ENERGY BALANCE

Energy balance for Pre heater

In this feed is heated from initial available temperature of 50^0C to 250^0C
By steam heating.steam is available at 600 psig.

Data :

Inlet temperature of feed = 50^0C

Outlet temperature of feed = 210^0C

Steam is available at 600 psig

Flow rate of feed gas = 529.74 kmol/hr

Flow rate of Methane in the feed mixture = 527.62 kmol/hr

Flow rate of nitrogen in the feed mixture = 2.12 kmol/hr

$(C_P)_{CH4}$ =0.625 cal/gm C =10 cal/gmol ^0C = 41.8 kJ/kmol K

$(C_P)_{H2}$ = 0.265 cal/g^0C = 7.42 cal/gmol^0C = 30.430 KJ/kmolK

$(C_P)_{mix}$ = 0.996 x 41.8 + 0.004*30.43

$(C_P)_{mix}$ =41.75 KJ/Kmol^0C

Also heat transferred by steam will be used by Feed gas for heating.

Heat received by gas = n x C_p x ΔT

= 529.62 x 41.75 x 160

= 3537861.6 KJ/h

Heat supplied by steam
Let steam flow rate be M Kg/h
Also
M x λ_s = 3537861.6 KJ/h

M = 0.44 kg/sec

Heat balance for waste heat boiler is given by

In W.H.B gas from reactor are cooled from cold water which is converted to steam with the heat transferred by gas cooling.

Data :

Inlet temperature of gas = 1300^0C

Oultlet temperature of gas = 250^0C

Boiler water is available at = 20^0C

Steam is produced at 600 psig

Gas Flow rate =1832.48 kmol/h

Gas	composition(vol%))	C_P (kJ/kmolC)
CO_2	4.32	70.00
CO	46.55	36.43
H_2	47.15	31.768
CH_4	0.60	100.48
N_2	0.56	36.343
H_2S	0.81	neglected

C_P of mixture = 35.773 kJ/kmol^{0}C

Heat transferred by gas = 1832.48 x 35.773 x 1050

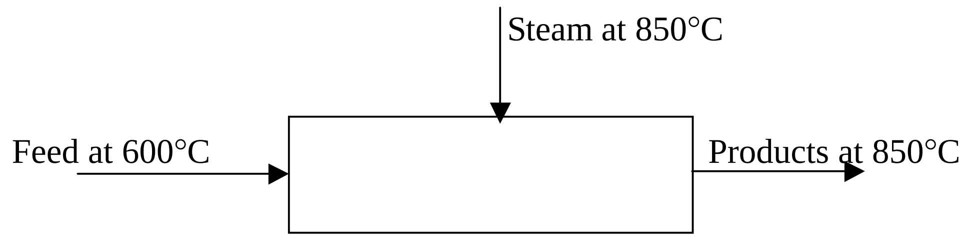
Heat taken by cold water = $M \times C_P \times \Delta T + M \times \lambda_s$

We have
$M \times C_P \times \Delta T + M \times \lambda_s = 1832.48 \times 35.773 \times 1050$

$M(4.187 \times 80 + 2210) = 1832.48 \times 35.773 \times 1050$

Mass flow rate of cold water = 27045.99 kg/h = 7.51 kg/s

1) Primary Reformer



Naptha feed rate 422987 kg/hr

For Naptha, specific heat is given by

$$Cp = \frac{(4.0 - S)(t + 670)}{6450} = Btu/lb°F$$

where S = Specific gravity

For Naptha S = 0.686

t = 1112°F

$$Cp = \frac{(4.0 - 0.686)(1112 + 670)}{6450}$$

= 0.9155 Kcal/kg°C

Now Datum Temperature = 850°C at which products are withdrawn

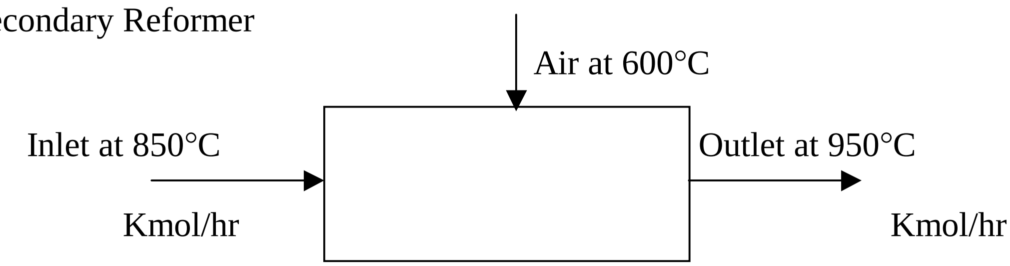
Energy coming with feed = mCp(ΔT)

$= 422987 \times 0.9155 \times (600 - 850)$

= - 96811073.33 Kcal/hr

This much heat is to be supplied to the reformer

2) Secondary Reformer



Inlet		Outlet	
CH_4	= 258.31	CH_4	= 7.73
CO	= 731.57	CO	= 967.817
CO_2	= 494.6	CO_2	= 508.88
H_2	= 2841.7	N_2	= 1292.5
		H_2	= 2911.392
H_20	= 1867.39	H_20	= 2373.05
		Ar	= 16.57

Assuming datum temperature = 850°C
Energy coming with air = $1988.8 \times 7.5 \times (600 - 850)$
= - 3729000 Kcal

At Outlet = $\sum$ ni Cpi dT
= $(7.73 \times 14.4 + 967.817 \times 7.5 + 508.88 \times 11.75 + 2911.392 \times 7.1 + 1292.5 \times 7.5 + 16.575 \times 4.95 + 2373.05 \times 9.1) \times 100$
= 6526146.395 Kcal/hr

After Reaction = -8476.19 Kcal/kmol
Total heat of reaction = -210584342.2 Kcal
Amount of energy to be supplied = 7535775Kcal/hr

Heat exchanger between second reformer and HTS converter

Water available at 25°C, outlet water temperature assumed to be 60°C
Amount of heat to be removed
= $nCp\Delta T$
= $(7.73 \times 14.4 + 967.817 \times 7.5 + 508.88 \times 11.75 + 2911.392 \times 7.1 + 1292.5 \times 7.5 + 16.575 \times 4.95 + 2373.05 \times 9.1) \times (950 - 340)$
= 39809493.01 Kcal/hr
Amount of water required to remove this much amount of heat
= $\frac{39809493.01}{60.25}$ = 1137414.086 Kg/hr

Energy balance for high temperature shift reaction :

		Kmol/hr			
CH_4	=	7.73	CH_4	=	7.73
CO	=	967.817	CO	=	193.56
CO_2	=	508.88	CO_2	=	1283.1
H_2	=	2911.392	H_2	=	3685.6
N_2	=	1292.51	N_2	=	1292.5
Ar	=	16.575	Ar	=	16.575
H_20	=	2373.05	H_20	=	1598.6

Applying energy balance, we get

$$\sum (n_j H_{fj}^\circ)_F + \left(\sum n_j \int_{298}^{T_f} C_{pj}\, dT\right) = \sum (n_j H_{fj}^\circ)_p + \left(\sum n_j \int_{298}^{T} C_{pj}\, dT\right)_p$$

LHS = 967.817 (-26416) + 508.88 (-94502) + 2373.05 (-57797.9) +

$$+ \int_{298}^{613} (68198.77 + 8.4298\, T + 992.4 \times 10^{-5}\, T^2 - 3786.62 \times 10\, T^3)\, dT$$

= - 187345367.1

RHS = 193.5634(-26416) + 1283.125 (-94052) + 1598.67 (-57797.9)

$$+ \int (66009.14 + 20.47 \times 10^{-2}\, T - 4949 \times 10^{-5}\, T^2 - 1031.23 \times 10^{-9}\, T^3)\, dT$$

T =

Energy balance around LTS

	Kmol/hr			Kmol/hr
CH_4	=	7.73	CH_4	= 7.73
CO	=	193.56	CO	= 8.417
CO_2	=	1283.125	CO_2	= 1465
N_2	=	1292.51	N_2	= 1292.51
H_2	=	3685.65	H_2	= 3685.65
Ar	=	16.575	Ar	= 16.85
H_2O	=	1598.67	H_2O	= 1416.67

$$\sum (n_j H_{fj}^\circ)_F + \left(\sum n_j \int_{298}^{T_f} C_{pj}\, dT\right)_F = \sum (n_j H_{fj}^\circ)_p + \left(\sum n_j \int_{298}^{T} C_{pj}\, dT\right)_p$$

LHS

$= - 210584342.2 + 66009.14(473-287) + 10.235 (473^2 – 298^2) –$
$16.39 \times 10^{-5}(473^3-298^3)-257.8\times10^{-9}(473^4 – 298^4)$
$= -210584342.2 + 12911926.19$
$=-197672415.99$

RHS

$=8.417 (-26416) + 1465 (-94052) +1416.67(-57797.9)$
$+65572.27(7.298) +2330.7 \times 10^{-2}/2 (T^2-298^2)-294.2\times 10^{-5}/3(T^3-$
$298^3) –382.2\times10^{-9}/4(T^4-298^4)$

T =