ENERGY BALANCE

REACTOR:

Feed temperature 35^oC
Outlet temperature 150^oC
Cp data at average feed temperature, 17.5^oC

$CpNH_3$ solution (31.2 mol%)	4.184 KJ/(Kg K)
Cp ethylene oxide	1.884 KJ/(Kg K)

At 150/2 =75^oC

$CpNH_3$ solution (15.2 mol%)	4.22 KJ/(Kg K)
Cp(MEA)	2.78
Cp(DEA)	2.66
Cp(TEA)	2.55

Heat liberated: ΔHr = 125 KJ/mole of ethylene oxide.
Moles of ethylene oxide reacted = 3690 kmoles/day
Balance equation:

Heat input + heat generated = heat output + heat removed

$M_f \times \sum(x_i \times Cp_i) + \Delta Hr \times \text{moles of EO} = M_o \times \sum(x_i \times Cp_i) + Q$

$\sum(x_i \times Cp_i)$ (input)= 3.32 KJ/(Kg K)
$\sum(x_i \times Cp_i)$(output)= 3.44 KJ/(Kg K)
$M_f = M_o$ = 456 tons/day

We get

Q = 5949.1 KJ/s

FLASH DRUM

All the ammonia entering the flash is completely removed. It is assumed that no water goes along with the ammonia. Feed from the reactor is passed through the heat exchanger before feeding into the flash drum.

Stream leaving the flash will be saturated, and hence the temperature of the outlet stream from T,x,y diagram is 112^oC.

Heat balance equation:

Heat input with input stream + heat removed = heat leaving in outlet stream (both top and bottom products)

$M_F \times \sum(x_i \times Cp_i) + Q = M_D \times \sum(x_i \times Cp_i) + M_D \times \lambda + M_B \times \sum(x_i \times Cp_i)$

λ for ammonia at 112°C is 648.52KJ/Kg

$\sum(x_i \times Cp_i)$ (input) = 4.05 KJ/(Kg K)
$\sum(x_i \times Cp_i)$(output) = 3.35 KJ/(Kg K)

M_D = 33.88 tons/day
M_B = 413.78 tons/day

Therefore heat must be removed is, Q = 1000.27KJ/s

DEHYDRATION TOWER:

Feed temperature = 112°C
Average temperature = 56°C

Cp (water) = 4.6 KJ/(Kg K) Cp (MEA) = 2.82 KJ/(Kg K)

Cp (DEA) = 2.68 KJ/(Kg K) Cp (TEA) = 2.56 KJ/(Kg K)

$\sum(x_i \times Cp_i)$ (input) = 3.65 KJ/(Kg K)

Outlet temperature
Bottom residue temperature = 163°C
Distillate temperature = 102°C

$\sum(x_i \times Cp_i)$ (distillate)=4.374 KJ/(Kg K)

$\sum(x_i \times Cp_i)$ (residue) = 2.815 KJ/(Kg K)

Heat balance equation:

Heat entering in input stream + re-boiler heat load(Q_R) = condenser load (Q_C) + heat out in distillate + heat out with residue stream

M_F = 413.78 tons/day
M_D = 197.48 tons/day
M_R = 216.3 tons /day

Therefore
REBOILER heat load ,Q_R= 5862.3 KJ/s

MONOETHANOLAMINE TOWER:

Feed stream, M_F =216.3 tons/day
Distillate, D = 148.03 tons/day (99% MEA and 1% DEA)
Residue, W = 68.27 tons/day (2.2% MEA, 76.3% DEA and 15.6% TEA)

Distillate temperature = 175°C which is slightly more than the boiling point of the MEA, since it consist small fraction of 1% DEA.

Average temperature = (175 +0)/2 = 87.5°C
Heat capacity data at average temperature are:

Cp (MEA) = 2.86 KJ/(Kg K)
Cp (DEA) = 2.71 KJ/(Kg K) Cp (TEA) = 2.59 KJ/(Kg K)

Residue temperature = 260°C, which is slightly below the boiling point of DEA and TEA.
Heat capacity data at average temperature are:
Cp (MEA) = 2.94 KJ/(Kg K)
Cp (DEA) = 2.85 KJ/(Kg K) Cp (TEA) = 2.75 KJ/(Kg K)

Condenser heat load calculation:

It is assumed that a very small quantity of the reflux is required for the separation of MEA and DEA, because of the large boiling point difference.
Hence reflux ratio is assumed as 0.1
Therefore

$$G=(R+1)\times D$$
$$= 1.1\times 148.08= 162.8 \text{ tons/day}$$

Condenser heat load $Q_C = G\times\lambda_D$

$$= 162.8\ (0.99\times 848.1+0.01\times 638.4)$$
$$= \underline{1594.089 \text{ KJ/s}}$$

$\sum(x_i\times Cp_i)$ (input)=2.815 KJ/(Kg K)
$\sum(x_i\times Cp_i)$ (distillate)=2.86 KJ/(Kg K)
$\sum(x_i\times Cp_i)$ (residue) = 2.67 KJ/(Kg K)

Heat balance equation:

Heat entering in input stream + re-boiler heat load(Q_R) = condenser load (Q_C) + heat out in distillate + heat out with residue stream

$$216.3\times10^3\times2.815\times163 + Q_R = 1594.089\times24\times3600 + 148.08\times10^3 \times 2.86\times175 +68.27\times2.67\times260$$

Therefore

REBOILER head load, Q_R = 1853 KJ/s