

Material balance

$$\begin{aligned} \text{Amount of Hydrogen required to be produced} &= 1 \times 10^6 \text{ m}^3/\text{day} \\ &= 41666.67 \text{ m}^3/\text{hr} \end{aligned}$$

Basis : 1 hr of operation

Amount of gas at NTP is given by

$$PV = nRT$$

$$n = PV/RT = (41666.67 \times 1) / (0.08256 \times 298)$$

$$\text{No. of moles of Hydrogen} = 1703.97 \text{ kmol/hr}$$

material balance is divided into different stages which includes

- | | |
|-----------------------------|----------------------------|
| 1) Reactor | 5) high temperature shift |
| 2) Waste heat boiler | 6) low temperature shift |
| 3) Quenching | 7) carbon dioxide scrubber |
| 4) hydrogen sulfide removal | |

feed stock : Natural gas (Raveena offshore)

component	vol%
Methane	99.52
Ethane	0.06
Propane	0.01
Nitrogen	0.40

In this case it is assumed that all other components are negligible as compared to Methane so all others are neglected. i.e. only Methane and Nitrogen are present in Feed.

Now synthesis gas composition for **shell type process** is given by -----(ref1)

Gas composition	vol%
CO ₂	4.32
CO	46.55
H ₂	47.15
CH ₄	0.60
N ₂	0.56
H ₂ S	0.81

Let 100 kmol of synthesis gas is formed in 1hr operation then we have

Gas composition	kmol
CO ₂	4.323
CO	46.55
H ₂	47.15
CH ₄	0.60
N ₂	0.56
H ₂ S	0.81

At inlet of H₂S removal tower

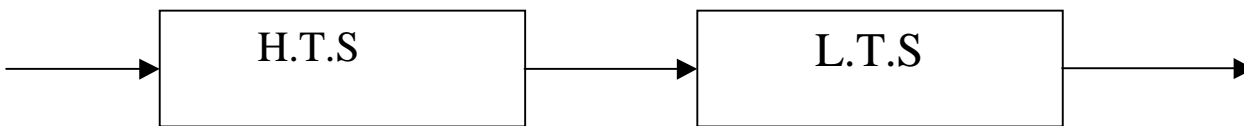
Assumption made

- 1) No CO₂ removal takes place in Hydrogen sulfide removal tower
- 2) No loss of gas takes place in leakage after hydrogen sulfide removal

After H₂S removal vol% will be :

Gas composition	vol%
CO ₂	4.36
CO	46.93
H ₂	47.54
CH ₄	0.60
N ₂	0.57

Material balance for high temperature shift and low temperature shift



From literature amount of co remainig after conversion =7.9% (Ref1)

At inlet of HTS we have

Gas composition	vol%	kmol
CO ₂	4.36	4.32
CO	46.93	46.55
H ₂	47.54	47.54
CH ₄	0.60	0.60
N ₂	0.57	0.56

For H.T.S

Let X moles of CO is converted into H₂ and CO₂

Then we have

%CO after H.T.S

$$7.9/100 = (46.55 - X) / \{ (46.55 - X) + (4.32 + X) + (47.15 + X) + 0.60 + 0.56 \}$$

$$X = 35.88 \text{ kmol}$$

Therefore amount after H.T.S

Gas composition	vol%	kmol
CO ₂	29.76	40.2
CO	7.90	10.67
H ₂	61.48	83.03
CH ₄	0.44	0.60
N ₂	0.41	0.56

Total no of moles in mixture = 135.06 kmol/hr

Low temperature shift balance

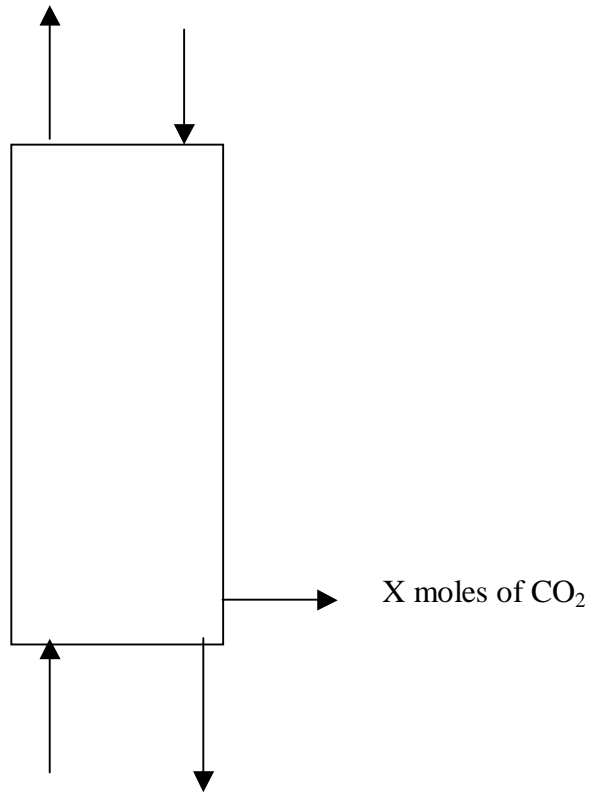
From literature range of conversion of CO is given 1.5% to 1.8%

Assuming CO is converted to 1.6% of gas mixture.

We have

Gas composition	vol%	kmol
CO ₂	33.86	48.58
CO	1.60	2.29
H ₂	63.73	91.41
CH ₄	0.42	0.60
N ₂	0.39	0.56

Absorber balance



It is assumed that here that only CO₂ removal takes place we have Hydrogen remaining constant. and 95% pure after the process.

At inlet of absorption coloumn we have

Gas composition		vol%	kmol
CO ₂		33.86	48.58
CO		1.60	2.29
H ₂	↑	63.73	91.41
CH ₄	↓	0.42	0.60
N ₂		0.39	0.56

Also since only carbondioxide is removed amount of hydrogen is constant.

Therefore we have

$$(63.73/100) \times (Y) = 1703.97 \text{ kmol/hr (amount of hydrogen to be produced is 1703.97)}$$

$$\text{kmol /hrof mixture} = 2673.73$$

Now kmols of other components in gas mixture are

At inlet of absorption coloumn we have

Gas composition		vol%	kmol
CO ₂		33.86	905.36
CO		1.60	42.69
H ₂		63.73	1703.97
CH ₄		0.42	11.3

N ₂	0.39	10.40
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Now X moles of CO₂ is removed, also amount of hydrogen is constant is constant

Therefore

$$95/100 = (1703.97)/\{(1703.97) + (905.36 - X) + (42.68) + (11.3) + (10.40)\}$$

$$X = 880.05$$

Final product amount is given by

Gas composition	vol%	kmol
CO ₂	1.41	25.29
CO	2.38	42.69
H ₂	95.00	1703.97
CH ₄	0.63	11.3
N ₂	0.58	10.40

Mass balance for the shell partial oxidation process

Inlet of Absorption column we have

Gas composition	vol%	kmol
CO ₂	33.86	905.36
CO	1.60	42.69
H ₂	63.73	1703.97
CH ₄	0.42	11.3
N ₂	0.39	10.40

At inlet of LTS we have

Gas composition	vol%	kmol
CO ₂	29.76	745.15
CO	7.90	202.89
H ₂	61.48	1543.7
CH ₄	0.44	11.30
N ₂	0.41	10.40

At inlet of H.T.S we have

Gas composition	vol%	kmol
CO ₂	4.36	64.19
CO	46.93	862.74
H ₂	47.54	883.85
CH ₄	0.60	11.3
N ₂	0.57	10.40

At inlet of H₂S removal tower

Gas composition	vol%	kmol
CO ₂	4.32	64.19
CO	46.55	862.74
H ₂	47.15	883.85
CH ₄	0.60	11.3
N ₂	0.56	10.40

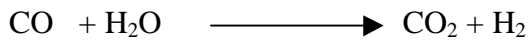
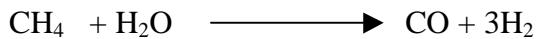
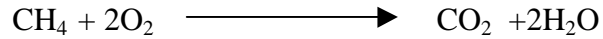
H₂S

0.81

14.96

MATERIAL BALANCE FOR REACTOR

CHEMICAL REACTION INVOLVED :



Now doing carbon balance for the system we get

$$\begin{aligned} \text{Moles of carbon in synthesis gas} &= 64.19 \cdot 12/44 + 862.72 \cdot 12/28 + 11.3 \cdot 12/16 \\ &= 395.72 \text{ kmol/hr} \end{aligned}$$

Now we have feed contains methane and nitrogen

So that moles of carbon in feed = 395.72 kmol/hr

Also moles of Methane in feed = $395.72 \cdot 16/12 = 527.62$

Feed Natural gas is 99.6% pure

Moles of feed = $527.62/0.996 = 529.74$ kmol/hr

$$(M)_{\text{feed}} = (16)99.6/100 + 28 \cdot (0.4/100)$$

$$M = 16.048$$

Kg of feed required is given by = $529.74 \times 16.048 = 8501.26752$

Also amount of oxygen required is

From literature we have

Steam = 0.75 kg/kg of feed.

Oxygen = 1.16 kg/kg of feed

Therefore

$$\text{Steam} = 0.75 \cdot (8501.2752)$$

$$= 6375.95 \text{ kg/hr}$$

$$\text{Oxygen} = 9861.47 \text{ kg/hr}$$

$$\text{Moles of Oxygen} = 308.17 \text{ kmol/hr}$$