

IV. NERACA MASSA DAN NERACA ENERGI

Perhitungan neraca massa dan energi dilakukan dengan basis perhitungan dan data konversi seperti dibawah ini :

Kapasitas : 50.000 ton/th

Operasi : 330 hari/th, 24 jam/hari

Proses : kontinyu

Basis : 1 jam

Bahan baku : Sodium klorida dan Asam Nitrat

Produk : Sodium nitrat 98 % berat

$$\begin{aligned} \text{Kapasitas produksi} &= \frac{50.000 \text{ ton}}{1 \text{ tahun}} \times \frac{1000 \text{ kg}}{1 \text{ ton}} \times \frac{1 \text{ tahun}}{330 \text{ hari}} \times \frac{1 \text{ hari}}{24 \text{ jam}} \\ &= 6.313,13 \text{ kg/jam} \end{aligned}$$

A. NERACA MASSA

1. Neraca Massa Keseluruhan

Tabel 4.1 Neraca Massa Keseluruhan

| Komponen | Input (Kg/jam) | | | Output (Kg/jam) | | | |
|-------------------|-------------------|-------------------|-----------------|-------------------|-------------------|-------------------|-------------------|
| | Aliran 1 | Aliran 3 | Aliran 7 | Aliran 15 | Aliran 16 | Aliran 8 | Aliran 9 |
| NaCl | 4.268,1836 | 0,0000 | 0,0000 | 0,0000 | 56,8182 | 0,0000 | 0,0000 |
| HNO ₃ | 0,0000 | 3.669,4220 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 |
| NaNO ₃ | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 6.186,8687 | 0,0000 | 0,0000 |
| NOCl | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 1.588,2748 |
| Cl ₂ | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 1.703,2345 | 17,2044 |
| H ₂ O | 47,2656 | 2.009,4485 | 436,7458 | 372,4747 | 69,4444 | 0,0000 | 436,7458 |
| Sub-total | 4.315,4492 | 5.678,8705 | 436,7458 | 372,4747 | 6.313,1313 | 1.703,2345 | 2.042,2250 |
| Total | 10.431,066 | | | 10.431,066 | | | |

2. Neraca Massa Komponen Tiap Alat

1. Neraca massa di sekitar *Solution tank* -101 (ST- 101)

Tabel 4.2. Neraca massa disekitar *Solution tank* -101(ST-101)

| Komponen | Input (Kg/jam) | | Output (Kg/jam) |
|------------------------|-------------------|-------------------|-------------------|
| | Aliran 1 | Aliran 13 | Aliran 2 |
| NaCl | 4.268,1836 | 411,1113 | 4.679,2949 |
| H ₂ O | 47,2656 | 3.338,9450 | 3.386,2106 |
| NaNO ₃ (nk) | | 618,6869 | 618,6869 |
| Sub-total | 4.315,4492 | 4.368,7432 | |
| Total | 8.684,1923 | | 8.684,1923 |

2. Neraca massa di sekitar *Mix point* (MP-101)

Tabel 4.3. Neraca massa di *Mix point* -101(MP-101)

| Komponen | Input (Kg/jam) | | Output (Kg/jam) |
|------------------|-------------------|-------------------|-------------------|
| | Aliran 3 | Aliran 10 | Aliran 4 |
| HNO ₃ | 3.669,4220 | 407,7136 | 4.077,1356 |
| H ₂ O | 2.009,4485 | 708,6419 | 2.718,0904 |
| Sub-total | 5.678,8705 | 1.116,3554 | |
| Total | 6.795,2260 | | 6.795,2260 |

3. Neraca massa di sekitar *Reactor* -201(RE-201)

Tabel 4.4. Neraca Massa di sekitar *Reactor* -201 (RE-201)

| Komponen | Input (kg/jam) | | Output (kg/jam) | |
|-------------------|--------------------|-------------------|--------------------|-------------------|
| | Aliran 2 | Aliran 4 | Aliran 5 | Aliran 6 |
| NaCl | 4.679,2949 | 0,0000 | 467,9295 | 0,0000 |
| HNO ₃ | 0,0000 | 4.077,1356 | 407,7136 | 0,0000 |
| H ₂ O | 3.386,2106 | 2.718,0904 | 4.489,5061 | 0,0000 |
| NaNO ₃ | 618,6869 | 0,0000 | 6.805,5556 | 0,0000 |
| Cl ₂ | 0,0000 | 0,0000 | 0,0000 | 1.720,4389 |
| NOCl | 0,0000 | 0,0000 | 0,0000 | 1.588,2748 |
| Sub total | 8.684,1923 | 6.795,2260 | 12.170,7047 | 3.308,7136 |
| Total | 15.479,4183 | | 15.479,4183 | |

4. Neraca massa di sekitar *Absorber* -301(T-301)**Tabel 4.5. Neraca massa disekitar *Absorber* -301 (T-301)**

| Komponen | input (kg/jam) | | Output (kg/jam) | |
|------------------|-------------------|----------|-------------------|------------|
| | Aliran 6 | Aliran 7 | Aliran 8 | Aliran 9 |
| NOCl | 1.588,2748 | | 15,8827 | 1.572,3920 |
| Cl ₂ | 1.720,4389 | | 1.720,4389 | 0 |
| H ₂ O | | 436,7458 | | 436,7458 |
| Sub-total | 3.308,7136 | 436,7458 | 1.736,3216 | 2.009,1378 |
| Total | 3.745,4595 | | 3.745,4595 | |

5. Neraca massa di sekitar *Evaporator* -301(EV-301)**Tabel 4.6. Neraca massa di sekitar *Evaporator*-301(EV-301)**

| Komponen | Input (Kg/jam) | Output (Kg/jam) | |
|-------------------|--------------------|--------------------|--------------------|
| | Aliran 5 | Aliran 10 | Aliran 11 |
| NaNO ₃ | 6.805,5556 | 0,0000 | 6.805,5556 |
| HNO ₃ | 407,7136 | 407,7136 | 0,0000 |
| H ₂ O | 4.489,5061 | 708,6419 | 3.780,8642 |
| NaCl | 467,9295 | 0,0000 | 467,9295 |
| Sub-total | | 1.116,3554 | 11.054,3492 |
| Total | 12.170,7047 | 12.170,7047 | |

6. Neraca massa di sekitar *Crystalizer* -301(CR-301)**Tabel 4.7. Neraca Massa di sekitar *Crystalizer* - 301 (CR-301)**

| Komponen | Input aliran 7 (kg/jam) | Output aliran 8 (kg/jam) | |
|------------------------|-------------------------|--------------------------|-------------------|
| | | Kristal | Liquid |
| NaCl | 467,9295 | 467,9295 | 0,0000 |
| NaNO _{3(k)} | 0,0000 | 6.186,8687 | 0,0000 |
| NaNO _{3 (nk)} | 6.805,5556 | 0,0000 | 618,6869 |
| H ₂ O | 3.780,8642 | 0,0000 | 3.780,8642 |
| Sub-total | | 6.654,7982 | 4.399,5511 |
| Total | 11.054,3492 | 11.054,3492 | |

7. Neraca massa di sekitar *Centrifuge* -301 (CF-301)**Tabel 4.8. Neraca massa di sekitar *Centrifuge* – 301 (CF-301)**

| Komponen | Input (kg/jam) Aliran 12 | Output (kg/jam) | |
|------------------------|-----------------------------|--------------------|---------------------|
| | | Aliran 14 | Aliran 13 (recycle) |
| H ₂ O | 3.780,8642 | 441,9192 | 3.338,9450 |
| NaCl | 467,9295 | 56,8182 | 411,1113 |
| NaNO ₃ (k) | 6.186,8687 | 6.186,8687 | 0,0000 |
| NaNO ₃ (nk) | 618,6869 | 0,0000 | 618,6869 |
| Sub-total | | 6.685,6061 | 4.368,7432 |
| Total | 11.054,3492 | 11.054,3492 | |

8. Neraca massa di sekitar *Rotary dryer* -301(RD-301)**Tabel 4.9. Neraca massa di sekitar *Rotary dryer* -301(RD-301)**

| Komponen | Input (kg/jam) Aliran 14 | Output (kg/jam) | |
|-----------------------|-----------------------------|-------------------|-------------------|
| | | Aliran 15 | Aliran 16 |
| H ₂ O | 441,9192 | 372,4747 | 69,4444 |
| NaCl | 56,8182 | 0,0000 | 56,8182 |
| NaNO ₃ (k) | 6.186,8687 | 0,0000 | 6.186,8687 |
| Sub-total | | 372,4747 | 6.313,1313 |
| Total | 6.685,6061 | 6.685,6061 | |

B. NERACA ENERGI

Dari perhitungan neraca massa, selanjutnya dilakukan perhitungan neraca energi.

Perhitungan neraca energi didasarkan pada :

Basis waktu : 1 jam

Satuan energi : kilo kalori (kkal)

Temperatur referensi : 25 °C (298 K)

Neraca energi :

(Energi masuk) – (Energi keluar) + (Energi tergenerasi) - (Energi terkonsumsi) =
Energi terakumulasi)

(Himmelblau,ed.6, 1996 : 400)

1. *Solution tank* -101 (ST-101)**Tabel 4.10. Neraca energi pada *Solution tank*-101 (ST-101)**

| Panas Masuk | | Panas Keluar | |
|-----------------|--------------------|--------------------|-------------|
| Keterangan | kkal/jam | Keterangan | kkal/jam |
| Q ₁ | 4.524,0195 | Q ₂ | 17.864,5956 |
| Q ₁₃ | 12.813,2611 | | |
| Q _s | 527,3149 | | |
| TOTAL | 17.864,5956 | 17.864,5956 | |

2. *Mix-point* -101 (MP-101)**Tabel 4.11. Neraca energi pada *Mix-point* -101 (MP-101)**

| Panas Masuk (kkal/jam) | | Panas keluar (kkal/jam) | |
|------------------------|--------------------|-------------------------|-------------|
| Q ₃ | 12.872,786 | Q ₄ | 16.619,5547 |
| Q ₁₀ | 3.746,769 | | |
| TOTAL | 16.619,5547 | 16.619,5547 | |

3. *Heater* -101 (HE-101)**Tabel 4.12. Neraca energi di sekitar *Heater* -101 (HE-101)**

| Panas masuk (kJ/jam) | | Panas keluar (kJ/jam) | |
|--------------------------|--------------------|---------------------------|-------------|
| Q ₂ input | 17.864,596 | Q ₂ output | 107.115,594 |
| Q _{steam} masuk | 125.677,933 | Q _{steam} keluar | 36.426,935 |
| Total | 143.542,529 | 143.542,529 | |

4. Heater -102 (HE-102)

Tabel 4.13. Neraca energi di sekitar *Heater -102 (HE-102)*

| Panas masuk (kJ/jam) | | Panas keluar (kJ/jam) | |
|--------------------------|--------------------|---------------------------|--------------------|
| Q ₄ input | 16.619,555 | Q ₄ output | 102.097,612 |
| Q _{steam} masuk | 120.365,103 | Q _{steam} keluar | 34.887,046 |
| Total | 136.984,658 | | 136.984,658 |

5. Reactor -201(RE-201)

Tabel 4.14. Neraca energi di sekitar *Reactor-201 (RE-201)*

| Panas aliran | Panas Masuk (kkal/jam) | Panas Generasi (kkal/jam) | Panas Keluar (kkal/jam) |
|---------------------------------|------------------------|---------------------------|-------------------------|
| Q ₂ + Q ₄ | 209.213,2054 | | |
| Q ₅ + Q ₆ | | | 186.551,5230 |
| Panas generasi | | 57.440,2621 | |
| Beban pendingin | 24.797,8809 | | 104.899,8254 |
| Total | | 291.451,3484 | 291.451,3484 |

6. Absorber -301 (T-301)

Tabel 4.15. Neraca energi pada *Absorber -301(T-301)*

| Panas masuk (kJ/jam) | | Panas keluar (kJ/jam) | |
|----------------------|-------------------|-----------------------|-------------------|
| Q ₆ | 1.521,7777 | Q ₈ | 663,5524 |
| Q ₇ | 1.135,3967 | Q ₉ | 1.993,6220 |
| Total | 2.657,1744 | | 2.657,1744 |

7. Compressor – 301 (CM-301)

Tabel 4.16. Neraca energi pada *Compressor - 301(CM-301)*

| Panas Masuk | | Panas Keluar | |
|-----------------------|-----------------|-----------------|-----------------|
| Keterangan | Kkal/jam | Keterangan | Kkal/jam |
| Q ₈ | 663,5524 | Q ₁₇ | 697,4741 |
| Q <i>intercooling</i> | 73,5632 | W _s | -1.706,684591 |
| | | ΔEk | 1.746,3261 |
| Total | 737,1156 | | 737,1156 |

8. *Condenser* – 302 (CD-302)Tabel.4.17. Neraca energi pada *Condensor -302* (CD-302)

| Panas Masuk | | Panas Keluar | |
|------------------------|----------------|------------------------|----------------|
| Keterangan | Kkal/jam | Keterangan | Kkal/jam |
| Q ₁₇ | 697,4741 | Q ₁₈ | 663,494 |
| Q _{pendingin} | 10,5195 | Q _{pendingin} | 44,4995 |
| Total | 707,994 | | 707,994 |

9. *Evaporator* -301 (EV-301)Tabel 4.18. Neraca energi pada *Evaporator - 301* (EV-301)

| Panas Masuk | | Panas Keluar | |
|--------------------------|---------------------|-----------------------------------|---------------------|
| Keterangan | kcal/jam | Keterangan | kcal/jam |
| Q ₅ | 185.029,7453 | Q ₁₀ + Q ₁₁ | 328.212,6060 |
| Panas penguapan | 0,0000 | Panas penguapan | 9.966,4842 |
| Q _{Steam masuk} | 215.655,7750 | Q _{Steam keluar} | 62.506,4302 |
| Total | 400.685,5203 | Total | 400.685,5203 |

10. *Condensor* - 301 (CD-301)Tabel 4.19. Neraca energi pada *Condensor -301* (CD-301)

| Panas Masuk | | Panas Keluar | |
|----------------------|-------------------|------------------------|-------------------|
| Keterangan | kcal/jam | Keterangan | kcal/jam |
| Q _{6 input} | 34.791,750 | Q _{6 output} | 3.748,492 |
| | | Q _{pendingin} | 31.043,258 |
| Total | 34.791,750 | Total | 34.791,750 |

11. *Crystalizer* – 301 (CR – 301)Tabel 4.20. Neraca Energi disekitar *Crystallizer-301* (CR-301)

| Panas aliran | Panas Masuk (kcal/jam) | Panas Generasi (kcal/jam) | Panas Keluar (kcal/jam) |
|--------------------|------------------------|---------------------------|-------------------------|
| Q ₁₁ | 328.212,6060 | | |
| Q ₁₂ | | | 17.082,0910 |
| Panas kristalisasi | | 367,5944 | |
| Beban pendingin | | | 311.498,1094 |
| Total | | 328.580,2004 | 328.580,2004 |

12. Rotary Dryer -301 (RD-301)

Tabel 4.21. Neraca energi pada Rotary Dryer-301 (RD-301)

| Panas Masuk (kkal/jam) | | Panas Keluar (kkal/jam) | |
|--------------------------------------|---------------------|---------------------------------------|---------------------|
| H solid masuk dryer, H _{s1} | 73.345,3178 | H solid keluar dryer, H _{s2} | 59.643,7197 |
| H udara masuk dryer, H _{G2} | 393.172,5233 | H udara keluar dryer, H _{G1} | 406.874,1214 |
| Total | 466.517,8411 | Total | 466.517,8411 |

13. Air Heater -301 (AH-301)

Tabel 4.22. Neraca energi pada Air Heater -301 (AH-301)

| Panas Masuk | | Panas Keluar | |
|--------------|---------------------|--------------|---------------------|
| Keterangan | kJ/jam | Keterangan | kJ/jam |
| Panas udara | 78.102,8194 | Panas udara | 510.491,4883 |
| Beban steam | 608.863,9398 | Beban steam | 176.475,2710 |
| TOTAL | 686.966,7593 | | 686.966,7593 |