft ≈ 51 ft

Jumlah elbow = 6 buah

Jumlah valve = 2 buah (gate valve)

Tinggi feed masuk (Z_2) = 9,5 m = 31,1676 ft

Dari perancangan Tangki Pengencer F – 142 diperoleh H_{liquid} total = 11,7335 ft

Z_1 = ½ m + 11,7335 ft = 1,6404 ft + 11,7335 ft = 13,3739 ft

$\Delta Z = Z_2 - Z_1$

$= 31{,}1676 \text{ ft} - 13{,}3739 \text{ ft}$

$= 17{,}7937 \text{ ft}$

Menghitung volume bahan masuk R – 140

ρ larutan HCl $= 1{,}0103 \text{ kg / lt} = 63{,}0913 \text{ lb / ft}^3$

$$\text{Volume bahan masuk R} - 140 = \frac{\text{massa bahan masuk R} - 140}{\rho \text{ larutan HCl}}$$

$$= \frac{5600{,}07 \text{ kg / jam}}{1010{,}3398 \text{ kg / m}^3}$$

$$= 5{,}5428 \text{ m}^3 \text{ / jam} = 195{,}7189 \text{ ft}^3 \text{ / jam}$$

μ larutan HCl = 15,0450 cp

Waktu pemompaan = 1 jam = 60 menit = 3600 dt

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk R} - 140}{\text{waktu pemompaan}}$$

$$\text{Rate pemompaan (Q)} = \frac{195{,}7189 \text{ ft}^3 \text{ / jam}}{3600 \text{ dt / jam}} = 0{,}0544 \text{ ft}^3 \text{ / dt}$$

ID optimum $= 3{,}9 \cdot Q^{0{,}45} \cdot \rho^{0{,}13}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9 \cdot (0{,}0544 \text{ ft}^3 \text{ / dt})^{0{,}45} \cdot (63{,}0913 \text{ lb / ft}^3)^{0{,}13}$

$= 1{,}8028 \text{ in}$

Maka dipilih pipa 2 in sch. 80 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 1,939 in = 0,1616 ft = 0,0493 m

OD = 2,375 in = 0,1979 ft = 0,0603 m

Luas penampang (A) = 0,0205 ft^2

Kecepatan aliran mula-mula = v_1 = 0

$$v_2 = \frac{Q}{A} = \frac{0{,}0544\ ft^3/dt}{0{,}0205\ ft^2} = 2{,}6520\ ft/dt$$

$$N_{Re} = \frac{ID.v_2.\rho_{campuran}}{\mu_{campuran}} = \frac{0{,}1616\ ft.2{,}6520\ ft/dt.63{,}0913\ lb/ft^3}{15{,}0450.cp.\ 6{,}72.10^{-4}\ lb/ft.dt.cp} = 2674{,}1252$$

N_{Re} > 2100 → aliran turbulen → dari Geankoplis, 1993, pp. 88, fig. 2.10-3 diperoleh :

Digunakan pipa commercial steel, e = 4,6 . 10^{-5} , $\frac{e}{ID} = \frac{4{,}6.10^{-5}\ m}{0{,}0493\ m} = 9{,}3399.10^{-4}$

Sehingga : f = 0,0125

Elbow 90° : 6 buah → $\frac{L_e}{ID} = 35$ → $L_e = 6.35.0{,}1616\ ft = 33{,}9325\ ft$

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 2 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 2 . 9 . 0,1616 ft = 2,9085 ft

Panjang total = 51 ft + 33,9325 ft + 2,9085 ft = 87,8410 ft

a. **Friksi karena gesekan dalam pipa**

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0{,}0125.(2{,}6520\ ft/dt)^2.87{,}8410\ ft}{32{,}1740\ lb.ft/lb_f.dt^2.0{,}1616\ ft}$$

$$f = 2{,}9709\ ft.lb_f/lb$$

b. **Friksi karena kontraksi dari tangki ke pipa**

$$f_C = \frac{K_C.v^2}{2.g_c.\alpha}$$ → untuk aliran turbulen α = 1 dan K_C = 0,55

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0{,}55.(2{,}6520\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2.1}$$

$$f_C = 0{,}0601\ ft.lb_f/lb$$

c. **Friksi karena perluasan (enlargement)**

$$f_e = \frac{(v_1 - v_2)^2}{2.g_c.\alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 2{,}6520\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2.1}$$

$$f_e = 0{,}1093\ ft.lb_f/lb$$

$\Sigma F = f + f_C + f_e$ = (2,9709 + 0,0601 + 0,1093) ft . lb_f/ lb = 3,1403 ft . lb_f/ lb

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$17{,}7937 \text{ ft} + \frac{0^2 - (2{,}6520 \text{ ft/dt})^2}{2.32{,}1740 \text{ lb.ft/lb}_f\text{.dt}^2} + 0 - 3{,}1403 \text{ ft.lb}_f\text{/lb} = W_S$$

$$W_S = 14{,}5441 \text{ ft.lb}_f\text{/lb}$$

Karena $W_S > 0$ maka tidak diperlukan pompa untuk mengalirkan bahan dari Tangki Pengencer F – 142 menuju ke Reaktor R – 140.

36. Pompa (L – 171)

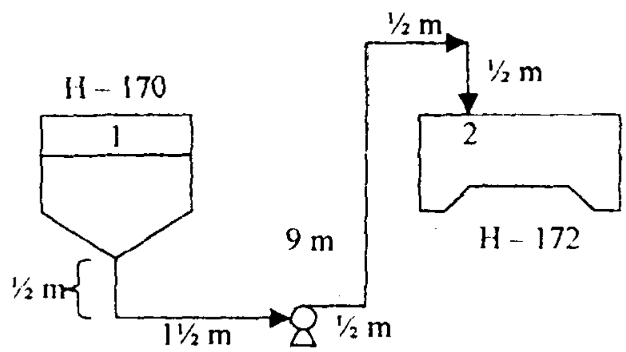
Fungsi : memompa larutan wet ossein dari Ekstraktor H – 170 menuju ke Centrifugal Separator H – 172

Tipe : centrifugal pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas rendah (< 2,5 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 1½ m + ½ m + 9 m + ½ m + ½ m

= 13 m = 42,6504 ft ≈ 43 ft

Jumlah elbow = 6 buah

Jumlah valve = 2 buah (gate valve)

Tinggi feed masuk (Z_2) = 8,5 m = 27,8868 ft

Dari perancangan Ekstraktor H – 170 diperoleh H_{liquid} = 8,5 ft

Z_1 = ½ m + 8,5 ft = 1,6404 ft + 8,5 ft = 10,1404 ft

$$\begin{aligned}\Delta Z &= Z_2 - Z_1 \\ &= 27{,}8868 \text{ ft} - 10{,}1404 \text{ ft} \\ &= 17{,}7464 \text{ ft}\end{aligned}$$

<u>Menghitung volume bahan masuk H – 172</u>

ρ bahan masuk H – 172 = 09693 kg / lt = 60,5279 lb / ft^3

$$\text{Volume bahan masuk H} - 172 = \frac{\text{massa bahan masuk H} - 172}{\rho \text{ bahan masuk H} - 172}$$

$$= \frac{2806{,}74 \text{ kg / jam}}{969{,}2896 \text{ kg / m}^3}$$

$$= 2{,}8957 \text{ m}^3 \text{ / jam} = 102{,}2481 \text{ ft}^3 \text{ / jam}$$

μ wet ossein = 7500 cp (www.norlandprod.com/twchrpts/fishgelrpt.html)

μ H_3PO_4 = 41,2 cp

μ H_2O pada 75°C = 0,38 cp

$$\mu_{larutan\ H_3PO_4}{}^{1/3} = X_{H_3PO_4} \cdot (\mu_{H_3PO_4})^{1/3} + X_{H_2O} \cdot (\mu_{H_2O})^{1/3}$$

$$\mu_{larutan\ H_3PO_4}{}^{1/3} = 5{,}4138.10^{-4} (41{,}2 \text{ cp})^{1/3} + 0{,}9995.(0{,}38 \text{ cp})^{1/3}$$

$$\mu_{larutan\ H_3PO_4} = 0{,}3823 \text{ cp}$$

$$\mu_{campuran}{}^{1/3} = X_{wet\ ossein} \cdot (\mu_{wet\ ossein})^{1/3} + X_{gelatin} \cdot (\mu_{gelatin})^{1/3} + X_{larutan\ H_3PO_4} \cdot (\mu_{larutan\ H_3PO_4})^{1/3}$$

$$\mu_{campuran}{}^{1/3} = 0{,}05 . (7500\ cp)^{1/3} + 0{,}4499 . (7500\ cp)^{1/3} + 0{,}5002 . (0{,}3823\ cp)^{1/3}$$

$$\mu_{campuran} = 2{,}4140\ cp$$

Waktu pemompaan = 1 jam = 60 menit = 3600 dt

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk H} - 172}{\text{waktu pemompaan}}$$

$$\text{Rate pemompaan (Q)} = \frac{102{,}2481\ ft^3 / jam}{3600\ dt / jam} = 0{,}0284\ ft^3 / dt$$

ID optimum $= 3{,}9 . Q^{0,45} . \rho^{0,13}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9 . (0{,}0284\ ft^3 / dt)^{0,45} . (60{,}5279\ lb / ft^3)^{0,13}$

$= 1{,}3388$ in

Maka dipilih pipa 1¼ in sch. 40 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 1,38 in = 0,1150 ft = 0,0351 m

OD = 1,660 in = 0,1383 ft = 0,0422 m

Luas penampang (A) = 0,0104 ft^2

Kecepatan aliran mula-mula = v_1 = 0

$$v_2 = \frac{Q}{A} = \frac{0{,}0284\ ft^3 / dt}{0{,}0104\ ft^2} = 2{,}7310\ ft / dt$$

$$N_{Re} = \frac{ID.v_2.\rho_{campuran}}{\mu_{campuran}} = \frac{0,1383\ ft.2,7310\ ft/dt.60,5279\ lb/ft^3}{2,4140.cp.\ 6,72.10^{-4}\ lb/ft.dt.cp} = 11718,2097$$

N_{Re} > 2100 → aliran turbulen → dari Geankoplis, 1993, pp. 88, fig. 2.10-3 diperoleh :

Digunakan pipa commercial steel, e = 4,6 .10^{-5} , $\frac{e}{ID} = \frac{4,6.10^{-5}\ m}{0,0422\ m} = 0,0013$

Sehingga : f = 0,007

<u>Elbow 90°</u> : 6 buah → $\frac{L_e}{ID} = 35$ → $L_e = 6.35.0,1150\ ft = 24,15\ ft$

(Geankoplis, 1993, pp. 93, table 2.10-1)

<u>Gate valve</u> : 2 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 2 . 9 . 0,1150 ft = 2,07 ft

Panjang total = 43 ft + 24,15 ft + 2,07 ft = 69,22 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0,007.(2,7310\ ft/dt)^2.69,22\ ft}{32,1740\ lb.ft/lb_f.dt^2.0,1150\ ft}$$

$f = 1,9534\ ft.lb_f/lb$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C . v^2}{2 . g_c . \alpha}$$ → untuk aliran turbulen α = 1 dan K_C = 0,55

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0,55 . (2,7310\ ft/dt)^2}{2 . 32,1740\ lb . ft/lb_f . dt^2 . 1}$$

$$f_C = 0,0637\ ft . lb_f / lb$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2 . g_c . \alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 2,7310\ ft/dt)^2}{2 . 32,1740\ lb . ft/lb_f . dt^2 . 1}$$

$$f_e = 0,1159\ ft . lb_f / lb$$

$\Sigma F = f + f_C + f_e$ = (1,9534 + 0,0637 + 0,1159) ft . lb_f / lb = 2,1131 ft . lb_f / lb

$$\Delta Z + \frac{\Delta v^2}{2 . g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$17,7464\ ft + \frac{0^2 - (2,7310\ ft/dt)^2}{2 . 32,1740\ lb . ft/lb_f . dt^2} + 0 - 2,1131\ ft . lb_f / lb = W_S$$

$$W_S = 15,4974\ ft . lb_f / lb$$

Karena $W_S > 0$ maka tidak diperlukan pompa untuk mengalirkan bahan dari Ekstraktor H – 170 menuju ke Centrifugal Separator H – 172.

37. Pompa (L – 174)

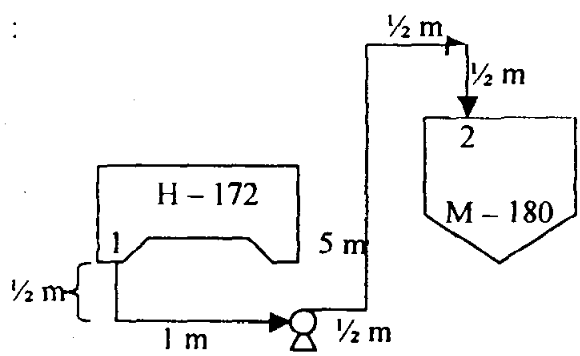
Fungsi : memompa gelatin yang terekstrak di Centrifugal Separator H – 172 menuju ke Mixer M – 180

Tipe : gear pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas tinggi (2,5 – 1500 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 1 m + ½ m + 5 m + ½ m + ½ m

= 8 m = 26,2464 ft ≈ 27 ft

Jumlah elbow = 6 buah

Jumlah valve = 2 buah (gate valve)

Tinggi feed masuk (Z_2) = 4,5 m = 14,7636 ft

Z_1 = ½ m = 1,6404 ft

$\Delta Z = Z_2 - Z_1$

$= 14{,}7636 \text{ ft} - 1{,}6404 \text{ ft}$

$= 13{,}1232 \text{ ft}$

Menghitung volume bahan masuk M – 180

ρ bahan masuk M – 180 = 0,9878 kg / lt = 61,6813 lb/ ft^3

$$\text{Volume bahan masuk M} - 180 = \frac{\text{massa bahan masuk M} - 180}{\rho \text{ bahan masuk M} - 180}$$

$$= \frac{2526{,}06 \text{ kg / jam}}{987{,}76 \text{ kg/ m}^3}$$

$$= 2{,}5574 \text{ m}^3 \text{ / jam} = 90{,}3023 \text{ ft}^3 \text{ / jam}$$

μ bahan masuk Mixer M – 180 = 1047,2813 cp

Waktu pemompaan = 1 jam = 60 menit = 3600 dt

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk M} - 180}{\text{waktu pemompaan}}$$

$$\text{Rate pemompaan (Q)} = \frac{90{,}3023 \text{ ft}^3 \text{ / jam}}{3600 \text{ dt / jam}} = 0{,}0251 \text{ ft}^3 \text{ / dt}$$

ID optimum $= 3{,}9 \cdot Q^{0,45} \cdot \rho^{0,13}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9 \cdot (0{,}0251 \text{ ft}^3 \text{ / dt})^{0,45} \cdot (61{,}6813 \text{ lb / ft}^3)^{0,13}$

$= 1{,}2693 \text{ in}$

Maka dipilih pipa 1¼ in sch. 80 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 1,278 in = 0,1065 ft = 0,0325 m

OD = 1,660 in = 0,1383 ft = 0,0422 m

Luas penampang (A) = 0,00891 ft^2

Kecepatan aliran mula-mula = v_1 = 0

$$v_2 = \frac{Q}{A} = \frac{0{,}0251\ ft^3/dt}{0{,}00891\ ft^2} = 2{,}8153\ ft/dt$$

$$N_{Re} = \frac{ID . v_2 . \rho_{campuran}}{\mu_{campuran}} = \frac{0{,}1065\ ft . 2{,}8153\ ft/dt . 61{,}6813\ lb/ft^3}{1047{,}2813 . cp.\ 6{,}72.10^{-4}\ lb/ft.dt.cp} = 26{,}2779$$

N_{Re} < 2100 → aliran laminar → dari Geankoplis, 1993, pp. 88, fig. 2.10-3

diperoleh : f = 0,1667

Elbow 90°: 6 buah → $\frac{L_e}{ID} = 35$ → $L_e = 6.35.0{,}1065\ ft = 22{,}3650\ ft$

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 2 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 2 . 9 . 0,1065 ft = 1,9170 ft

Panjang total = 27 ft + 22,3650 ft + 1,9170 ft = 51,2820 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0{,}1667.(2{,}8153\ ft/dt)^2.51{,}2820\ ft}{32{,}1740\ lb.ft/lb_f.dt^2.0{,}1065\ ft}$$

$$f = 39{,}5470\ ft.lb_f/lb$$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C.v^2}{2.g_c.\alpha}$$ → untuk aliran laminar α = ½ dan K_C = 0,55

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0,55.(2,8153\ ft/dt)^2}{2.32,1740\ lb.ft/lb_f.dt^2.1/2}$$

$$f_C = 0,1355\ ft.lb_f/lb$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2.g_c.\alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 2,8153\ ft/dt)^2}{2.32,1740\ lb.ft/lb_f.dt^2.1/2}$$

$$f_e = 0,2463\ ft.lb_f/lb$$

$\Sigma F = f + f_C + f_e$ = (39,5470 + 0,1355 + 0,2463) ft . lb_f/ lb = 39,9288 ft . lb_f/ lb

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$13,1232\ ft + \frac{0^2 - (2,8153\ ft/dt)^2}{2.32,1740\ lb.ft/lb_f.dt^2} + 0 - 39,9288\ ft.lb_f/lb = W_S$$

$$W_S = -26,9288\ ft.lb_f/lb$$

$$m_1 = \frac{2526,06\ kg}{3600\ dt} = 0,7017\ kg/dt = 1,5472\ lb/dt$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S \cdot m_1}{\eta \cdot 550} = \frac{26{,}9288 \text{ ft.lb}_f / \text{lb.}1{,}5472 \text{ lb/dt}}{0{,}20.550} = 0{,}3788 \text{ ft.lb}_f / \text{dt}$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%} 0{,}3788 \text{ hp} = 0{,}4456 \text{ hp}$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,4456 hp × 2 = 0,8912 hp → dipilih motor 1 hp

Bahan konstruksi : carbon steel

38. Pompa (L – 173)

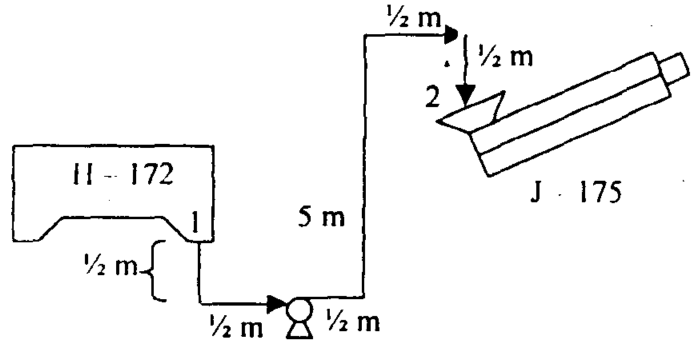
Fungsi : memompa wet ossein yang tidak terekstrak di Centrifugal Separator H – 172 menuju ke Screw Conveyor J – 175

Tipe : centrifugal pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas tinggi (2,5 – 1500 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + ½ m + ½ m + 5 m + ½ m + ½ m

= 7,5 m = 24,606 ft ≈ 25 ft

Jumlah elbow = 6 buah

Jumlah valve = 2 buah (gate valve)

Tinggi feed masuk (Z_2) = 4 m = 13,1232 ft

Z_1 = ½ m = 1,6404 ft

$\Delta Z = Z_2 - Z_1$

= 13,1232 ft – 1,6404 ft

= 11,4828 ft

Menghitung volume bahan masuk J – 175

ρ bahan masuk J – 175 = 0,9912 kg / lt = 61,8976 lb / ft^3

$$\text{Volume bahan masuk J} - 175 = \frac{\text{massa bahan masuk J} - 175}{\rho \text{ bahan masuk J} - 175}$$

$$= \frac{280{,}68 \text{ kg / jam}}{991{,}2238 \text{ kg / m}^3}$$

$$= 0{,}2832 \text{ m}^3 \text{ / jam} = 9{,}9988 \text{ ft}^3 \text{ / jam}$$

μ bahan masuk Mixer J – 175 = 1047,0664 cp

Waktu pemompaan = 1 jam = 60 menit = 3600 dt

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk J} - 175}{\text{waktu pemompaan}}$$

Rate pemompaan (Q) $= \dfrac{9{,}9988\ ft^3/jam}{3600\ dt/jam} = 0{,}0028\ ft^3/dt$

ID optimum $= 3{,}9 \cdot Q^{0,45} \cdot \rho^{0,13}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9 \cdot (0{,}0028\ ft^3/dt)^{0,45} \cdot (61{,}8976\ lb/ft^3)^{0,13}$

$= 0{,}4717$ in

Maka dipilih pipa 3/8 in sch. 40 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 0,493 in = 0,0411 ft = 0,0125 m

OD = 0,675 in = 0,0563 ft = 0,0171 m

Luas penampang (A) = 0,00133 ft^2

Kecepatan aliran mula-mula = $v_1 = 0$

$$v_2 = \frac{Q}{A} = \frac{0{,}0028\ ft^3/dt}{0{,}00133\ ft^2} = 2{,}0883\ ft/dt$$

$$N_{Re} = \frac{ID \cdot v_2 \cdot \rho_{campuran}}{\mu_{campuran}} = \frac{0{,}0411\ ft \cdot 2{,}0883\ ft/dt \cdot 61{,}8976\ lb/ft^3}{1047{,}0664 \cdot cp \cdot 6{,}72 \cdot 10^{-4}\ lb/ft \cdot dt \cdot cp} = 7{,}5472$$

$N_{Re} < 2100$ → aliran laminar → dari Geankoplis, 1993, pp. 88, fig. 2.10-3

diperoleh : f = 0,1667

Elbow 90°: 6 buah → $\dfrac{L_e}{ID} = 35$ → $L_e = 6 \cdot 35 \cdot 0{,}0411\ ft = 8{,}6275\ ft$

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 2 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

$Le = 2 \cdot 9 \cdot 0{,}0411 \text{ ft} = 0{,}7395 \text{ ft}$

Panjang total = 25 ft + 8,6275 ft + 0,7395 ft = 34,3670 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2 \cdot f \cdot v^2 \cdot L}{g_c \cdot D}$$

$$f = \frac{2 \cdot 0{,}1667 \cdot (2{,}0883 \text{ ft/dt})^2 \cdot 34{,}3670 \text{ ft}}{32{,}1740 \text{ lb.ft/lb}_f \cdot \text{dt}^2 \cdot 0{,}0411 \text{ ft}}$$

$$f = 37{,}8026 \text{ ft.lb}_f/\text{lb}$$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C \cdot v^2}{2 \cdot g_c \cdot \alpha}$$ → untuk aliran laminar α = ½ dan K_C = 0,55

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0{,}55 \cdot (2{,}0883 \text{ ft/dt})^2}{2 \cdot 32{,}1740 \text{ lb.ft/lb}_f \cdot \text{dt}^2 \cdot 1/2}$$

$$f_C = 0{,}0745 \text{ ft.lb}_f/\text{lb}$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2 \cdot g_c \cdot \alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 2{,}0883\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2.1/2}$$

$$f_e = 0{,}1355\ ft.lb_f/lb$$

$\Sigma F = f + f_C + f_e = (37{,}8026 + 0{,}0745 + 0{,}1355)\ ft\ .\ lb_f / lb = 38{,}0127\ ft\ .\ lb_f / lb$

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$11{,}4828\ ft + \frac{0^2 - (2{,}0883\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2} + 0 - 38{,}0127\ ft.lb_f/lb = W_S$$

$$W_S = -26{,}5976\ ft.lb_f/lb$$

$$m_l = \frac{280{,}68\ kg}{3600\ dt} = 0{,}0780\ kg/dt = 0{,}1719\ lb/dt$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S.m_l}{\eta.550} = \frac{26{,}5976\ ft.lb_f/lb.0{,}1719\ lb/dt}{0{,}20.550} = 0{,}0416\ ft.lb_f/dt$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%}0{,}0416\ hp = 0{,}0489\ hp$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0489 hp × 2 = 0,0978 hp → dipilih motor 0,5 hp

Bahan kosntruksi : carbon steel

39. Pompa (L – 183)

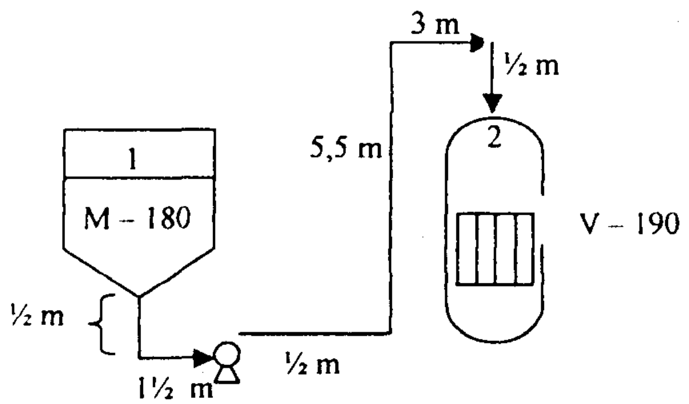
Fungsi : memompa gelatin dari Mixer M – 180 menuju ke Evaporator V – 190

Tipe : gear pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas tinggi (2,5 – 1500 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 1½ m + ½ m + 5,5 m + 3 m + ½ m

= 11,5 m = 37,7292 ft ≈ 38 ft

Jumlah elbow = 6 buah

Jumlah valve = 2 buah (gate valve)

Tinggi feed masuk (Z_2) = 5 m = 16,404 ft

Dari perancangan Mixer M – 180 diperoleh H_{liquid} = 9,2 ft

Z_1 = 9,2 ft + 0,5 m = 10,8404 ft

$\Delta Z = Z_2 - Z_1$

$= 16{,}404 \text{ ft} - 10{,}8404 \text{ ft}$

$= 5{,}5636 \text{ ft}$

<u>Menghitung volume bahan masuk V – 190</u>

ρ bahan masuk V – 190 = 0,9771 kg / lt = 61,0142 lb / ft^3

$$\text{Volume bahan masuk V} - 190 = \frac{\text{massa bahan masuk V} - 190}{\rho \text{ bahan masuk V} - 190}$$

$$= \frac{2526{,}84 \text{ kg / jam}}{977{,}0773 \text{ kg / m}^3}$$

$$= 2{,}5861 \text{ m}^3 \text{ / jam} = 91{,}3178 \text{ ft}^3 \text{ / jam}$$

μ gelatin = 7500 cp (www.norlandprod.com/twchrpts/fishgelrpt.html)

μ H_2O pada 64,2°C = 0,4025 cp (Geankoplis, 1993, pp. 855, A.2-4)

<u>Asumsi</u> ; dianggap bahan masuk Evaporator V – 190 berupa wet ossein dan air.

$$\mu_{campuran}{}^{1/3} = X_{wet\ ossein} \cdot (\mu_{wet\ ossein})^{1/3} + X_{H_2O} \cdot (\mu_{H_2O})^{1/3}$$

$$\mu_{campuran}{}^{1/3} = 0{,}4997 . (7500 \text{ cp})^{1/3} + 0{,}5003 . (0{,}4025 \text{ cp})^{1/3}$$

$$\mu_{campuran} = 1045{,}8172 \text{ cp}$$

Waktu pemompaan = 1 jam = 60 menit = 3600 dt

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk V} - 190}{\text{waktu pemompaan}}$$

$$\text{Rate pemompaan (Q)} = \frac{91{,}3178 \text{ ft}^3 \text{ / jam}}{3600 \text{ dt / jam}} = 0{,}0254 \text{ ft}^3 \text{ / dt}$$

ID optimum $= 3,9 \,.\, Q^{0,45} \,.\, \rho^{0,13}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3,9 \,.\, (0,0254\ ft^3 / dt)^{0,45} \,.\, (61,0142\ lb / ft^3)^{0,13}$

$= 1,2738$ in

Maka dipilih pipa 1¼ in sch. 80 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 1,278 in = 0,1065 ft = 0,0325 m

OD = 1,660 in = 0,1383 ft = 0,0422 m

Luas penampang (A) = 0,00891 ft^2

Kecepatan aliran mula-mula = $v_1 = 0$

$$v_2 = \frac{Q}{A} = \frac{0,0254\ ft^3/dt}{0,00891\ ft^2} = 2,8469\ ft/dt$$

$$N_{Re} = \frac{ID.\, v_2 \cdot \rho_{campuran}}{\mu_{campuran}} = \frac{0,1065\ ft.2,8469\ ft/dt.61,0142\ lb/ft^3}{1045,8172.cp.\ 6,72.10^{-4}\ lb/ft.dt.cp} = 26,3227$$

$N_{Re} < 2100$ → aliran laminar → dari Geankoplis, 1993, pp. 88, fig. 2.10-3

diperoleh : f = 0,1667

Elbow 90°: 7 buah → $\frac{L_e}{ID} = 35$ → $L_e = 7.35.0,1065\ ft = 26,0925\ ft$

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 2 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 2 . 9 . 0,1065 ft = 1,9170 ft

Panjang total = 30 ft + 26,0925 ft + 1,9170 ft = 58,0095 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0,1667.(2,8469\ ft/dt)^2.58,0095\ ft}{32,1740\ lb.ft/lb_f.dt^2.0,1065\ ft}$$

$$f = 45,7468\ ft.lb_f/lb$$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C.v^2}{2.g_c.\alpha}$$ → untuk aliran laminar α = ½ dan K_C = 0,55

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0,55.(2,8469\ ft/dt)^2}{2.32,1740\ lb.ft/lb_f.dt^2.1/2}$$

$$f_C = 0,1386\ ft.lb_f/lb$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2.g_c.\alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 2,8469\ ft/dt)^2}{2.32,1740\ lb.ft/lb_f.dt^2.1/2}$$

$$f_e = 0,2519\ ft.lb_f/lb$$

$\Sigma F = f + f_C + f_e$ = (45,7468 + 0,1386 + 0,2519) ft . lb_f / lb = 46,1373 ft . lb_f / lb

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$5{,}5636\ ft + \frac{0^2 - (2{,}8469\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2} + 0 - 46{,}1373\ ft.lb_f/lb = W_S$$

$$W_S = -40{,}6996\ ft.lb_f/lb$$

$$m_l = \frac{2526{,}84\ kg}{3600\ dt} = 0{,}7019\ kg/dt = 1{,}5477\ lb/dt$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S.m_l}{\eta.550} = \frac{40{,}6996\ ft.lb_f/lb.1{,}5477\ lb/dt}{0{,}20.550} = 0{,}5726\ ft.lb_f/dt$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%} 0{,}5726\ hp = 0{,}6737\ hp$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,6737 hp × 2 = 1,3474 hp → dipilih motor 1,5 hp

Bahan konstruksi : carbon steel

40. Ware House Tulang (F – 110)

Fungsi : untuk menyimpan bahan baku berupa tulang

Tipe : gedung dengan bahan konstruksi concrete beton

Dasar pemilihan : cocok untuk menyimpan bahan yang berbebtnuk padat seperti tulang dan tidak membutuhkan biaya yang terlalu besar

Kondisi operasi : 30°C

Jumlah : 1 buah

Perhitungan :

Rate tulang masuk $= 505,05 \text{ kg / jam . 24 jam / hari}$

$= 12121,2 \text{ kg / hari} = 26727,246 \text{ lb / hari}$

$\rho_{tulang} = 1,6346 \text{ kg / lt} = 102,0751 \text{ lb / ft}^3$

$$\text{Volume tulang} = \frac{\text{massa tulang}}{\rho_{tulang}} = \frac{505,05 \text{ kg/jam}}{1m6346 \text{ kg/lt}}$$

$$= 308,9701 \text{ lt/jam} = 10,91 \text{ ft}^3\text{/jam}$$

Diambil volume ruang kosong dalam tulang = 15% . volume tulang

$= 15\% . 10,91 \text{ ft}^3$

$= 1,6365 \text{ ft}^3$

$$\varepsilon = \text{void fraction} = \frac{\text{vol ruang kosong}}{\text{vol ruang kosong} + \text{vol tulang}} = \frac{1,6365 \text{ ft}^3}{1,6365 \text{ ft}^3 + 10,91 \text{ ft}^3} = 0,1304$$

$\rho_{bulk\ tulang} = 102,0751 \text{ lb / ft}^3 (1 - 0,1304) = 88,7609 \text{ lb / ft}^3$

$$\text{Volume total} = \frac{26727,2446 \text{ lb/hari}}{88,7609 \text{ lb/ft}^3} = 301,1150 \text{ ft}^3\text{/hari}$$

Catatan : ware house hanya digunakan untuk menampung tulang dalam waktu 24 jam

Volume Ware House F – 110 = 2 . volume tulang total

$= 2 . 301,1150 \text{ ft}^3 = 602,2299 \text{ ft}^3$

Ware House mempunyai alas bujursangkar dengan ketentuan :

Tinggi bangunan = 7,5 m

$$\text{Panjang} = \text{lebar} = \sqrt{\frac{602{,}2299\ ft^3}{15\ ft}} = 6{,}3363\ ft \approx 6{,}4\ ft = 1{,}9507\ m$$

Diambil panjang = lebar bangunan = 5 m

41. Tangki Penampung Produk (F – 196)

Fungsi : Untuk tempat penampungan produk berupa gelatin

Tipe : Tangki silinder dengan bagian bawah konis dan tutup atas berbentuk datar (flat)

Dasar pemilihan : cocok digunakan untuk menampung bahan yang berbentuk padat / solid

Jumlah : 1 buah

Perhitungan :

Suhu = 65,1°C

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft^3 (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft^3

(www.usd.edu/biol/courses/cellthics/cpa3answers.html)

ρ H_2O pada 65,1163°C = 0,9804 kg / lt = 61,2217 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Gelatin

Protein $= 146{,}46 \text{ kg} \rightarrow X_{protein} = \dfrac{\text{Massa protein}}{\text{Massa wet ossein}} = \dfrac{146{,}46 \text{ kg}}{1262{,}63 \text{ kg}} = 0{,}1160$

Lemak $= 5{,}05 \text{ kg} \rightarrow X_{lemak} = \dfrac{\text{Massa lemak}}{\text{Massa wet ossein}} = \dfrac{5{,}05 \text{ kg}}{1262{,}63 \text{ kg}} = 3{,}9996.10^{-3}$

H_2O $= 1111{,}12 \text{ kg} \rightarrow X_{H_2O} = \dfrac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \dfrac{1111{,}12 \text{ kg}}{1262{,}63 \text{ kg}} = 0{,}8800$

Gelatin $= 1262{,}63$ kg

$$\rho_{gelatin} = \frac{1}{X_{protein}\dfrac{1}{\rho_{protein}} + X_{lemak}\dfrac{1}{\rho_{lemak}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{gelatin} = \frac{1}{0{,}1160\dfrac{1}{0{,}8955 \text{ kg/lt}} + 3{,}9996.10^{-3}\dfrac{1}{0{,}9290 \text{ kg/lt}} + 0{,}88\dfrac{1}{0{,}9804 \text{ kg/lt}}}$$

$\rho_{gelatin} = 0{,}9695 \text{ kg/lt} = 60{,}5425 \text{ lb/ft}^3$

$Ca_3(PO_4)_2$ = 1,09 kg

H_2O = 7,58 kg

Massa bahan masuk total = 1262,63 kg + 1,09 kg + 7,58 kg = 1271,30 kg

Sehingga :

$X_{gelatin} = \dfrac{1262{,}63 \text{ kg}}{1271{,}30 \text{ kg}} = 0{,}9932$

$X_{padatan\ Ca_3(PO_4)_2} = \dfrac{1{,}09 \text{ kg}}{1271{,}30 \text{ kg}} = 8{,}57.10^{-4}$

$$X_{H_2O} = \frac{7{,}58\ kg}{1271{,}30\ kg} = 0{,}00596$$

$$\rho_{campuran} = \frac{1}{X_{gelatin}\dfrac{1}{\rho_{gelatin}} + X_{Ca_3(PO_4)_2\,(s)}\dfrac{1}{\rho_{Ca_3(PO_4)_2\,(s)}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$

(Perry, 1999)

$$\rho_{campuran} = \frac{1}{0{,}9932\dfrac{1}{0{,}9695\,kg/lt} + 8{,}57.10^{-4}\dfrac{1}{3{,}04\,kg/lt} + 0{,}00596\dfrac{1}{0{,}9804\,kg/lt}}$$

$$\rho_{campuran} = 0{,}9702\,kg/lt = 60{,}5819\ lb/ft^3$$

Tangki dirancang untuk menyimpan produk selama 7 hari.

$$\text{Volume produk} = \frac{\text{massa produk}}{\rho_{campuran}}$$

$$= \frac{1271{,}30\,kg/jam.7\,hari.24\,jam/hari}{0{,}9702\ kg/lt}$$

$$= 220148{,}96\ lt/hari = 7773{,}62\ ft^3/hari$$

Asumsi : Ruang kosong = 20 % volume tangki

$$\text{Volume tangki} = \frac{100\%}{80\%}7773{,}62\ ft^3 = 9717{,}03\ ft^3$$

$\frac{H}{D} = 1$, sehingga : Volume tangki $= \frac{\pi}{4}.D^2.H$

$$9717{,}03\ ft^3 = \frac{\pi}{4}.D^2.D$$

$$D^3 = 12367{,}125\ ft^3$$

D = 23,1254 ft ≈ 23,2 ft = 7,0714 m

H = 23,2 ft = 7,0714 m

Bahan konstruksi : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}$ in

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$$7773{,}62\ ft^3 = \frac{\pi}{4} . D^2 . H_l$$

$$7773{,}62\ ft^3 = \frac{\pi}{4} . (23{,}2\ ft)^2 . H_l$$

$$H_l = 18{,}3816\ ft$$

$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

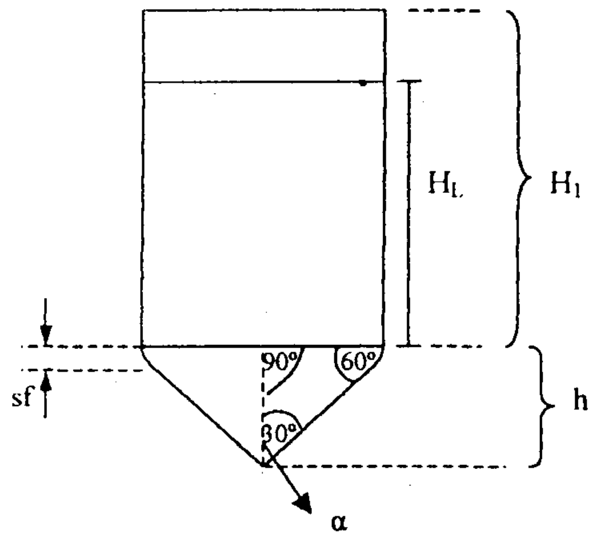
$$t_S = \frac{60{,}5819\ lb/ft^3 . (18{,}3816\ ft).(12 . 23{,}2)\ in}{2 . 18750\ lb/in^2 . 0{,}80 . (144\ in^2/ft^2)} + \frac{1}{8} in$$

t_S = 0,1968 in → diambil t_S $\frac{3}{16}$ in

Penentuan tebal head (t_h)

Tutup atas digunakan flat head (tutup atas berbentuk datar) dengan tebal diambil sama dengan tebal shell yaitu $\frac{3}{16}$ in.

Penentuan tebal konis (t_k)



sf = 2 in

$$\tan x = \frac{h - sf}{0{,}5.D} \quad ; \ h : \text{tinggi konis, ft}$$

$$h = \tan 60^\circ.0{,}5.23{,}2\,ft + \frac{2}{12}\,ft$$

$$h = 20{,}2780 \text{ ft}$$

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(23{,}2 \text{ ft})^2.20{,}2780 \text{ ft}$$

$$= 2858{,}5453 \text{ ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$7773{,}62\ ft^3 - 2858{,}5453\ ft^3 = \frac{1}{4}.\pi.(23{,}2\ ft)^2.H_L$$

$$H_L = 11{,}6222\ ft$$

Tinggi liquid total (H)

$$H = H_L + h$$

$$H = 11{,}6222\ ft + 20{,}2780\ ft$$

$$H = 31{,}9003\ ft \approx 32\ ft$$

$$P_{hidrostatis} = \frac{\rho.H}{144} = \frac{60{,}5819\ lb/ft^3.32\ ft}{144\ in^2/ft^2} = 13{,}4626\ psia$$

$$t_k = \frac{P.D}{2.\cos\alpha(f.E - 0{,}6.P)} + C$$ (Brownell & Young, 1959, pp.254, eq. 13.1)

$$t_k = \frac{13{,}4626\ lb/in^2.23{,}2.12\ in}{2.\cos 30^\circ(18750\ lb/in^2.0{,}8 - 0{,}6.13{,}4626\ lb/in^2)} + \frac{1}{8}\ in$$

$t_k = 0{,}2694\ in$ → diambil $t_k = \frac{5}{16}\ in$

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tebal head + tinggi silinder + tinggi konis + jarak pemasangan pipa

= 0,1875 ft + 23,2 ft + 20,2780 ft + 3 ft

= 46,6655 ft

42. Screw Conveyor (J – 191)

Fungsi : mengangkut gelatin dari Evaporator V – 190 menuju ke Spray Dryer B – 194

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

Perhitungan :

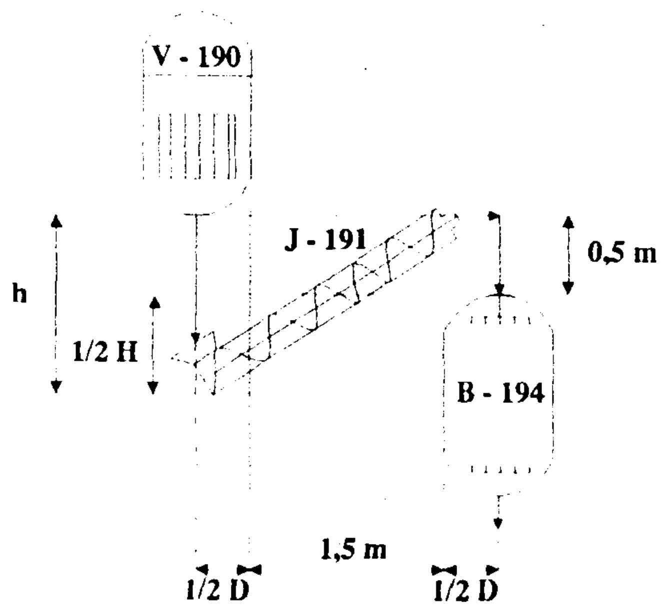
Kapasitas = 1642,66 kg / jam

Jarak Evaporator ke Spray Dryer

$= \frac{1}{2} D_{evaporator} + 1,5 \text{ m} + \frac{1}{2} D_{Spray\ Dryer}$

$= \frac{1}{2} \cdot 5,9481 \text{ ft} + 1,5 \text{ m} + \frac{1}{2} \cdot 6,7057 \text{ m}$

$= 5,7593 \text{ m} = 18,8953 \text{ ft}$



h = ½ H Spray Dryer + ½ m

h = 0,5 . 8,8 ft + ½ m

h = 6,0404 ft

Panjang Screw Conveyor J – 191 = $\sqrt{6{,}0404^2 + 18{,}8953^2}$ ft = 19,8373 ft ≈ 20 ft

Sudut Screw Conveyor J – 191 :

$$\tan x = \frac{6{,}0404 \text{ ft}}{18{,}8953 \text{ ft}} = 0{,}3197$$

$$x = 17{,}73°$$

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft³ (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft³

(www.usd.edu/biol/courses/cellthies/cpa3answers.html)

ρ H_2O pada 75°C = 0,99781 kg / lt = 62,3088 lb / ft³

(Geankoplis, 1993, pp.855, A.2-3)

Gelatin

Protein = 146,46 kg → $X_{protein} = \frac{\text{Massa protein}}{\text{Massa wet ossein}} = \frac{146{,}46 \text{ kg}}{1262{,}63 \text{ kg}} = 0{,}1160$

Lemak = 5,05 kg → $X_{lemak} = \frac{\text{Massa lemak}}{\text{Massa wet ossein}} = \frac{5{,}05 \text{ kg}}{1262{,}63 \text{ kg}} = 3{,}9996.10^{-3}$

H_2O = 1111,12 kg → $X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \frac{1111{,}12 \text{ kg}}{1262{,}63 \text{ kg}} = 0{,}8800$

Gelatin = 1262,63 kg

$$\rho_{gelatin} = \frac{1}{X_{protein}\frac{1}{\rho_{protein}} + X_{lemak}\frac{1}{\rho_{lemak}} + X_{H_2O}\frac{1}{\rho_{H_2O}}} \quad \text{(Perry, 1999)}$$

$$\rho_{gelatin} = \frac{1}{0{,}1160\frac{1}{0{,}8955\,kg/lt} + 3{,}9996.10^{-3}\frac{1}{0{,}9290\,kg/lt} + 0{,}88\frac{1}{0{,}99781\,kg/lt}}$$

$$\rho_{gelatin} = 0{,}9845\,kg/lt = 61{,}4759\ lb/ft^3$$

Larutan $Ca_3(PO_4)_2$

$Ca_3(PO_4)_2$ = 0,01 kg → $X_{Ca_3(PO_4)_2} = \frac{\text{Massa } Ca_3(PO_4)_2}{\text{Massa lar } Ca_3(PO_4)_2} = \frac{0{,}01\,kg}{378{,}94\ kg} = 2{,}64.10^{-5}$

H_2O = 378,94 kg → $X_{H_2O} = \frac{\text{Massa } H_2O}{\text{Massa lar } Ca_3(PO_4)_2} = \frac{378{,}94\ kg}{378{,}95\ kg} = 0{,}9999$

Larutan $Ca_3(PO_4)_2$ = 378,95 kg

$$\rho_{lar.Ca_3(PO_4)_2} = \frac{1}{X_{Ca_3(PO_4)_2}\frac{1}{\rho_{Ca_3(PO_4)_2}} + X_{H_2O}\frac{1}{\rho_{H_2O}}} \quad \text{(Perry, 1999)}$$

$$\rho_{lar.Ca_3(PO_4)_2} = \frac{1}{2{,}64.10^{-5}\frac{1}{3{,}04\ kg/lt} + 0{,}9999\frac{1}{0{,}99781\,kg/lt}}$$

$$\rho_{lar.Ca_3(PO_4)_2} = 0{,}9978\,kg/lt = 62{,}3096\ lb/ft^3$$

Padatan $Ca_3(PO_4)_2$

$Ca_3(PO_4)_2$ = 1,08 kg

Massa bahan masuk total = 1262,63 kg + 378,95 kg + 1,08 kg = 1642,66 kg

<u>Sehingga</u> :

$$X_{gelatin} = \frac{1262,63\ kg}{1642,66\ kg} = 0,7686$$

$$X_{larutan\ Ca_3(PO_4)_2} = \frac{378,95\ kg}{1642,66\ kg} = 0,2307$$

$$X_{padatan\ Ca_3(PO_4)_2} = \frac{1,08\ kg}{1642,66\ kg} = 6,5747.10^{-4}$$

$$\rho_L = \frac{1}{X_{gelatin}\dfrac{1}{\rho_{gelatin}} + X_{lar.Ca_3(PO_4)_2}\dfrac{1}{\rho_{lar.Ca_3(PO_4)_2}} + X_{Ca_3(PO_4)_{2\,(s)}}\dfrac{1}{\rho_{Ca_3(PO_4)_{2(s)}}}}$$

(Perry, 1999)

$$\rho_L = \frac{1}{0,7686\dfrac{1}{0,9845\,kg/lt} + 0,2307\dfrac{1}{0,9978\,kg/lt} + 6,5747.10^{-4}\dfrac{1}{3,04\,kg/lt}}$$

$$\rho_L = 0,988\,kg/lt = 61,6939\ lb/ft^3$$

$$\text{Massa yang dipindahkan} = 1642,66\frac{kg}{jam}.2,205\frac{lb}{kg}.\frac{1\ jam}{60\ menit} = 60,3678\,lb/menit$$

$$\text{Volume yang dipindahkan} = \frac{1642,66\,kg/jam}{0,988\,kg/lt} = 1730,4467\ lt/jam = 61,1033\,ft^3/jam$$

Maka kapasitas Screw Conveyor J – 191 = 61,1033 ft^3 / jam

Waktu pemindahan = 60 menit

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

Power :

$hp = \dfrac{Co \cdot Ca \cdot L}{33000}$, dimana : Co : koefisien (untuk wet ossein Co = 1,3)

Ca : kapasitas Screw Conveyor (= 60,3678 lb/menit)

L : panjang Screw Conveyor (= 20 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3 \cdot 60{,}3678\,lb/menit \cdot 20\,ft}{33000} = 0{,}0476\ hp$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{0{,}0476\ hp}{0{,}8} = 0{,}0595$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0595 hp × 2 = 0,1189 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

43. Screw Conveyor (J – 195)

Fungsi : mengangkut gelatin dari Spray Dryer B – 194 menuju ke Tangki Penampung F – 196

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

Perhitungan :

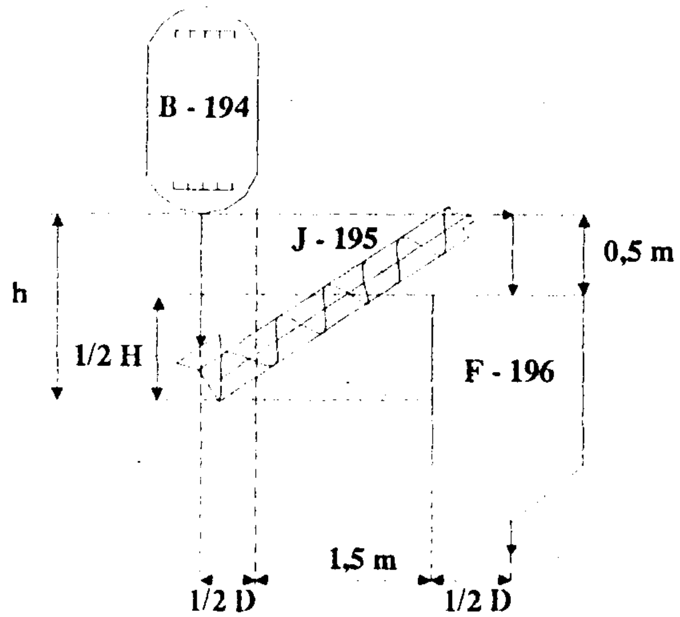
Kapasitas = 1144,17 kg / jam

Jarak Spray Dryer ke Tangki Penampung

= ½ $D_{Spray\ Dryer}$ + 1,5 m + ½ $D_{Tangki\ Penampung}$

= ½ . 6,7057 ft + 1,5 m + ½ . 7,0714 m

= 8,3886 m = 27,5212 ft



h = ½ H Tangki Penampung + ½ m

h = 0,5 . 23,2 ft + ½ m

h = 13,2404 ft

Panjang Screw Conveyor J – 195 = $\sqrt{27{,}5212^2 + 13{,}2404^2}$ ft = 30,5405 ft ≈ 31 ft

Sudut Screw Conveyor J – 195 :

$$\tan x = \frac{13{,}2404 \text{ ft}}{27{,}5212 \text{ ft}} = 0{,}4811$$

$$x = 25{,}69°$$

$\rho_{protein}$ = 0,8955 kg / lt = 55,9200 lb / ft^3 (www.ccp4.ac.uk)

ρ_{lemak} = 0,9290 kg / lt = 58,0120 lb / ft^3

(www.usd.edu/biol/courses/cellthics/cpa3answers.html)

ρ H_2O pada 70°C = 0,97781 kg / lt = 61,0599 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Gelatin

Protein = 146,46 kg → $X_{protein} = \dfrac{\text{Massa protein}}{\text{Massa wet ossein}} = \dfrac{146{,}46 \text{ kg}}{1262{,}63 \text{ kg}} = 0{,}1160$

Lemak = 5,05 kg → $X_{lemak} = \dfrac{\text{Massa lemak}}{\text{Massa wet ossein}} = \dfrac{5{,}05 \text{ kg}}{1262{,}63 \text{ kg}} = 3{,}9996.10^{-3}$

H_2O = 1111,12 kg → $X_{H_2O} = \dfrac{\text{Massa } H_2O}{\text{Massa wet ossein}} = \dfrac{1111{,}12 \text{ kg}}{1262{,}63 \text{ kg}} = 0{,}8800$

Gelatin = 1262,63 kg

$$\rho_{gelatin} = \frac{1}{X_{protein}\dfrac{1}{\rho_{protein}} + X_{lemak}\dfrac{1}{\rho_{lemak}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$ (Perry, 1999)

$$\rho_{gelatin} = \frac{1}{0{,}1160\dfrac{1}{0{,}8955 \text{ kg/lt}} + 3{,}9996.10^{-3}\dfrac{1}{0{,}9290 \text{ kg/lt}} + 0{,}88\dfrac{1}{0{,}97781 \text{ kg/lt}}}$$

$$\rho_{gelatin} = 0{,}9673 \text{ kg/lt} = 60{,}4032 \text{ lb/ft}^3$$

$Ca_3(PO_4)_{2\,(s)}$ = 1,09 kg

H_2O = 7,58 kg

Massa bahan masuk total = 1262,63 kg + 1,09 kg + 7,58 kg = 1271,30 kg

<u>Sehingga</u> :

$$X_{gelatin} = \frac{1262,63\ kg}{1271,30\ kg} = 0,9932$$

$$X_{padatan\ Ca_3(PO_4)_2} = \frac{1,09\ kg}{1271,30} = 8,57.10^{-4}$$

$$X_{H_2O} = \frac{7,58\ kg}{1271,30kg} = 0,00596$$

$$\rho_{campuran} = \frac{1}{X_{gelatin}\dfrac{1}{\rho_{gelatin}} + X_{Ca_3(PO_4)_2\,(s)}\dfrac{1}{\rho_{Ca_3(PO_4)_2\,(s)}} + X_{H_2O}\dfrac{1}{\rho_{H_2O}}}$$

(Perry, 1999)

$$\rho_{campuran} = \frac{1}{0,9932\dfrac{1}{0,9673\,kg/lt} + 8,57.10^{-4}\dfrac{1}{0,3,04\,kg/lt} + 0,00596\dfrac{1}{0,97781\,kg/lt}}$$

$$\rho_{campuran} = 0,9679\,kg/lt = 60,4424\ lb/ft^3$$

$$\text{Massa yang dipindahkan} = 1271,30\frac{kg}{jam}.2,205\frac{lb}{kg}.\frac{1\ jam}{60\ menit} = 46,7203\,lb/menit$$

$$\text{Volume yang dipindahkan} = \frac{46,7203\,kg/jam}{0,9679\,kg/lt} = 48,2687\,lt/jam = 1366,3684\,ft^3/jam$$

Maka kapasitas Screw Conveyor J – 195 = 1366,3684 ft^3 / jam

Waktu pemindahan = 60 menit

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

Power :

$$hp = \frac{Co . Ca . L}{33000}$$, dimana : Co : koefisien (untuk wet ossein Co = 1,3)

Ca : kapasitas Screw Conveyor (= 46,7203 lb/menit)

L : panjang Screw Conveyor (= 31 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3 . 46{,}7203 \text{ lb/menit} . 31 \text{ ft}}{33000} = 0{,}0571 \text{ hp}$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{0{,}0571 \text{ hp}}{0{,}8} = 0{,}0713$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0713 hp × 2 = 0,1426 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

APPENDIX 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 Pabrik Gelatin ini didasarkan pada harga alat yang terdapat pada pustaka sebagai berikut :

a. Garret, D.E., 1989, "Chemichal Engineering Economics", Van Nostrand Reinhold, New York.

b. Peters,M.S., Timmerhouse, K.D., 1991, "Plant Design and Economics for Chemical Engineers", 4^{th} ed., Mc.Graw Hill Co., Singapore.

c. Ulrich, G.D., 1984, "A Guide To Chemical Engineering Process Design and Economic", John Willey and Sons, Singapore.

A. PERHITUNGAN HARGA PERALATAN

Dalam perhitungan ini digunakan indeks harga sebagai berikut:

- Marshall & Swift Installed Equipment 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 (Mei 2002) = 392,7 (Chemical Engineering, Agustus 2002)

Contoh perhitungan :

Nama alat : Jaw Crusher (C – 120)

Fungsi : mengecilkan ukuran tulang yang akan dimasukkan ke dalam Screen H – 122

Tipe : Dodge jaw crusher

Kapasitas : 631,31 kg / jam

Jumlah : 1 buah

Harga tahun 1990 : $US 12500 (Peter & Timmerhaus, fig. 14-79, p.563)

Harga alat saat ini $= \frac{1073,5}{904} \times \$\ 12500 = \$\ 14843,75$

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, @ Rp	Total Rp
Belt conveyor	J-111	1	15.240.600	15.240.600
Crusher	C-120	1	94.500.000	94.500.000
Belt conveyor	J-121	1	15.240.600	15.240.600
Screen	H-122	1	186.888.330	186.888.330
Screw conveyor	J-123	1	16.193.160	16.193.160
Belt conveyor	J-131	1	15.240.600	15.240.600
Tumbling mill	C-130	1	748.125.000	748.125.000
Belt conveyor	J-132	1	15.240.600	15.240.600
Screen	H-133	1	186.888.330	186.888.330
Screw conveyor	J-134	1	16.193.160	16.193.160
Screw conveyor	J-135	1	16.193.160	16.193.160
Tangki penampung larutan HCl	F-143	1	463.124.970	463.124.970
Pompa	L-145	1	999.990	999.990
Tangki pengencer	F-142	1	213.750.000	213.750.000
Pompa	L-144	1	999.990	999.990
Reaktor	R-140	1	249.374.970	249.374.970
Pompa	L-141	1	999.990	999.990
Centrifugal separator	H-150	1	178.125.030	178.125.030
Screw conveyor	J-151	1	16.193.160	16.193.160
Mixer	M-160	1	160.312.500	160.312.500
Pompa	L-161	1	1.800.000	1.800.000

Nama alat	Kode	Jumlah	Harga tahun 2002, @ Rp	Total Rp
Filter press	H-162	3	64.125.000	192.375.000
Srew conveyor	J-163	1	16.193.160	16.193.160
Ekstraktor	H-170	1	356.249.970	356.249.970
Pompa	L-171	1	999.990	999.990
Tangki umpan H_3Po_4	F-176	1	53.437.500	53.437.500
Tangki umpan $Ca(OH)_2$	F-182	1	53.437.500	53.437.500
Screw conveyor	J-181	1	16.193.160	16.193.160
Centrifugal separator	H-172	1	106875.000	106875.000
Mixer	M-180	1	160.312.500	160.312.500
Pompa	L-174	1	1.800.000	1.800.000
Pompa	L-173	1	999.990	999.990
Screw conveyor	J-175	1	16.193.160	16.193.160
Pompa	L-183	1	999.990	999.990
Heater	E-198	1	14.249.970	14.249.970
Barometric condenser	X-192	1	11.756.250	11.756.250
Evaporator	V-190	1	748.125.000	748.125.000
Ejector	X-193	1	5.343.750	5.343.750
Screw conveyor	J-191	1	16.193.160	16.193.160
Spray dryer	B-194	1	998.881.875	998.881.875
Cyclone separator	H-197	1	25.200.000	25.200.000

Nama alat	Kode	Jumlah	Harga tahun 2002, @ Rp	Total Rp
Screw conveyor	J-195	1	16.193.160	16.193.160
Tangki penampung produk	F-196	1	3.206.250.000	3.206.250.000
TOTAL				**8.629.884.225**

Tabel D.2 Harga Peralatan Utilitas

No	Nama alat	Kode	Jumlah	Total, Rp
1.	Settling Tank	F – 210	1	2.600.000
2.	River Pump	L – 211	1	1.000.000
3.	Clarifier	H – 212	1	5.250.000
4.	Sand Filter	H – 213	1	13.500.000
5.	Water Storage Tank	F – 214	1	2.600.000
6.	Process Water Pump	L – 215	1	1.000.000
7.	Softener Pump	L – 216	1	1.000.000
8.	Water Softener Tank	F – 220	1	12.500.000
9.	Boiler Feed Water Tank	1 – 221	1	720.000
10.	Boiler Water Pump	L – 222	1	1.000.000
TOTAL				**41.700.000**

Total harga peralatan = Harga Peralatan Poses + Harga Peralatan Utilitas

= Rp. 8.629.884.225- + Rp. 41.700.000,-

= Rp. 8.671.054.225-

B. PERHITUNGAN HARGA TANAH DAN BANGUNAN

Luas tanah = 10.000 m^2

Luas bangunan = 4.400 m^2

Harga tanah = Rp. 500.000,- /m^2

Harga bangunan = Rp. 750.000,-/m^2

Jadi :

Harga tanah = 10.000 m^2 × Rp.500.000,-/m^2 = Rp. 5.000.000.000,-

Harga bangunan = 4.400 m^2 × Rp. 750.000,-/m^2 = Rp. 3.300.000.000,-

Total harga tanah dan bangunan = Rp. 5.000.000.000,- + Rp. 3.300.000.000,-

= Rp. 8.300.000.000,-

C. PERHITUNGAN HARGA BAHAN BAKU DAN HARGA JUAL PRODUK

- **Harga Bahan Baku**

1. Tulang

   Harga : Rp. 1.200,- / kg

   Kebutuhan : 12.121,2 kg / hari

   Total : Rp. 4.799.995.200,- / tahun

2. HCl

   Harga : Rp. 2.500,- / lt

   Kebutuhan : 16.688,532 lt / hari

   Total : Rp. 13.768.038.900,- / tahun

3. H_3PO_4

Harga : Rp. 6500,- / kg

Kebutuhan : 19,2 kg / hari

Total : Rp. 41.184.000,- / tahun

4. $Ca(OH)_2$

Harga : Rp. 5000,- / kg

Kebutuhan : 18,72 kg / hari

Total : Rp. 30.888.000,- / tahun

Total harga bahan baku per tahun

= Rp. 4.799.995.200,- + Rp. 13.768.038.900,- + Rp. 41.184.000,- + Rp. 30.888.000,-

= Rp. 18.640.106.100,-

- **Harga Jual Produk**

Harga : Rp. 5.000,- / kg

Produksi : 30303,12 kg / hari

Total : Rp. 50.000.148.000,- / tahun

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

No.	Jabatan	Jumlah	Gaji/bulan (Rp)	Total (Rp)
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	8	1.000.000,-	8.000.000,-
25	Seksi Laboratorium & QC	4	1.000.000,-	4.000.000,-
26	Seksi Promosi & Penjualan	4	1.000.000,-	4.000.000,-
27	Seksi Keuangan	2	1.000.000,-	2.000.000,-
28	Seksi Pembelian	2	1.000.000,-	2.000.000, -
29	Seksi Personalia	2	1.000.000,-	2.000.000,-
30	Seksi Gudang	8	800.000,-	6.400.000,-
31	Seksi Keamanan	12	800.000,-	9.600.000,-
32	Sopir & Pesuruh	12	600.000,-	7.200.000,-
	TOTAL	**106**	**-**	**124.200.000,-**

Total gaji karyawan per bulan = Rp. 124.200.000,-

Ditetapkan 1 tahun produksi adalah 12 bulan + 1 bulan tunjangan, jadi gaji karyawan

per tahun = Rp. 124.200.000,- × 13

= Rp. 1.614.600.000,-

E. PERHITUNGAN BIAYA UTILITAS

Kebutuhan Air

Air PDAM yang harus disuplai per hari = 18 m^3 / hari

Harga beli air PDAM per 10 m^3 pertama = Rp. 750,-

Harga beli air PDAM per 10 m^3 kedua = Rp. 1300,-

Biaya untuk air PDAM per tahun

= (10 × Rp. 750,- + 8 × Rp. 1300,-) × 330

= Rp. 2.485.400,-

Kebutuhan Listrik

Total kebutuhan listrik = 205,0681 kWh

Beban listrik terpasang = 210 kVA

Biaya beban per bulan = Rp.25.000,- / kVA

Biaya listrik per tahun = Rp. 25.000,- × 210 × 12 = Rp. 63.000.000,-

Biaya penggunaan listrik :

- Waktu Beban Puncak = Rp. 425,- / kWh (pk. 18.00 – 22.00)
- Luar Waktu Beban Puncak = Rp. 350,- / kWh (pk. 22.00 – 18.00)

Biaya penggunaan listrik = (Rp. 425,- × 4 × 205,0681 × 330) + (Rp. 350,- × 20 × 205,0681 × 330)

= Rp. 588.750.515,-

Biaya listrik terpakai per tahun = biaya beban + biaya penggunaan listrik

= Rp. 63.000.000,- + Rp. 588.750.515,-

= Rp. 651.750.515,-

Kebutuhan bahan bakar

Densitas bahan bakar = 55 lb / ft^3 = 0,881 kg / lt

(Perry, 1999, 16-29)

Kebutuhan bahan bakar per bulan = 333,53 kg / bulan = 378,5736 lt / bulan

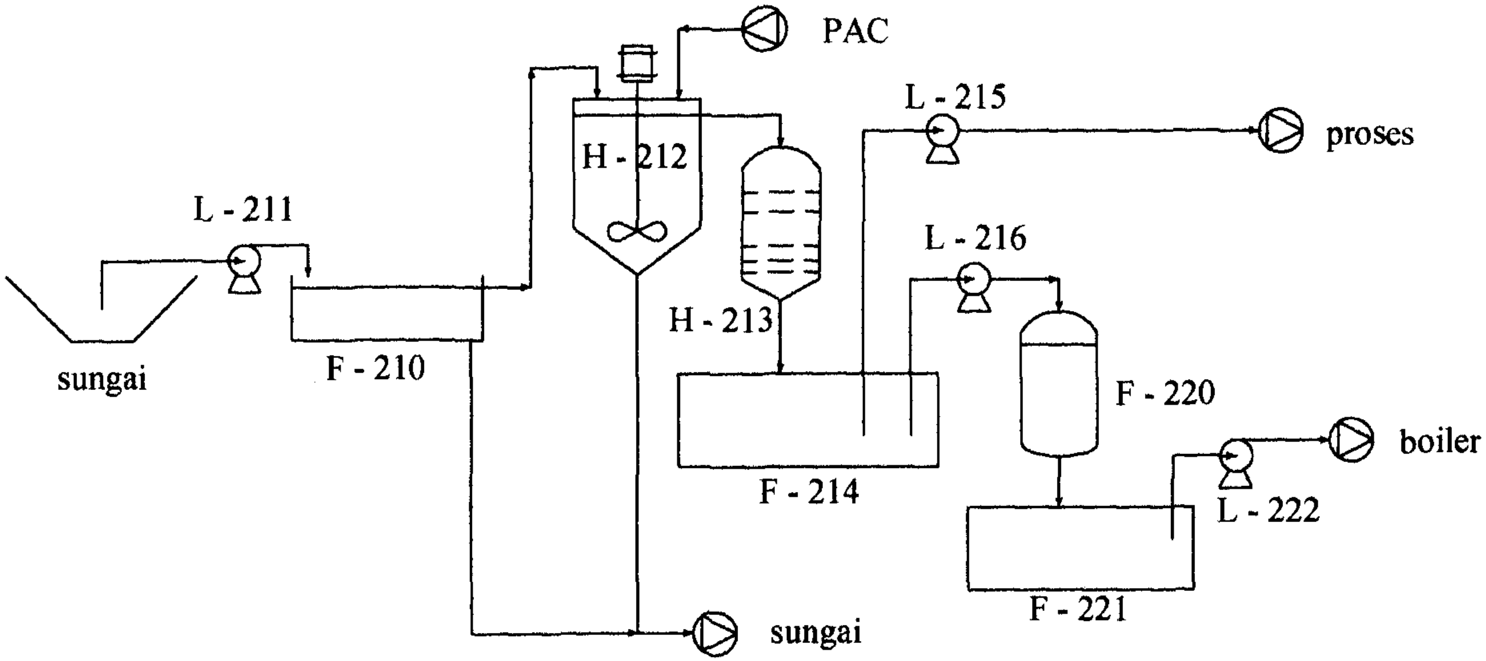
Harga bahan bakar per liter = Rp.1440,- / lt

Biaya bahan bakar per tahun = 378,5736 / bulan × 12 bln / th × Rp.1440,- / lt

= Rp. 6.541.752,-

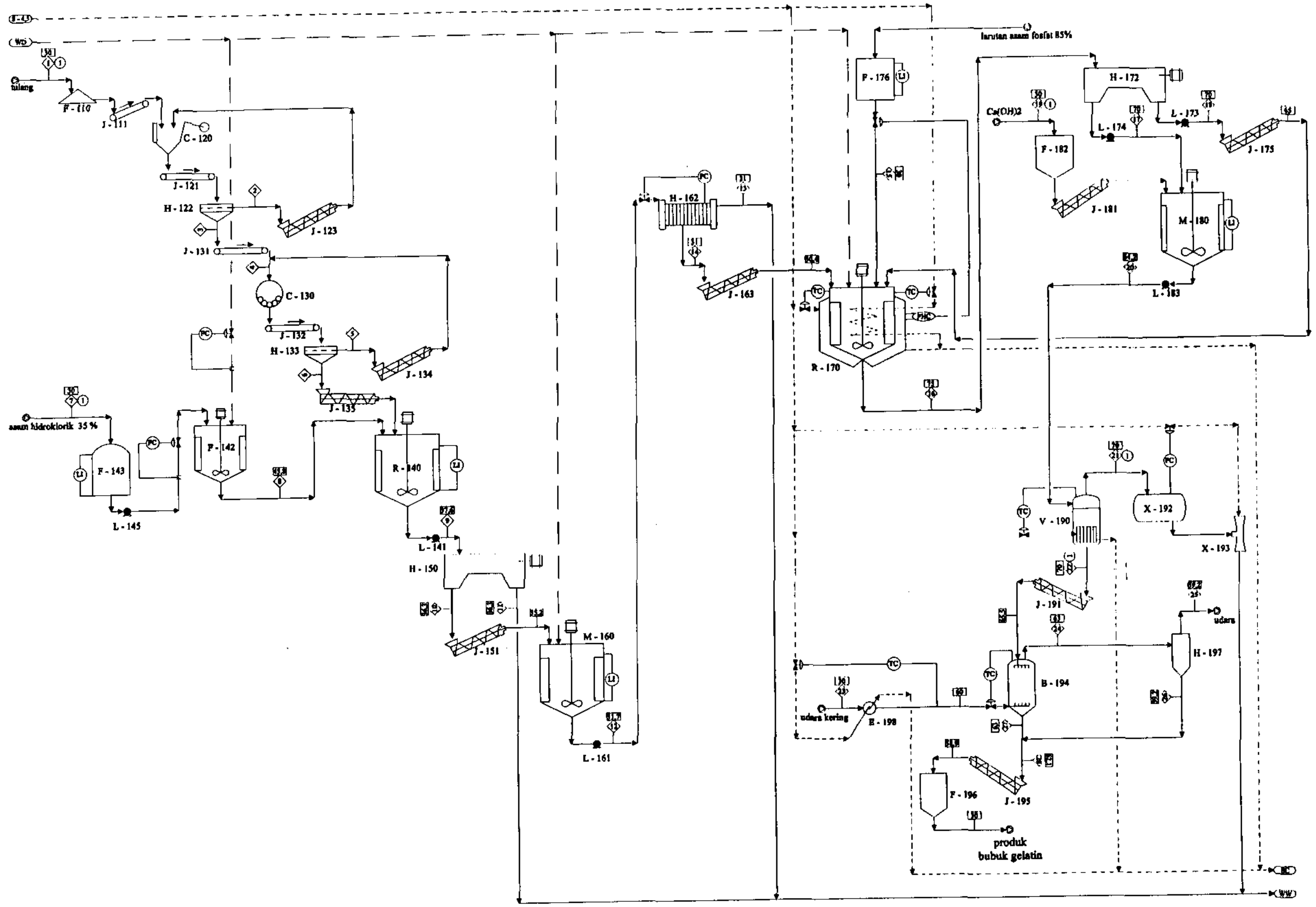
Total biaya utilitas per tahun = Rp. 2.485.400,- + Rp. 651.750.515,- + Rp. 6.541.752,-

= Rp. 660.777.667,-



No.	Kode	Nama Alat
1	F-210	Settling Tank
2	L-211	River pump
3	H-212	Clarifier
4	H-213	Sand Filter
5	F-214	Water Storage Tank
6	L-215	Process Water Pump
7	L-216	Softener Pump
8	F-220	Water Softener tank
9	F-221	Boiler feed water tank
10	L-222	Boiler Water Pump

Flowsheet Utilitas



Nomor Aliran / Komponen	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Protein	146,46	36,62	146,46	183,08	36,62	146,46			146,46	146,46		146,46		146,46
Lemak	5,05	1,26	5,05	6,31	1,26	5,05			5,05	5,05		5,05		5,05
H2O (l)	30,3	7,58	30,3	37,88	7,58	30,3	474,5	5344,57	4382,02	1111,12	4270,9	2373,75	1262,63	1111,12
Ca3(PO4)2	262,63	65,66	262,63	328,29	65,66	262,63								
CaCO3	18,18	4,54	18,18	22,72	4,54	18,18								
MgCO3	18,18	4,54	18,18	22,72	4,54	18,18								
Mg3(PO4)2	24,25	6,06	24,25	30,31	6,06	24,25								
HCl							255,5	255,5	20,62		20,62			
CaCl2									302,3		302,3			
MgCl2									46,95		46,95			
H3PO4									184,2		184,2			
Ca(OH)2														
H2O (g)														
CO2									17,52		17,52			
udara														
TOTAL	505,05	126,26	505,05	631,31	126,26	505,05	730	5600,07	5105,12	1262,63	505,05	2525,26	1262,63	1262,63

Nomor Aliran / Komponen	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Protein		162,74	146,46	16,28		146,46		146,46		14,65		14,65	131,81	146,46
Lemak		5,61	5,05	0,56		5,05		5,05		0,50		0,50	4,55	5,05
H2O (l)	0,12	2637,63	2373,87	263,76		2374,24		1490,06		111,87		111,87	1006,83	1118,70
Ca3(PO4)2						1,09		1,09		0,11		0,11	0,98	1,09
CaCO3														
MgCO3														
Mg3(PO4)2														
HCl														
CaCl2														
MgCl2														
H3PO4	0,68	0,76	0,68	0,08										
Ca(OH)2					0,78									
H2O (g)							884,18			371,36	371,36			
CO2														
udara									2700,08	2700,08	2700,08			
TOTAL	0,8	2806,66	2526,06	280,68	0,78	2526,84	884,18	1642,66	2700,08	3198,57	3071,44	127,13	1144,17	1271,3

Diagram Alir Pabrik Gelatin

Instrumentation :
- LI : Level Indicator
- PI : Pressure Indicator
- FC : Flow Control
- PC : Pressure Control
- TC : Temperature Control
- RC : Ratio Control

Simbol
- ◇ : Mass Stream Number
- ○ : Pressure Condition, atm
- ▭ : Temperature Condition, °C

NO.	KODE	NAMA ALAT
40	J-195	Screw Conveyor
39	J-191	Screw Conveyor
38	L-183	Pompa
37	J-181	Screw Conveyor
36	L-174	Pompa
35	L-173	Pompa
34	J-163	Screw Conveyor
33	J-151	Screw Conveyor
32	L-141	Pompa
31	L-145	Pompa
30	J-135	Screw Conveyor
29	J-134	Screw Conveyor
28	J-132	Belt Conveyor
27	J-131	Belt Conveyor
26	J-123	Screw Conveyor
25	J-121	Belt Conveyor
24	J-111	Belt Conveyor
23	F-196	Tangki Penampung Produk
22	E-198	Heat Exchanger
21	H-197	Cyclone Separator
20	B-194	Spray Dryer
19	X-193	Steam Jet Ejector
18	X-192	Barometric Condenser
17	V-190	Evaporator
16	F-182	Tangki Umpan Ca(OH)2
15	M-180	Mixer
14	H-172	Centrifugal Separator
13	F-176	Tangki Umpan H3PO4
12	H-170	Ekstraktor
11	H-162	Filter Press
10	M-160	Mixer
9	H-150	Centrifugal Separator
8	R-140	Reaktor
7	F-142	Tangki Pengencer
6	F-143	Tangki Penampung Larutan HCl
5	H-133	Screen
4	C-130	Tumbling Mill
3	H-122	Screen
2	C-120	Jaw Crusher
1	F-110	Ware House Tulang

Digambar Oleh :

Vonny Cinthia Dewi — Nrp. 5203099035

Fenny Rosita — Nrp. 5203099067

Disetujui Oleh :

Pembimbing I: Ir. Suryadi Ismadji, MT., PhD.

Pembimbing II: Antaresti, ST., M.Eng., Sc.

FLOWSHEET PRA RENCANA PABRIK GELATIN

JURUSAN TEKNIK KIMIA
FAKULTAS TEKNIK
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