Operating experience with the latest Primary Reformer Catalyst replacement at IFFCO Kalol Ammonia Plant

By

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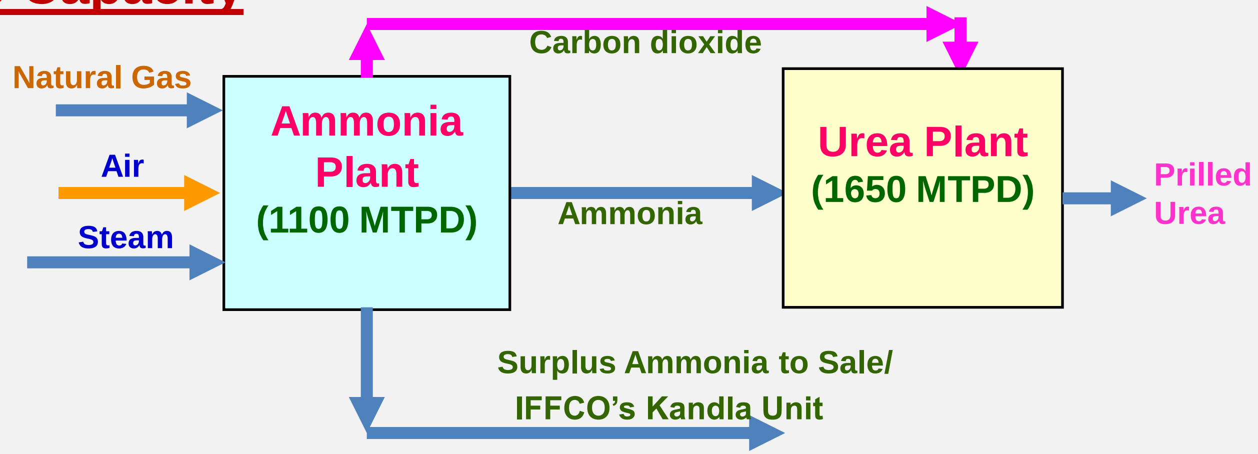
About IFFCO Kalol

Year of Commissioning : 1975 ; Year of Revamp : 1997

Energy Saving Projects : 2003, 2006 & 2014 & 2017

Revamp Capacity



Current Production and Energy

Plant	Daily Production, MTPD	Energy Consumption, Gcal per MT (LHV)
Ammonia	1140	7.90
Urea	1880	5.42

Ammonia Plant- Primary Reformer

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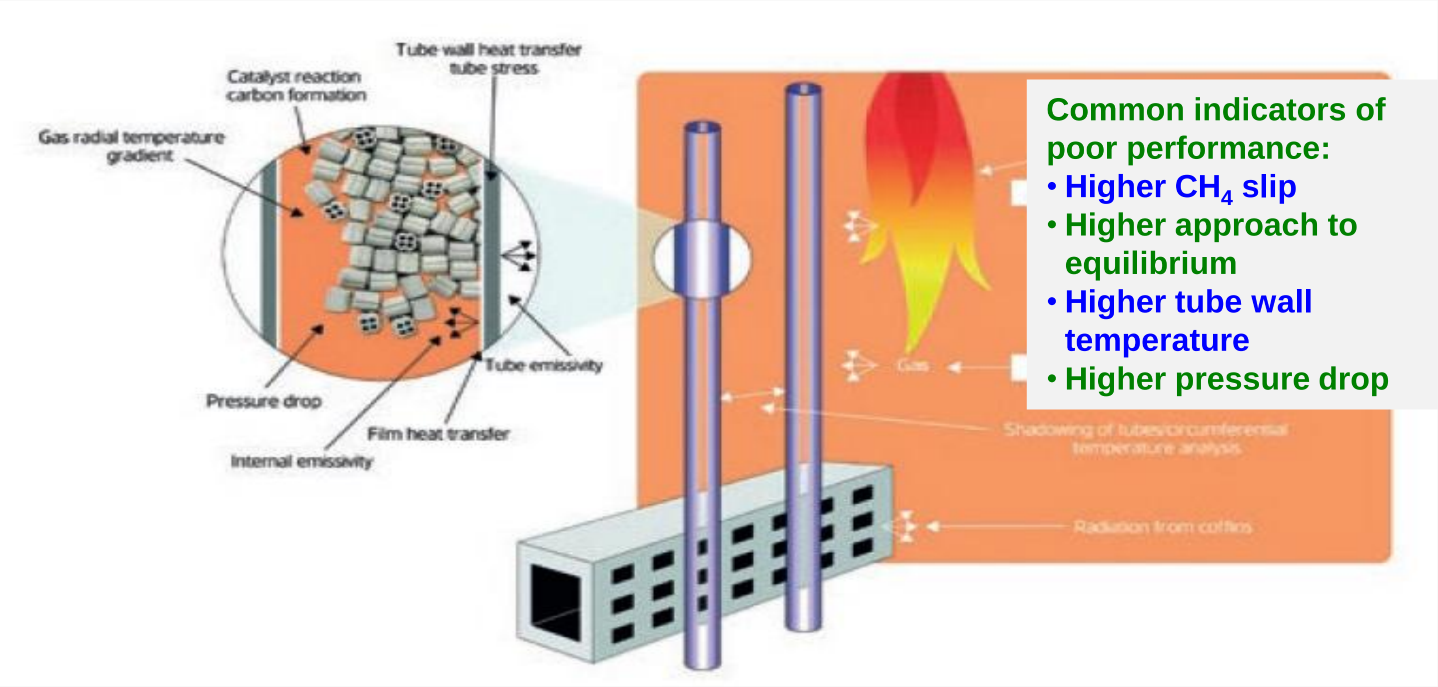
- **An important step in the ammonia manufacturing process is steam reforming i.e., conversion of hydrocarbon into hydrogen.**
- **Primary Reformer is heart of the Ammonia Plant and is the most complex and expensive equipment of the Plant.**
- **Optimum performance of the reformer and the installed reforming catalyst is critical to ensuring high plant productivity and efficiency.**
- **Poisoning, fouling or incorrect operation can adversely affect the catalyst's performance.**
- **High tube wall temperatures (TWT) of both the catalyst and riser tubes can arise from several sources:**
  - **Sulfur slip on the primary reformer catalyst, and subsequent carbon formation.**
  - **Low steam to gas ratio -may lead to carbon formation on catalyst**
  - **Maldistribution of fuel gas and burner flame impingement issues on tubes and refractory causing high TWTs.**
  - **Reformer tube weld failures.**
  - **Maloperation of furnace**

Ammonia Plant : Primary Reformer

- **Kalol -Ammonia Plant using steam reforming process based on M/s. MW Kellogg, USA technology with top fired burners and induced draft.**
- **The total number of catalyst tubes are 336 and total number of burners are 128.**
- **Since 2009, Ammonia Plant is in operation with 100 % gas as feed and fuel.**
- **Activated Carbon beds were in used for feed desulphurization since commissioning of plant.**
- **In 2017, Feed gas Desulphurization section was converted to Hot Hydro-desulphurization.**

Primary Reformer consists of:

- **Heat exchanger**
- **Chemical reaction over Ni-based catalyst**
- **Combustion reaction at outer side**



Common indicators of poor performance:

- **Higher CH_4 slip**
- **Higher approach to equilibrium**
- **Higher tube wall temperature**
- **Higher pressure drop**

Reformer Tubes Details

Description	Reformer Details
	Revamp-III, 2006
Catalyst tubes	G-4852 Micro
Catalyst tube top	SA -213 Gr TP 304H
Trunnion	ASME SA 106 Gr.B
Flange	SA - 182 Gr, F304H
Riser Tube	G-4852 Micro
Riser tube top (SF-10)	SB 564 / 408 UNS 8811 (Incoloy 800 HT)
Transition cone	SB 409 UNS 8811 (Incoloy 800 HT)
Weldolet (Catalyst tube)	SB-564 / 408 UNS 8811(Incoloy 800 HT)
Weldolet (Riser)	SB 564 / 408 UNS 8811 (Incoloy 800 HT)
Pigtail	A213 T 304 H
Inlet Manifold	A312 TP 304H

Catalyst Tubes:

OD 112 mm, ID 90 mm, MSW: 11 mm

Design pressure	35.9 kg/cm^2 g
Design temperature	930^{o}C

Riser

OD 132 mm, ID 91.4 mm, MSW: 16.5 mm

Design pressure	33.2 kg/cm^2 g
Design temperature	970^{o}C

Primary Reformer Catalyst

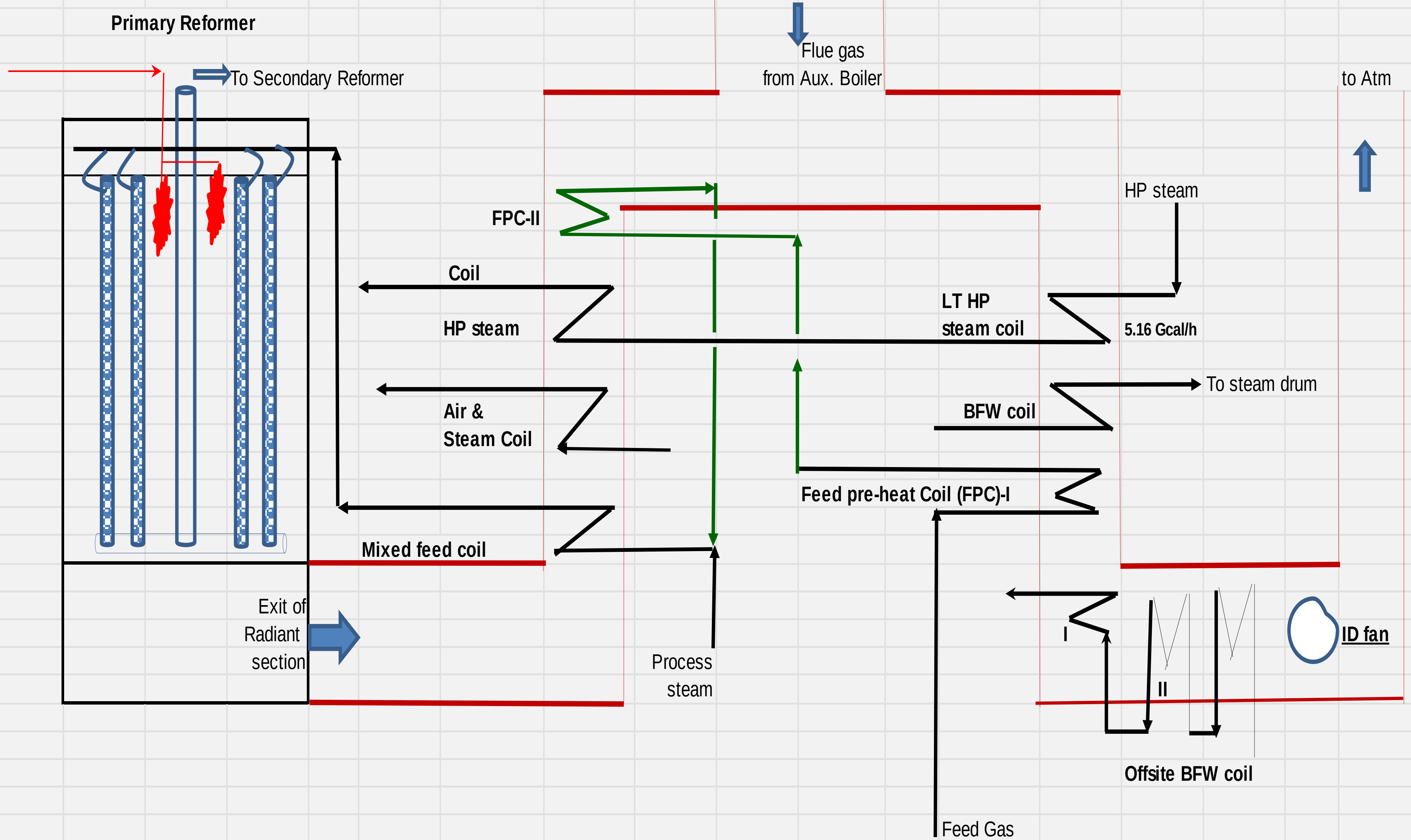
As supplied –NiO on support
Active species-Ni crystallites

Reduction process needed;

$NiO + H_2 – Ni + H_2O$

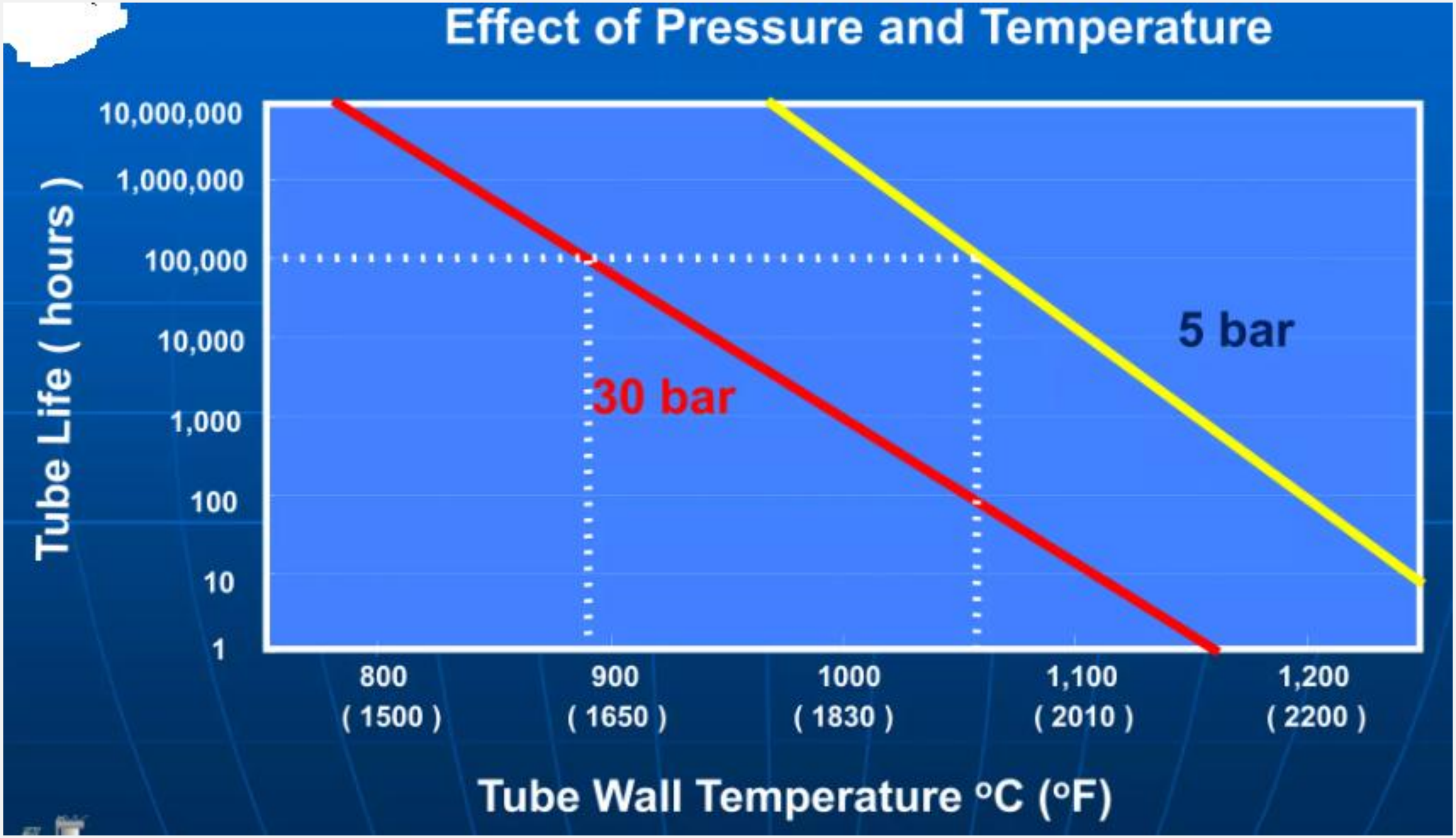
Catalyst stagnant heating upto 350 degC, then reduction with steam upto 650 degC @ 50 degC/hr

Primary Reformer , Convection Section and heat Recovery

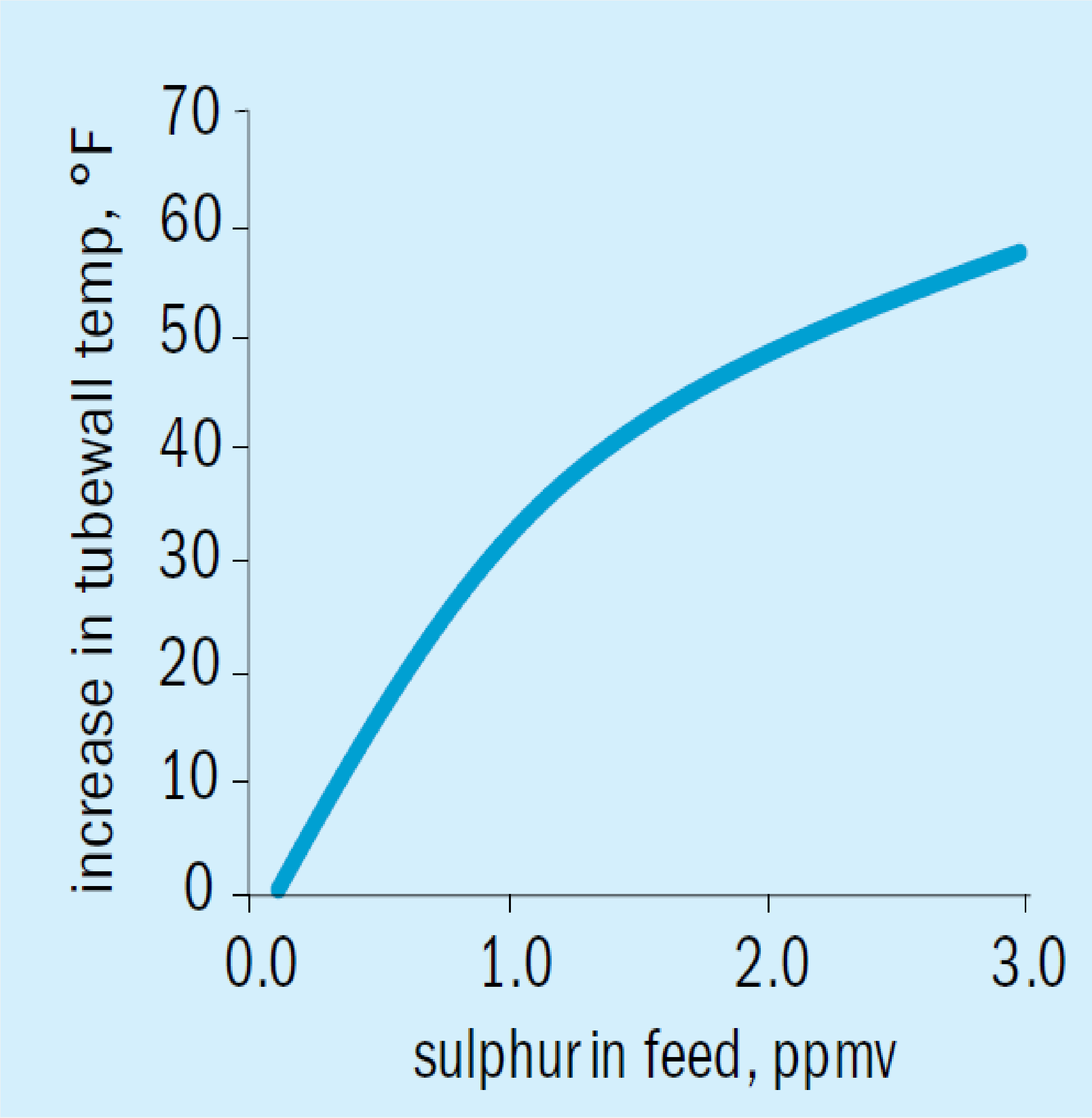


Primary Reformer Catalyst Tube Life

Primary Reformer catalyst tube are design for service life of 1,00,000 hrs.



Effect of Sulphur on Catalyst Tube Wall Temperature



Primary Reformer operation with Higher CV gas

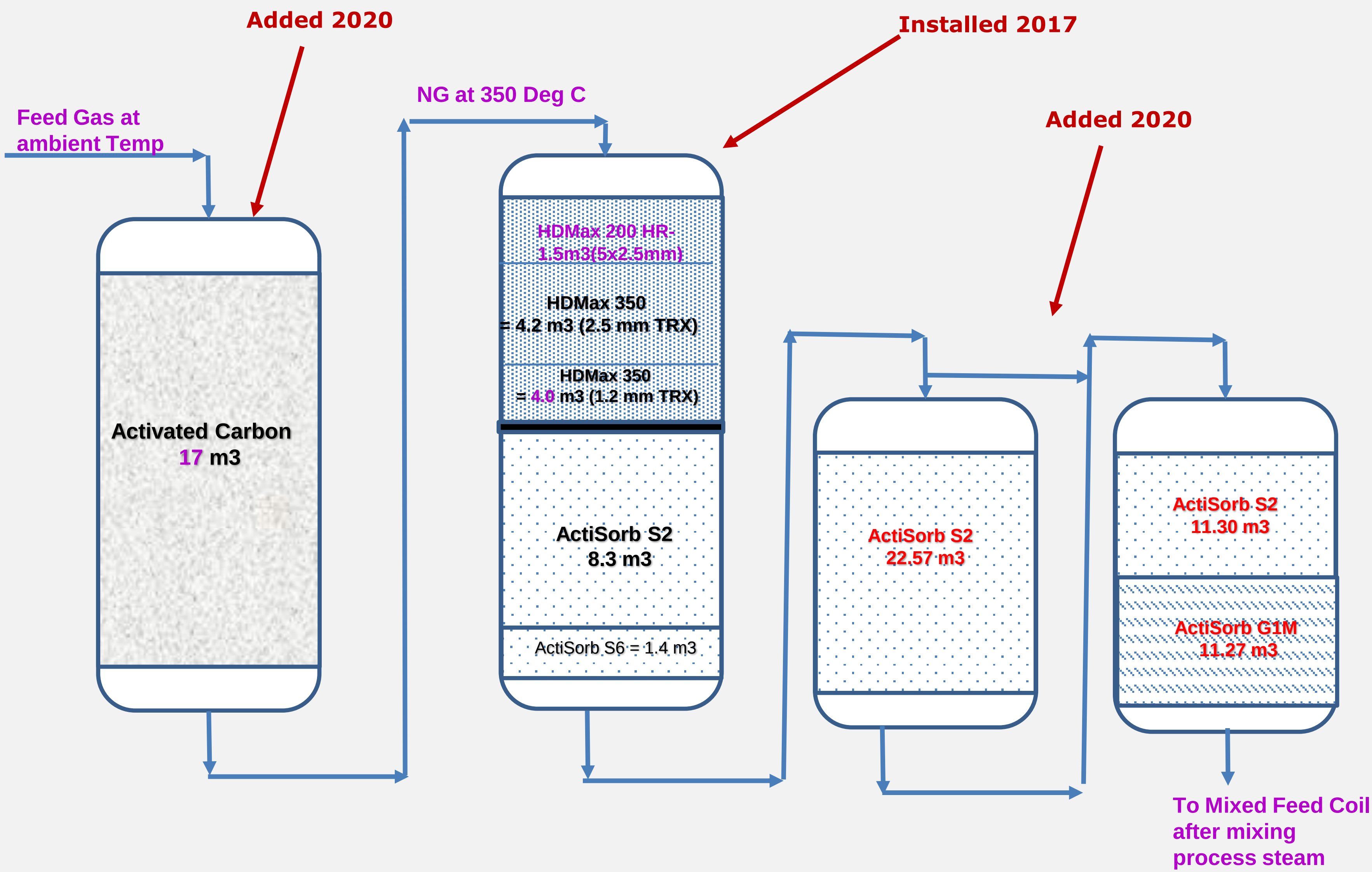
- **As mentioned, Ammonia Plant is in operation with 100 % gas as feed and fuel with R-LNG, having no Sulphur contamination @ S/C ratio of 3.2 since 2009.**
- **Activated Carbon beds were in used for feed desulphurization since commissioning of plant.**
- **In 2017, Feed gas Desulphurization section was converted to Hot Hydro-desulphurization.**
- **From Aug.2019, high calorific gas from CAIRN gas field from Barmer Rajasthan started in GSPL gas pipelines.**
- **Higher CV gas creates lot of operational problem in Primary Reformer. Hot bands and high tube skin temperature have been faced.**

Typical Analysis of CAIRN Gas at Barmer

Description	Min	Max
Components	Mole %	
Methane	83.50%	86.00%
Ethane	9.80%	11.00%
Propane	2.40%	3.00%
i-Butane	0.80%	1.10%
n-Butane	0.45%	0.80%
i-Pentane	0.10%	0.20%
n-Pentane	0.07%	0.15%
n-Hexane	0.01%	0.07%
n-Heptane	0.00%	0.02%
n-Octane	0.00%	0.00%

Components	CAIRN	R-LNG
C6+	0.0670	0.0000
Propane	2.9637	0.5200
I - Butane	1.0049	0.0900
n- Butane	0.6410	0.1200
Neo Pentane	0.0000	0.0000
I - Pentane	0.1562	0.0000
n- Pentane	0.1232	0.0000
Nitrogen	0.2558	0.6500
Methane	85.3167	97.0600
Carbon Dioxide	0.0059	0.0000
Ethane	9.4624	1.5600
Total	100.00	100.0000
MW	19.13	16.57
Carbon No.	1.215	1.026

Desulphurization of Feed gas



Change in Gas Composition

- **With higher CV gas supply, previous catalyst supplier suggested to maintain the S/C ratio of 3.2 minimum due to catalyst configuration.**
- **Despite higher S/C ratio, hot bands and higher catalyst tubes temperature have been faced in the Primary Reformer.**
- **The gas samples at exit of Desulphurization sections were also analyzed at outside fertiliser Units to assess the actual problem.**
- **Sulphur slippages was observed at exit of Desulphurization section.**
- **Then it was planned to replace the old charge of Primary Reformer Catalyst with new one for operation with higher hydrocarbons in the feed @ S/C ratio of 3.0**
- **In April 2021, turnaround, Primary Reformer catalyst was replaced with new one**

Primary Reformer Catalyst Replacement

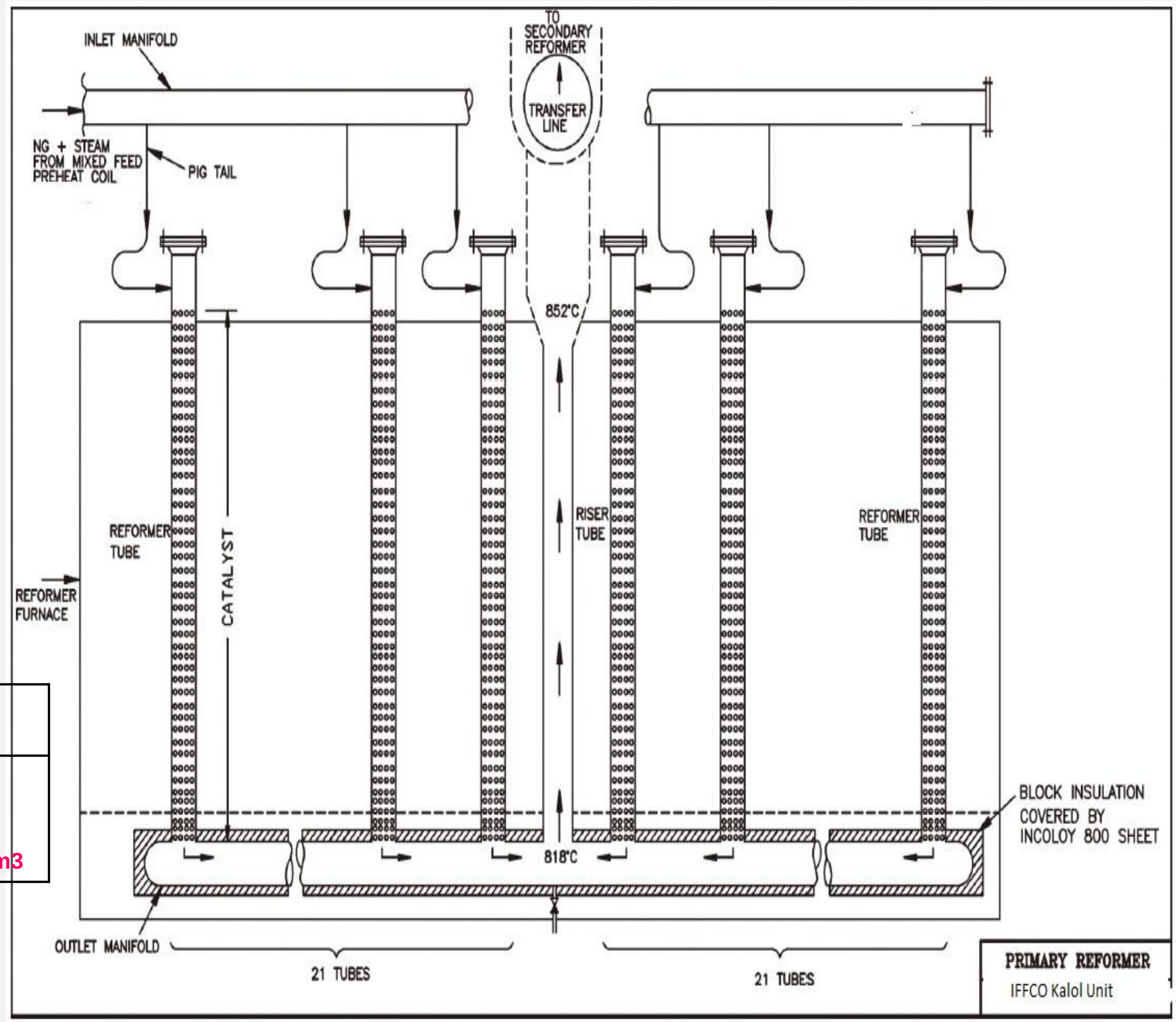
Composition

Nickel oxide dispersed on an alpha alumina ceramic support, typically containing 17% NiO, 01. % SiO_2 amd 0.05% SO_3.

Physical properties (typical)

Catalyst	23-4MQ	23-4GQ
Form (QUADRALOBE)	4-hole cylinders with 4 flutes and domed edges	4-hole cylinders with 4 flutes and domed edges
Length (mm)	13	20
Outer diameter (mm)	10.5	16
Inner diameter (mm)	2.7	4.4
Typical loaded density (kg/m^3 / lb/ft^3)	1140 / 73	1050 / 67

Primary Reformer



Catalyst	JM Top Katalco 25-4MQ JM Bot Katalco 57-4GQ
Date of loading	May, 2021, Dense loading Top 45% 25-4MQ. : 9.9 m3 Bot 55 % 57-4GQ : 12 m3 Total catalyst volume: 21.9 m3

Outlet CH_4 : 12.01% (Des.: 14.51%)

Outlet Temp.: 789°C (Des. :786°C)

Cost-economic Benefit of Primary Reformer Catalyst Replacement

- **Steam saving due to operation at lower S/C**

MP Steam Saving	:	49 MT/Day
Energy Saving	:	32 Gcal/D
Monetary Saving	:	372 Rs. Lakh
Payback	:	1.0 Year

Parameter	Unit	Before Primary Reformer catalyst replacement, earlier charge since 2018	After Primary Reformer catalyst replacement in ATR-2021
Tube skin Temp, Max/Min	^0C	905 / 885	882/ 865
Hot Spot	No	20-25	0

- **Benefit: Elongate the life of catalyst tubes.**
- **Better reforming leading to lower methane slip and higher H2 production**

Conclusion

- Teething problem of the process plant can be solved by detailed in-house analysis and adaptation of technically feasible options available in the market.
- Lower S/C ratio operation improved the operational flexibility reliability of Primary Reformer.
- It improve the over all productivity and utilities saving of Kalol Complex.

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