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UPGRADATION OF AMMONIA-UREA COMPLEX AT IFFCO-KALOL FOR SUSTAINED HIGH LEVEL PERFORMANCE

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RESUME

L'unité Kalol est la première des quatre unités productrices d'IFFCO. Les ateliers d'ammoniac de 910 t/j et d'urée de 1200 t/j ont été réceptionnés fin 1974. Le feedstock de cette unité vient des gisements de gaz naturel voisins. La technologie adoptée pour l'atelier d'ammoniac était de M.W. Kellogg, Etats-Unis et pour l'urée de Stamicarbon, Pays-Bas.

Pour maintenir des performances élevées et éviter l'obsolescence des ateliers, l'unité Kalol a suivi les derniers développements technologiques dans ce domaine et mis en oeuvre un certain nombre d'améliorations au cours des vingt dernières années. Ces améliorations visaient surtout à augmenter la fiabilité opérationnelle, réduire la consommation d'énergie et augmenter le niveau de sécurité et la qualité de l'environnement.

Nous avons l'intention de traiter des principaux projets d'amélioration pour augmenter durablement la performance globale de l'unité.

IFFCO vient d'entreprendre un projet majeur intitulé « Expansion de Kalol » pour augmenter la capacité de production de l'atelier d'ammoniac jusqu'à 1100 t/j et celle de l'unité d'urée jusqu'à 1600 t/j, à un coût d'environ US$ 40 millions. Le projet d'expansion de Kalol a été formulé pour obvier à la pénurie de gaz naturel et profiter des possibilités maximum de l'unité en faisant sauter les contraintes identifiées. La communication donne aussi des détails des projets mis en oeuvre dans ce but.

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Indian Farmers Fertiliser Cooperative Limited (IFFCO) is one of the country's premier cooperative societies. It is also the country's biggest producer and marketeer of chemical fertilisers. From its inception in 1967 as a multi-unit cooperative society the organisation had experienced great success in its contribution to the growth of Indian agriculture. At present IFFCO has four operating units, three of them are producing ammonia - urea, located at Kalol, Phulpur and Aonla and the fourth one at Kandla is involved in production of complex fertilisers. The brief resume of IFFCO's operating units is enumerated in Annex-I.

In anticipation of increased demand of fertiliser in the country and also with an objective to bridge the gap between the demand and supply IFFCO have initiated major expansion programme of its plants. Three projects of expansion of ammonia-urea capacity are already under implementation. The expansion of complex fertiliser unit at Kandla and setting up of grassroot ammonia-urea complex at Nellore in the state of Andhra Pradesh are likely to take off by the end of 1996. The brief profile of IFFCO's projects at hand and under planning are provided in Annex-II.

In conjunction with IFFCO's massive expansion programme it has been our endeavor to pursue continuous upgradation of its existing plants. It is well established that the return on properly engineered revamp/retrofits of the old operating units to avail benefits of technological upgradation is far more economical than setting up of new capacities. The Kalol unit of IFFCO which is the oldest of the four operating units is a standing example of successful upgradation for sustained high level performance.

The Kalol unit consisting of a 910 TPD ammonia plant utilising Kellogg's process and 1200 TPD urea plant of Stamicarbon process was commissioned in the last quarter of 1974. The plant receives natural gas and associated gas from the adjacent gas fields. IFFCO has implemented series of retrofit and revamp schemes in this plant with the objective of improving upon the operational reliability, energy conservation, safety and pollution control. This paper will briefly cover the major retrofits done since inception which have contributed towards improvement in operational reliability, sustained high level of production and energy conservation.

1. Installation of PGR

To maintain optimum level of inerts a small portion of gas from synthesis loop was being purged like most plants installed in 1970s. In 1980 a purge gas recovery unit based on cryogenic technology was installed to recycle hydrogen back into the synthesis loop. This has enabled increased production by around 5% and reduction in energy by 0.23 Gcal/MT of ammonia.

2. Modification in Primary Reformer Section

2.1 Reformer Revamp

The primary reformer is a typical of Kellogg design top fired reformer having 336 tubes arranged in 8 harps having 42 tubes each. The 126 burners installed in nine rows in the reformer are capable of firing associated gas as well as naphtha as fuel. The first reformer revamp was taken up in 1986 due to repeated failures of reformer tubes as a result of ageing. There was no significant change in the design nor was any metallurgical upgradation in the first revamp. However, during the second revamp which took place in the year 1993, considerable upgradation was carried out both in the metallurgy as well as furnace design. During the second revamp the HK-40 tubes of the reformer were replaced with G4852(HP) material. This enabled use of thinner tubes even though the outer diameter of tubes remain same. The tube thickness was reduced from 15.6 mm to 12 mm and the inner diameter was increased from 73.9 to 82 mm.

To improve upon the distribution of feed to all the reformer tubes the inner diameter of pigtails have been reduced from 21 mm to 19.3 mm and the material of construction changed from ASTM-A-335 to ASTM-A-213. The above arrangement have substantially improved the flow distribution of feed to Reformer due to increase in pressure drop in the pig tails in comparison to the overall pressure drop across the primary reformer. The design condition and materials of construction of the primary reformer before and after revamp is provided in Annex-III.

The resultant benefits of the second primary reformer revamp are given below:

(i) increase in catalyst volume by 23% have reduced the hydrocarbon loading in the primary reformer.
(ii) due to reduced thickness of catalyst tubes both heat flux and tube skin temperature have reduced.
(iii) due to increased cross section of catalyst tube the pressure drop across the reformer tube has reduced from 3.5 kg/cm^2 to 2.1 kg/cm^2 .

These factors together have contributed favourably to the less severe operating condition as well as reduction in energy consumption.

In order to take care of the increase in Reformer inlet feed temperature due to bigger mixed feed coil the material of construction of inlet manifolds has been changed from ASTM-106 Gr.B to ASTM-A-335 Gr.P-II.

2.2 Convection Zone Modification

To improve upon the recovery of convection heat from flue gas and thermal efficiency of the primary reformer, number of modifications have been carried out in the convection zone as below:

2.2.1 *Installation of additional Boiler Feed Water Coil*

Two sets of boiler feed water coils meant for heating water for offsite boiler were installed upstream of ID fan. The first set consisted of 8 coils were installed in 1986. The second set consisting of 4 coils was installed in the year 1993. These two sets of coils have substantially contributed in energy saving as a result of reduction in stack temperature as well as energy saving.

2.2.2 *Replacement of Mixed Feed Coil*

Against the design temperature of feed at mixed feed coil outlet of 510°C, the plant was operating at 460°C. The old coil had the heat transfer area of 271.3 m^2. This has been replaced with a new mixed feed coil of 345.2 m^2 heat transfer area. The material of construction of the new mixed feed coil is SS-304H as against A-335 P11. This has improved the mixed feed coil outlet temperature to 490°C as against 460°C before revamp. Due to increase in the size of mixed feed coil the pressure drop has reduced from 1.88 kg/cm^2 to 0.69 kg/cm^2 resulting in substantial relief to the natural gas compressor duty.

2.2.3 *Replacement of Mixed Feed Coil*

Against a design of 441°C the super heated steam temperature the actual temperature was about 415°C. Lower superheater temperature results in lower cycle efficiency of steam turbines. To obviate the shortcomings the old HT superheater coil having heat transfer area of 1737 m^2 has been replaced by a new coil of 2492 m^2 area. The material of construction have also been upgraded with P-22 in place of A-335 P-11. This has resulted in increase of super heated steam temperature from 415°C to 428°C and reduction in pressure drop across the super heater coil from 1.98 to 1.01 kg/cm^2. Further, the recovery of heat from flue gas has improved from 16.179 Gcal/h to 18.756 Gcal/h.

2.2.4 *Increase in Reformer Stack height*

The reformer stack height was increased from 32 m to 40 m in 1990. The increase in stack height has substantially improved the draft by 4 mm WC thereby reducing the turbine speed from 3500 rpm to 3150 rpm apart from improving the ground level pollution.
The combined effect of these retrofits have been the reduction of stack temperature from 280°C to 200°C resulting in Energy Saving of Appr 0.24 Gcal/MT Ammonia. The diagramatic depiction of Reformer section is shown in Annex.-IV.

3. Ammonia Converter Retrofit

The ammonia converter of Kalol unit is the typical bottle shaped Kellogg converter with four beds having inter bed quench facility. Total catalyst volume was 64 m^3. The synthesis gas flowed through the catalyst bed in axial direction and cooled before entry into subsequent beds with interbed quench system. The catalyst size was 6-12 mm.

In order to save energy in Ammonia synthesis it was decided to carry out synthesis converter retrofit for Kalol as well as Phulpur unit who had identical converters using Ammonia Casale's technology.

In the converter modification the catalyst is contained between two concentric walls perforated to allow entry and exit of gas. There are no top cover on the catalyst beds. This enable some gas to take axial radial direction through the top of catalyst bed. Through rest of the catalyst bed the gas flow is radial. To get uniform flow of gas, the wall perforation is designed to offer optimum pressure drop. The perforated bottoms of Kellogg designed beds are sealed to stop gas flow from the beds in axial direction. The predominantly radial flow of gas through the beds, considerably reduce the pressure drop since the effective cross sectional area of flow is increased, thereby reducing the gas velocity. The effective depth of packed bed along the flow direction is also reduced. The significant reduction in pressure drop enables use of 1.5 to 3.0 mm size high activity catalyst. The new arrangement also facilitates greater volume of catalyst which is about 75 m^3 as compared to 64 m^3 before retrofit. Please see Annex.-V.

One of the interesting features of Ammonia Casale retrofit is supply of converter internals in sectors small enough to be taken inside the converter through the top cover after removal of feed effluent exchanger 122C. The relative ease with which these internals are assembled insitu is another interesting feature. By and large the pressure parts of the converter remain untouched.

The following benefits were accrued as a result of the converter retrofit:

a. Due to superior activity and smaller size of catalyst the ammonia concentration in the exit gas increased from 12% to 15.2%.

b. Increased conversion per pass resulted in reduction in flow rate of recycle gas requiring less power from the synthesis gas compressor and reduce load on the refrigeration compressor.

c. Due to change in flow configuration and reduction in gas throughput pressure drop across the converter as well as synthesis loop has been reduced, which has contributed to further reduction in power output of the synthesis gas compressor.

d. The higher exit temperature of converted gas resulted in greater heat recovery in BFW heater (123-C) Exit Synthesis Converter.

As a result of the retrofit there has been an overall saving of about 0.27 Gcal/MT of ammonia, apart from increase in capacity of synthesis section.

4. Installation of UCAR Amine Guard in CO_2 Removal System

Originally the CO_2 removal section was operating with conventional MEA solution as absorbent. The circulating solution had 18% MEA by wt. Regeneration heat was 2100 Kcal/Nm^3 of CO_2.
To lower the regeneration heat requirement UCAR Amine Guard system was introduced which enabled gradual increase of MEA strength in solution to 27% and increase of CO_2 loading of solution. The regeneration heat requirement was brought down to around 1570 Kcal/Nm^3 CO_2.

5. Inert Gas Circulating System

With the passage of time the natural gas price has gone up. The introduction of inert gas circulation system became imminent from economic consideration. This system was installed in 1993, which enabled circulation of nitrogen along with hydrogen or without in a closed loop system through primary reformer, secondary reformer, HTS, LTS for heating, cooling and reduction of catalyst. Introduction of carrier gas circulation system has substantially reduced venting of precious natural gas for LT catalyst reduction as this operation can be done independently when rest of the plant is shut down. Apart from curtailing flarings of natural gas it has been possible to cut down start up time by prior planning and advance action.

6. Replacement of equipment, piping and other retrofits

In addition to these major retrofits/revamps in order to sustain high level of production following actions have been taken in a planned manner:

6.1 Replacement of exchangers and piping:- Number of ageing exchangers and vulnerable pipings have been replaced with superior metallurgy. Most of the Process Gas Piping which was earlier of P-1 material has been replaced with P-11 .

6.2 The boiler blow down and process condensate are utilised for jacket cooling and then as cooling water make-up.

6.3 To save venting of synthesis gas during start-up the same is diverted to fuel gas header.

6.4 Installation of natural gas compressor to boost the pressure of natural gas which has gradually come down to 20 kg/cm^2 from 40 kg/cm^2 due to depleting reserve and over withdrawal by other consumer.

6.5 The old high pressure carbamate condenser in urea plant have been replaced by a new modified condenser of superior material, equivalent to 2 RE69 in place of 316L. This has reduced the plant down time.

6.6. The inner liner of the autoclave of urea plant was failing repeatedly leading to long shutdown of the plant. It was observed that most vulnerable area was the bottom hemisphere. Accordingly, the complete liner of the bottom hemisphere was replaced in 1993 since then there has been no further leakage.

As a result of the series of revamps/retrofits undertaken from time to time the Kalol unit, which has already completed two decades of operation, is attaining greater heights in terms of performance. The graphs enclosed amply demonstrates sustained improvement of both ammonia and urea plant be it in terms capacity utilisation or in terms of energy conservation. So much so, in its 20th year which incidentally is the year 1995-96. the plant has attained its all time best capacity utilisation in a complete financial year. The urea production of 454590.82 in 1995-96 amounts to 114.8% of rated capacity.

The above stated energy conservation retrofits have yielded sustained results. The annual energy figure of Ammonia Plant started with 10.7-10.8 Gcal/MT of ammonia in 1976-77 and gradually came down to 9.3 Gcal/MT in 1994-95 which was all time best. This figure in comparison to the original design of 9.844 Gcal/MT of ammonia speaks high of the achievement of our Kalol team. In the year 1995-96 the ammonia plant energy was 9.787 Gcal/MT and capacity utilisation of ammonia plant remained limited to 103.48% partly due to inadequate natural gas supply.

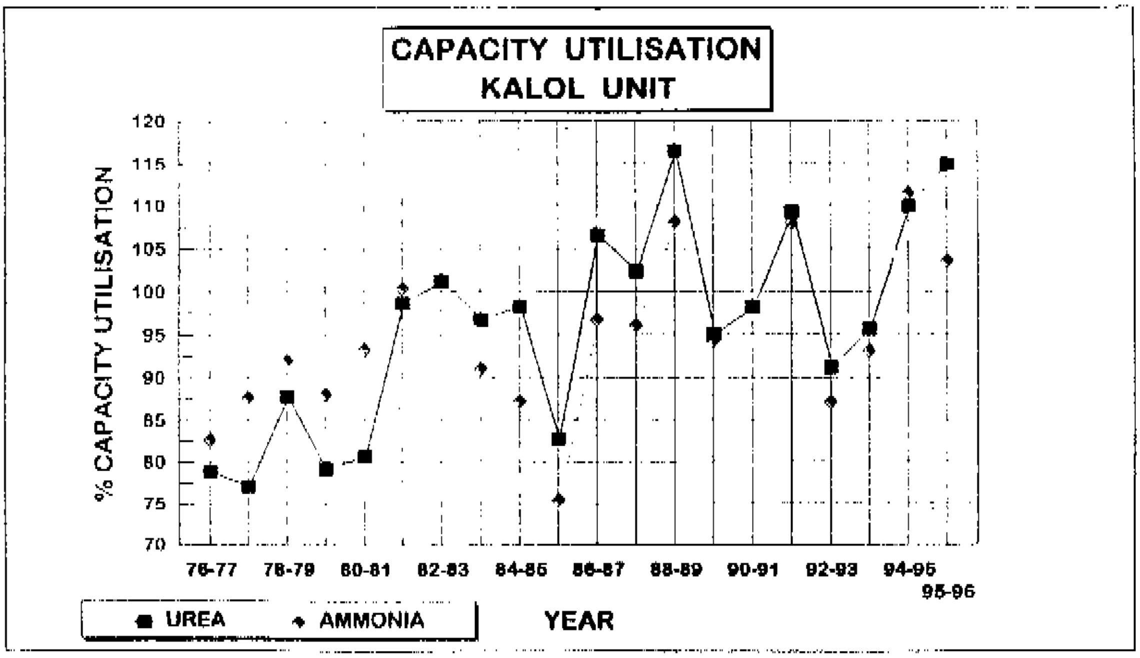
7. Future programme - Increasing capacity of ammonia-urea plants

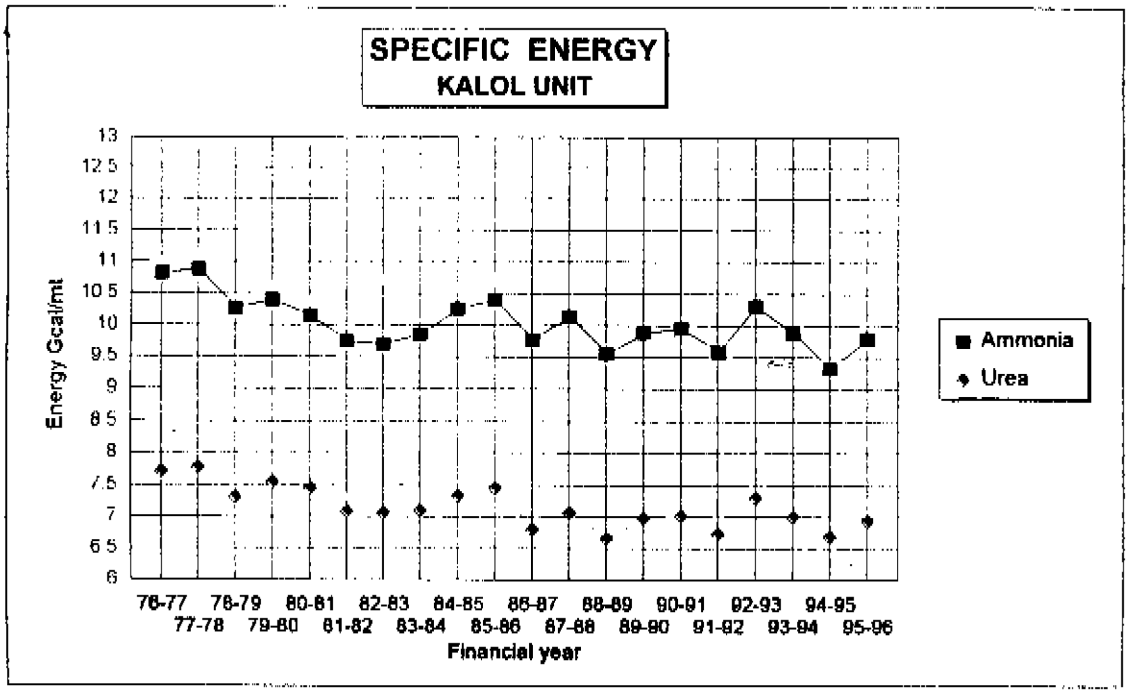
It has been established that due to limitation in supply of natural gas the plant is unable to produce at its total potential. It has been decided to augment the capacity of ammonia plant from 910 tpd to 1100 tpd and urea plant from 1200 tpd to 1650 tpd. In order to achieve the above stated objective a new set of schemes have been evolved under a project called **Kalol expansion** which is at present under implementation at an estimated cost of US$ 40 million.

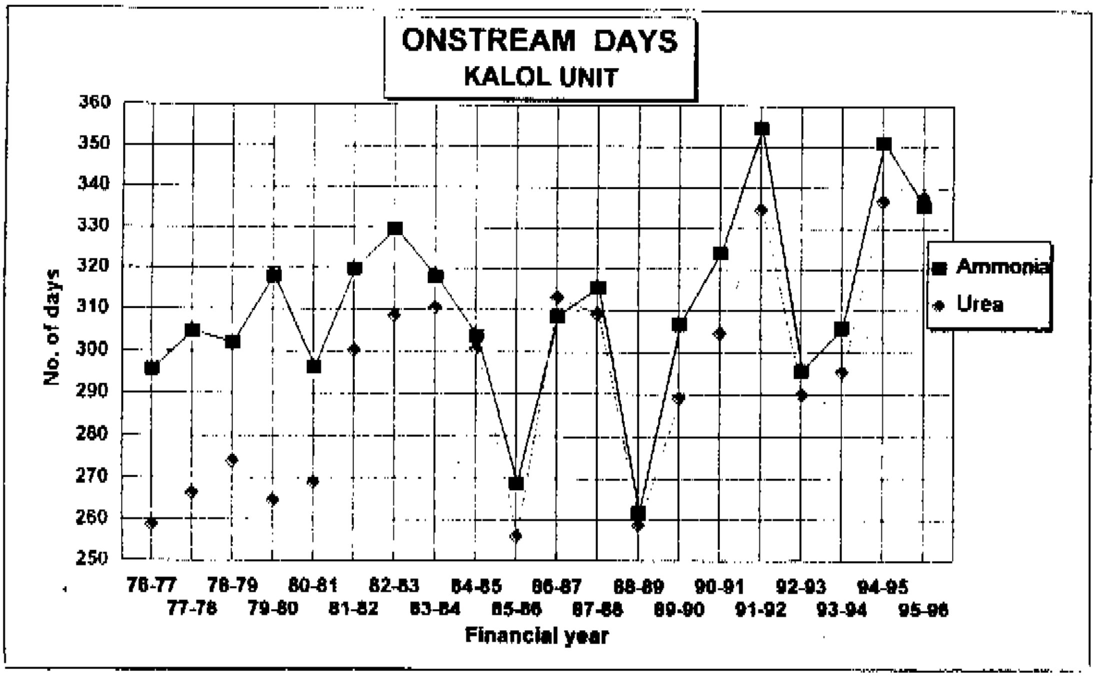
It is anticipated that on implementation of the proposed expansion project, not only the new capacity would be achieved but the ammonia plant is expected to be more energy efficient and achieve specific energy consumption of 9.0-9.2 Gcal/MT of ammonia. The major schemes included in the on going Kalol expansion project are as given below:

1. Urea plant revamp for uprating the plant capacity.
2. Naphtha pre-reformer system.
3. Process air compressor revamp.
4. $C0_2$ removal system revamp.
5. Syn. gas chilling.
6. Replacement of cooling water pump turbine with efficient condensing type turbines.
7. Second natural gas booster compressor.
8. Replacement of equipment/critical pipings.
9. Optimiser and microprocessor based instruments.

With the above schemes likely to be completed by September 1997, it is anticipated that IFFCO Kalol unit will set new standards in attaining sustained high level performance from more than 20 years old ammonia/urea complex.


CAPACITY UTILISATION
KALOL UNIT
% CAPACITY UTILISATION
120
115
110
105
100
95
90
85
80
75
70
76-77
78-79
80-81
82-83
84-85
86-87
88-89
90-91
92-93
94-95
95-96
UREA
AMMONIA
YEAR


SPECIFIC ENERGY
KALOL UNIT
Energy Gcal/mt
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
76-77
77-78
78-79
79-80
80-81
81-82
82-83
83-84
84-85
85-86
86-87
87-88
88-89
89-90
90-91
91-92
92-93
93-94
94-95
95-96
Financial year
Ammonia
Urea


ONSTREAM DAYS
KALOL UNIT
No. of days
360
350
340
330
320
310
300
290
280
270
260
250
76-77
77-78
78-79
79-80
80-81
81-82
82-83
83-84
84-85
85-86
86-87
87-88
88-89
89-90
90-91
91-92
92-93
93-94
94-95
95-96
Financial year
Ammonia
Urea

ANNEX.- I

THE OPERATING UNITS OF IFFCO

Sl.No.	Unit	Main features	Capacity te/annum	Technology	Year of Commissioning
1	Kalol	Ammonia	300300	Kellogg	1975
		Urea	396000	Stamicarbon	
2	Kandla	NPK	309000	Dorr Oliver	2 trains in 1974
		DAP	**P2O5**		2 trains in 1981
3	Phulpur	Ammonia	297000	Kellogg	1980
		Urea	495000	Snamprogetti	
4	Aonla	Ammonia	445500	Haldor Topsoe	1988
		Urea	726000	Snamprogetti	

ANNEX. - II

IFFCO - EXPANSION PROJECTS AT A GLANCE

Sl No.	Projects	Main Features	New capacity te/annum	Technology	Estimated Cost (Million US$)	Status
1	Aonla expansion	Ammonia	445500	Haldor Topsoe	300	Project in progress
		Urea	726000	Snamprogetti		
2	Phulpur expansion	Ammonia	445500	Haldor Topsoe	322	Project in progress
		Urea	726000	Snamprogetti		
3	Kalol expansion	Ammonia	95700	Haldor Topsoe	40	Project in progress
		Urea	132000	Stamicarbon		

IFFCO - PROJECTS UNDER PLANNING

Sl No.	Projects	Main Features	New capacity te/annum	Technology	Estimated Cost (Million US$)	Status
1	Kandla expansion	NPK&DAP	231000 P2O5	Yet to be decided	66	Proposal is awaiting clearance
2	Nellore(grass root)	Ammonia	445500	Yet to be decided	459	Proposal is awaiting clearance
		Urea	726000			

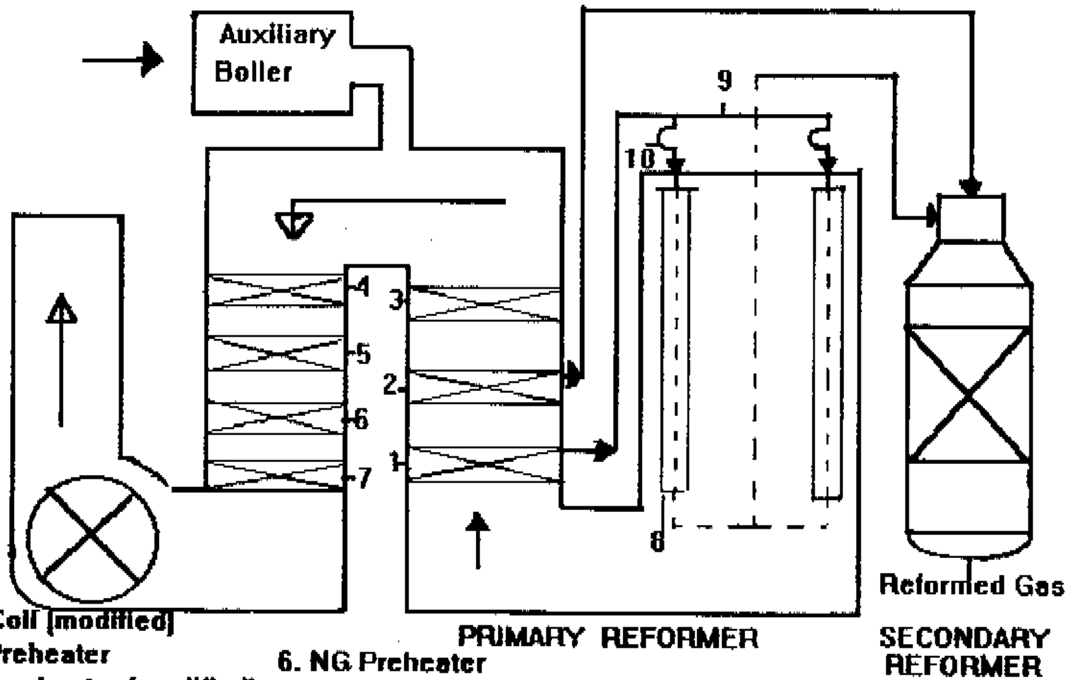
Annex-III

DESIGN CONDITION OF PRIMARY REFORMER	Original design	Revamp-I (April'86)	Revamp-II (Sept.'93)
Catalyst tube design press, kg/cm2g	35.9	35.9	35.9
Catalyst tube design temp., deg.C.	925	907	930
Riser design press, kg/cm2g	31.6	31.6	33.5
Riser design temp., deg.C.	930	927	970
Outlet manifold design press, kg/cm2g	31.6	31.6	33.6
Outlet manifold design temp., deg.C.	835	835	850
Pressure drop, kg/cm2 ** (total)	4.88	4.52	3.24
a) Inlet manifold	0.09	0.09	0.05
b) Pigtails	0.18	0.18	0.33
c) Catalyst tube	4.09	3.66	2.27
d) Outlet manifold, riser thru transfer line	0.52	0.59	0.59

*** = Pressure drop in all the cases have steam to carbon ratio of 3.5*

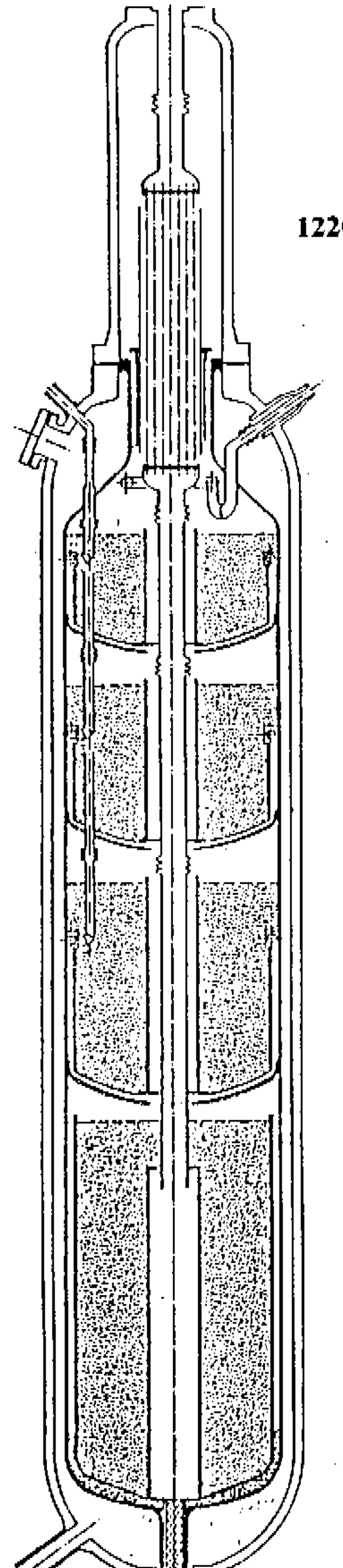
MATERIAL OF CONSTRUCTION OF PRIMARY REFORMER COMPONENTS	Original Design	Revamp-I (April'86)	Revamp-II (Sept.'93)
Catalyst tube	HK-40 (As cast)	HK-40 (Machined)	G-4852 Mod. (Machined)
Riser	HK-40 (as cast)	HK-40 (Machined)	G-4852 mod. (Machined)
Outlet manifold	Incoloy-800	Incoloy-800H	G-4859
Pigtails	A335 P11	A335 P11	A213 T11
Inlet manifold	A106 GrB	A106 GrB	A335 P11
Catalyst tube top	A161	A106 GrB	A335 P11
Catalyst tube top flange	A105	A105	A182 Gr.F11
Riser transition assbly	Incoloy 800H	SB-564	Incoloy 800HT

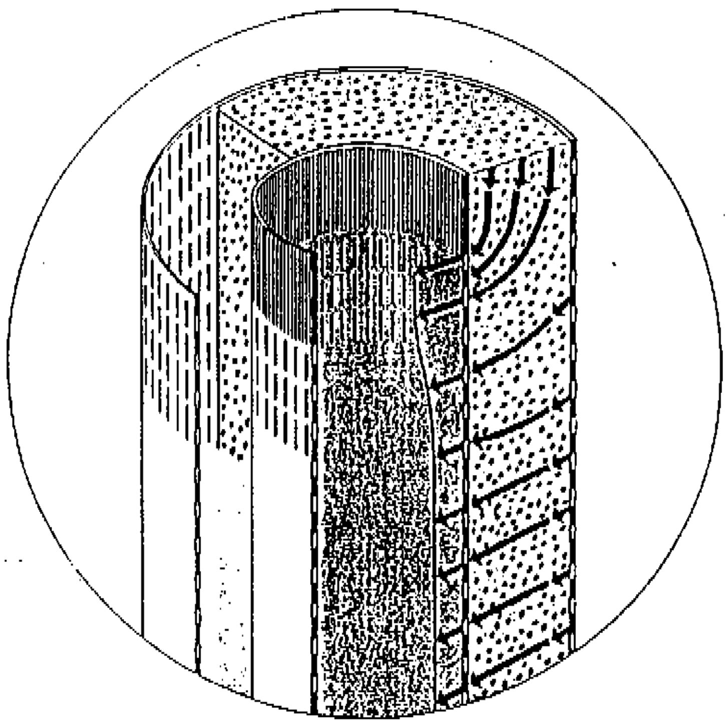
ANNEX. - IV



1. Mixed Feed Coil [modified]
2. Process Air Preheater
3. HT Steam Superheater [modified]
4. LT Steam Superheater
5. BFW Preheater
6. NG Preheater
7. New BFW Preheater for offsites [modified]
8. Reformer Tubes
9. Inlet manifold
10. Inlet Pigtails

ANNEX.- V





AXIAL-RADIAL FLOW PROFILE OF SYNTHESIS GAS THROUGH CATALYST BED

KELLOGG'S CONVERTER AFTER AMMONIA CASALE RETROFIT