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ENERGY CONSERVATION MEASURES IN AMMONIA PLANTS AT IFFCO KALOL AND PHULPUR UNITS

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Indian Farmers Fertiliser Cooperation Limited (IFFCO) est le plus gros producteur d'engrais en Inde et produit environ 5,3 millions de tonnes d'engrais annuellement dont environ 3,5 millions d'urée et le reste NPK/DAP. Les unités d'ammoniac/urée sont situées à Kalol (Etat de Gujarat). L'unité d'ammoniac à Kalol conçue par Kellogg, avait une capacité de production de 910 t/j et l'unité d'urée une capacité de 1 200 t/j et conçue par Stamicarbon, a été réceptionnée en 1974. La capacité de ces unités a été accrue jusqu'à 1 100 t/j d'ammoniac et 1 650 t/j d'urée en 1997. A Phulphur, l'unité d'ammoniac conçue par M.W. Kellogg a une capacité de 900 t/j et utilise le naphta comme matière première. L'unité d'urée a une capacité de 1 500 t/j et a été conçue par Snamprogetti. Ces unités ont été réceptionnées en 1981.

En 1988, une unité d'ammoniac de 1350 t/j à Aonla basée sur la technologie Haldor Topsoe (HTAS) utilisant le gaz naturel comme matière première et une unité d'urée avec une capacité de 2 200 t/j basée sur la technologie de Snamprogetti ont été réceptionnées.

Par la suite, des projets d'expansion à Aonla et Phulpur ont été lancés. Deux unités d'ammoniac supplémentaires avec une capacité de 1 350 t/j chacune basée sur la technologie de HTAS et des unités d'urée (deux lignes chacune) avec une capacité de 2 200 t/j ont été réceptionnées en décembre 1996 et décembre 1997 à Aonla et Phulpur respectivement.

Cet exposé donne des détails des mesures de conservation de l'énergie dans les unités d'ammoniac de Kalol et Phulpur qui ont été réceptionnées il y a plus de deux décennies.

Indian Farmers Fertiliser Cooperative Limited (IFFCO) is the largest producer of fertiliser in India and produces around 5.3 million MT of fertiliser annually, out of which about 3.5 million MT is urea and rest is NPK/DAP. Ammonia / urea plants are located at Kalol (Gujarat State), Phulpur and Aonla (Uttar Pradesh State). NPK / DAP is produced at Kandla (Gujarat State). Ammonia plant at Kalol, designed by M.W. Kellogg, had a capacity to produce 910 TPD and the urea plant with a capacity of 1200 TPD, designed by Stamicarbon, was commissioned in 1974. The capacity of these plants have been increased to 1100 TPD of ammonia and 1650 TPD of urea in 1997. At Phulpur, the ammonia plant, designed by. M.W. Kellogg, has a capacity of 900 TPD and uses naphtha as feed stock. The urea plant has capacity of 1500 TPD and was designed by Snamprogetti. These plants were commissioned in 1981.

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______In 1988, a 1350 TPD ammonia plant at Aonla based on Haldor Topsoe Technology (HTAS) using natural gas as feed stock and a urea plant with a capacity of 2200 TPD based on the design of Snamprogetti were commissioned.

Subsequently, expansion projects at Aonla and Phulpur were taken up. Two more ammonia plants having capacity of 1350 TPD each based on technology of HTAS and urea plants (two trains each) having capacity of 2200 TPD were commissioned in December, 1996 and December, 1997 at Aonla and Phulpur respectively.

This paper gives details of energy conservation measures taken in ammonia plants at Kalol and Phulpur which were commissioned more than two decades ago.

KALOL

1.0 Revamp of Ammonia Plant

The 910 TPD ammonia plant with Kellogg technology commissioned in 1974 was designed for a guarantee test run energy consumption of 10.23 Gcal per tonne had been operating around 100-110 % capacity utilisation since inception. The annual capacity utilisation of this plant for the last five years is around 100%, touching 111 % in the year 1994-95.

1.1 Ammonia Plant Retrofits

1.1.1 Primary Reformer

Primary reformer is a typical Kellogg design having 336 tubes distributed in 8 rows, having 42 tubes in each row. The original revamp-I and revamp-II data of primary reformer is given below :

	Original	Revamp-I	Revamp-II
Year of Installation	1975	1986	1993
No. of Tubes	336	336	336
No. Of Harps	8	8	8
Material of Construction	HK-40 Cast	HK-40 Internally machined	HP-Micro-alloy G-4852 modified
I.D.of tubes (mm)	73.9	74	82
Thickness (mm)	15.6	15.4	12.0
Catalyst volume (M3)	13.6	14.4	17.7
Pressure drop kg/cm2	3.5	3.4	2.10

Capacity utilisation at a higher level on consistent basis plays a big role in the energy consumption levels of the ammonia plant. That is why, after 11 years of successful operation, when the primary reformer tubes started failing, a revamp scheme was implemented in 1986.

Primary Reformer - 1st Revamp in 1986

The reformer tubes were replaced after 88,000 hours of operating life against the design of 100,000 hours. In this revamp all the 8 harp assemblies having a total of 336 tubes were replaced. Tube material HK-40 was retained but I.D was marginally increased with the use of machined tubes. But after this revamp, the first tube failure took place in 1987 and subsequently, many tube failures took place. Tubes started failing at a much earlier stage than design mainly due to primary reformer arch burners bad firing problem.

Therefore, a second revamp was carried out in September 1993 after 58,343 hours of operating life. In this revamp the material of construction of harp assemblies along with riser tubes and the bottom header used was changed to micro alloy G-4852 in place of HK-40. Due to better material, it was possible to reduce the tube wall thickness from 15.4 mm to 12 mm, and increasing ID from 74 mm to 82 mm. Due to increased ID of tubes, pressure drop across the primary reformer was reduced from 3.5 kg/cm2 to 2.1 kg/cm2. Higher catalyst volume (from 14.4 m3 to 17.7 m3) on one hand facilitated the higher throughput, enabling increase in production from 910 tpd ammonia to 1100 tpd and on the other hand, it reduced heat flux from 73000 kcal/m2hr to 65000 kcal/m2hr and tube skin temperature from 860 deg C to 830 deg C. This in turn has increased the life of the catalyst tubes.
Performance of reformer before and after revamp is as follows :

Parameters	Before Revamp II	After Revamp II
Tube diameter, mm	74	82
Catalyst volume, m3	14.4	17.7
Reformer pressure drop, kg/cm2	3.5	2.1
Tube skin temperature,deg C	860-890	830-850
Heat flux, kcal/m2hr	73000	65000
Methane slip, %(v/v)	12.4	10.4

This has improved the reliability in primary reformer operation.

1.1.2 Installation of BFW Coil in Convection Section

The flue gas temperature at the exit of ID fan in initial stages was around 280 ^{o}C. To lower this temperature, a boiler feed water heater coil was installed in 1976 in the space available at ID fan suction which resulted lowering the flue gas temperature by about 50 ^{o}C to around 230 ^{o}C. To bring down the flue gas temperature further, an additional coil of boiler feed water was installed below the old one in 1993, resulting into reduction of flue gas temperature to 210-215 ^{o}C. The height of the stack was also increased from 32 metres to 40 metres, to improve the draft by 4 mm WC which reduced the I.D. fan turbine speed from 3700 rpm to 3600 rpm thus saving energy.

Performance of the BFW coil before and after modification is as follows :

	Parameters	Before Modification	After Modification
1	Tube side outlet temperature, deg C	189.6	205
2	Tube side pressure drop, kg/cm2	1.89	2.75
3	Coil heat duty, Gcal/hr	7.484	8.884
4	Energy saving, Gcal/t		0.030

1.1.3 Replacement of Mixed Feed Coil

The actual temperature of mixed feed at the coil outlet was 460 ^{o}C as against the design of 510 ^{o}C resulting into higher energy requirements in the primary reformer. Therefore, the old mixed feed coil of 271.3 sq.m. of surface area was replaced by a new mixed feed coil having 345.2 sq.m. surface area with an improved material of construction SS-304H in place of A-335-P11. Performance of the coil before and after modification is as follows :

	Parameters	Before Modification	After Modification
1	Coil material	P-11	SS-304-H
2	Tube side outlet temperature, deg C	458	500
3	Tube side pressure drop, kg/cm2	1.88	0.69
4	Coil heat duty, Gcal/hr	9.019	10.408
5	Energy saving, Gcal/t		0.030

As shown in the above table this replacement resulted into a reduction in pressure drop across the mixed feed coil from 1.88 kg per sq cm to 0.69 kg per sq cm and increase in the temperature of mixed feed at coil outlet from 460 ^{o}C to 500 ^{o}C and reduction in flue gas temperature at I.D. fan exhaust which has lowered the energy consumption in the primary reformer.

1.1.4 Replacement of Steam Heater Coil

Steam temperature at the exit of steam super heater coil was 415 ^{o}C against the design of 441 ^{o}C resulting into higher steam consumption in the turbines. Therefore, the old steam HT coil having 1737.2 sq m surface area was replaced by a new coil having 2492.3 sq m surface area and improved tube material P-22 in place of A-335-P11.

Performance of the coil before and after modification is as follows :

.	Parameters	Before Modification	After Modification
1	Coil material	P-11	P-22
2	Tube side outlet temperature, deg C	415	428
3	Tube side pressure drop, kg/cm2	1.98	1.01
4	Coil heat duty, Gcal/hr	16.179	18.756
5	Energy saving, Gcal/t		0.06

Replacement of the coil has resulted in a reduction in the pressure drop across the coil from 1.98 kg per sq cm to 1.01 kg per sq cm and increased a steam temperature from 415 to 428 ^{o}C resulting into savings in steam consumption in the turbines.

1.2 Retrofit of CO2 Removal System

The IFFCO Kalol ammonia plant was originally designed to use 18 % MEA as chemical absorbent in the CO2 removal system. The regeneration heat initially was 2100 kcal/Nm^3 of CO2 which was reduced to 1500 kcal/Nm^3 CO2 by adopting UCAR Amine Guard System in 1978 and increasing the concentration of MEA solution to 24-26 %. Energy saving achieved by this system were 0.14 Gcal/tonne of ammonia. The CO2 removal system was again retrofitted in 1997 by swaping a-MDEA solution in place of Amine Guard System. This has increased the capacity of CO2 removal system generated due to use of naphtha feed stock by about 30 %. This was required to compensate the shortage of natural gas supply and/ increase in ammonia plant capacity from 910 TPD to 1100 TPD. This has reduced energy consumption to about 1160 kcal/Nm^3 of CO2.

Operating data of a-MDEA CO2 removal system are tabulated below :

	Parameters	MEA with UCAR amine guard II	a-MDEA
1.	Plant load, tpd	910	1100
2.	Reboiler duty, Gcal/hr	40	35
3.	Energy requirement, kcal/Nm3 of CO2 removed	1500	1160
4.	Solution circulation rate m3/hr	780	620
5.	CO2 slip in raw syn gas, ppm	<100	<250
6.	CO2 product gas purity, %	99	99
7.	Stripper Temperature, deg C		
	Top	93	84
	Bottom	118	115
8.	Energy savings Gcal/t	---	0.08

Thus, retrofitting of the system has reduced the energy consumption by 0.08 Gcal/tonne of ammonia.

1.3 Synthesis Converter Retrofit

The synthesis ammonia converter is a typical Kellogg design with four beds having a total 64.19 cu m catalyst having synthesis gas flow through the catalyst bed in axial direction. The catalyst size used was 6-12 mm. In 1993 the synthesis converter was retrofitted using Ammonia Casale technology to make the synthesis gas flow axial radial in place of axial and reducing the size of catalyst to 1.5-3 mm and increased the catalyst volume from 64.19 cu m to 75 cu m. Performance of the synthesis converter before and after retrofit is tabulated below :

	Parameters	Before Retrofit	After Retrofit
1	Gas flow pattern	Axial	Axial-Radial
2	Converter pressure drop, kg/cm2	4.0	2.5
3	Ammonia at converter inlet, %(v/v)	2.1	2.1
4	Ammonia at converter outlet, %(v/v)	12.0	14.75
5	Converter outlet temperature, deg C	282	323
6	Energy saving, Gcal/t		0.252

1.4 Purge Gas Recovery System

The purge gas stream from the synthesis loop to maintain the inerts level in the loop containing about 60 % hydrogen was being burnt along with the fuel in the primary reformer furnace. To recover this hydrogen from the purge gas, a purge gas recovery system was installed in 1980 using cryogenic separation technique and the hydrogen recovered is recycled to the synthesis loop and tail gas is burnt as fuel in the primary reformer. With commissioning the system, there was an energy saving of 0.23 Gcal per MT ammonia.

1.5 Sustaining the Capacity utilization

With the depletion of natural gas wells located in the surrounding area, the supply of natural gas reduced and pressure dropped from 40 kg/sq cm in 1984-85 and subsequently to 20 kg/sq cm. Accordingly a natural gas compressor was installed in the ammonia plant in 1986 to boost NG pressure from 20 kg/sq cm to 40 kg/sq cm. Another natural gas booster compressor has been installed for boosting NG pressure from 10 kg/sq cm to 20 kg/sq cm in 1996.

2.0 Increase in Capacity of Ammonia Plant from 910 TPD to 1100 TPD

In 1997, the capacity of ammonia plant has been increased from 910 TPD to 1100 TPD after operating for about 22 years. Some of the revamp steps taken in addition to the stated above, are given below :

2.1 Installation of Pre-Reformer

A naphtha pre-reformer system was installed in 1997 to use naphtha as feed stock to the tune of around 350 TPD of ammonia production to take care of the shortage of natural gas to this extent and to meet the increased ammonia production capacity of 1100 tonnes per day.

2.2 Air Compressor Revamp

As a part of de-bottlenecking scheme of the ammonia plant to increase the capacity to 1100 tonnes per day the internals of the air compressor were changed in 1997 by the original manufacturers Demag Delaval. This increased the capacity of the air compressor by 30 % with only marginal increase in steam consumption.

2.3 Suction Chiller for Syn Gas Compressor

A syn gas chiller at the suction of the syn gas compressor was installed in 1997 to lower down the gas temperature to about 8 ^{o}C resulting the increase of compressor capacity so as to produce 1100 TPD of ammonia.

2.4 Condensing Turbine for Cooling Water Pump

The back pressure turbine of the cooling water pump was replaced by a condensing turbine in 1997, resulting in reduction in the steam consumption from 13030 kg/hr to 5600 kg/hr. Thus even after installation of additional two NG compressors and naphtha pre-reformer system, the specific energy consumption/MT of ammonia has reduced from 10.233 to 9.9 Gcal per tonne.

ENERGY CONSERVARTION SCHEMES IMPLEMENTED IN AMMONIA PLANT- I OF PHULPUR UNIT

3.0 Energy Saving Schemes

As discussed earlier the ammonia plant at Phulpur Unit-I has a capacity of 900 MTPD with naphtha as feed stock. It is designed by M.W. Kellog and was commissioned in 1981. The details of energy saving schemes implemented are given below:

3.1 Purge Gas Recovery Unit

In order to achieve optimum conversion in synthesis convertor, it is necessary to purge a certain quantity of gas from synthesis loop so as to reduce inert concentration in the loop. This purge gas containing about 60% hydrogen was utilized as primary reformer fuel. A cryogenic purge gas recovery unit, designed by L'Air Liquide, France has been installed in order to recover H2 from it which is recycled back to synthesis loop thereby reducing the requirement of feed naphtha for the same ammonia production. Therefore the primary reformer load is also reduced resulting in saving of fuel naphtha used in primary reformer. Tail gas from PGR unit is burnt as fuel in the primary reformer. The purge gas from synthesis loop of ammonia plant is washed with an aqueous solution of ammonia and then washed gas having low ammonia content is sent to the absorption unit, where remaining ammonia and water is removed completely. The gas delivered by the purification unit is cooled by exchange with hydrogen and tail gas stream. coming out of exchangers in cold box unit. The cooled gas is let down to sub cooled gas where it is partially condensed. The gas and liquid are separated in the vessel. The gaseous fraction, containing the main part of hydrogen is warmed in this exchanger and recycled back to synloop to be converted to ammonia. The liquid fraction, after expansion through a valve is vaporized and warmed in a exchanger and used as a fuel in the primary reformer. Ammonia solution from the ammonia washing tower is concentrated in the distillation unit and fed back to the main refrigeration loop.

This has been installed in March 1985 and resulted in energy savings of 0.11 GCAL/MT of ammonia.

3.2 Revamping of Primary Reformer

The design catalyst volume (19.6M3) provided in the primary reformer was inadequate vis-a-vis high aromatics content of feed naphtha as well as naphtha loading of catalyst (kg/hr of Naphtha/lit of catalyst). Also, the feed gas flow distribution among the catalyst tubes were not uniform, due to these design limitations, it was not possible to run ammonia plant at design plant load on a sustained basis. It had been planned to replace all the catalyst tubes of primary reformer with tubes of superior micro alloy material having same OD but higher ID as compared to the existing tubes so as to accommodate higher catalyst volume (26.5M3) . The ID of pigtails at inlet of catalyst tube was also reduced leading to more uniform feed flow distribution. This modification has allowed the operation of primary reformer at design plant load on a sustained basis and alleviate the problems of carbon deposition on catalysts leading to increase in tube pressure drop, reduced catalyst activity, higher energy consumption, relatively frequent catalyst changeover and other associated problems like, high tube skin temperature and subsequent hot spot formation causing tube failure, etc.

Though this job was not done as energy saving modification, but it has resulted in considerable energy savings due to consistent and sustained operation of plant at and above design capacity. The average reduction in energy consumption achieved in ammonia plant is about 0.5 Gcal/MT of ammonia by way of sustained and consistent operation and optimization of plant operating parameters. This revamping job was carried out during the annual-turn-around of 1987-88 (March,1988) within a record minimum time period of 16 days as compared to the time required to carry out the same job in other plants.

In April 2000, the primary reformer tube assembly was replaced with new tube assembly. New tubes have better material and therefore the thickness of tubes has been kept lower. This enables to load more catalyst and therefore lower temperature is required for same conversion. This resulted in marginal saving of fuel naphtha in the primary reformer. Due to more ID of tube, pressure drop across reformer is also lower thereby marginal saving in steam consumption of synthesis gas compressor turbine has also been achieved.

	Original	**Revamp-I**	**Revamp-II**
Year of installation	1978	1988	2000
No. of Tubes	336	336	336
No. of Harps	8	8	8
Material of construction	HK-40	MANURITE	G 4852

	(as cast)	36X	MICRO
I.D. of Tubes (mm)	81.3	95.2	100.2
Thickness (mm)	16.7	12.5	9.7
Catalyst volume (M3)	19.6	26.85	29.77
Catalyst loading (kg/hr/lit)	1.04	0.78	0.68
Pressure Drop (Bar)	4.2	2.6	2.35

3.3 Synthesis Converter Retrofit

The original synthesis converter is a Kellogg designed 4 bed, axial flow, quench reactor The high pressure drop in axial flow necessitates the use of bigger size (6 to 10 mm) catalyst which are less effective on account of lower active surface area. In this retrofit carried out by Ammonia Casale of Switzerland. The gas flow pattern across the catalyst beds has been changed from axial to axial-radial flow by modifying converter internals to give low pressure drop and higher conversion per pass by using small size catalyst (1.5 to 3 mm) and ensuring better utilization of catalyst volume. The benefits of this retrofit are :

- Increased ammonia conversion per pass
- Reduction in overall synthesis loop flow leading to reduced pressure drop, both resulting in saving of synthesis gas and refrigeration compressor powers.

Scheme is in operation since May 1993. Energy savings achieved is 0.2 GCal/MT of ammonia.

3.4 Lo-heat Benfield Retrofit in CO_2 Removal System

In the original design, Benfield system has been adopted for CO_2 removal from synthesis gas in ammonia plant. This system had one absorber and two strippers working in parallel. CO_2 absorption is carried out by semilean and lean K_2CO_3 solutions. This solution is regenerated in strippers with the design regeneration energy of 1056 Kcal/NM3 of CO_2. Actual regeneration energy was 1150 KCal/NM3 of CO_2.

In order to conserve energy, Lo Heat Benfield system of UOP, USA has been adopted. In Lo Heat Benfield retrofit the internal energy of the semilean solution is exploited by letting it down to a lower pressure to generate flash steam in 4 stages. The flash steam thus produced in each stage is compressed with the help of steam ejectors and used for regeneration of Benfield solution in strippers. This has resulted in saving of LP (4.5 ata) steam used for regeneration. After modification, regeneration energy of CO_2 removal system has come down to 925 KCal/Nm3 of CO_2 against the modified design value of 900 KCal/Nm3 of CO_2. Equivalent energy saving is 0.14 GCal/MT of ammonia. scheme is in operation since June 1995.

3.5 Additional Rows of LT Steam Superheater Coil in Primary Reformer

In the original design, LT steam superheater coil was provided in the convection section of primary reformer furnace to superheat the HP steam utilising the sensible heat of flue gases. Earlier the coil was having 6x14 extended surface tubes. In order to improve the furnace efficiency further, two additional row of superheater coils having 14 in number of identical tube in each row was installed. After this installation the flue gas temperature has been reduced by about 20 to 25 deg C. The equivalent energy savings come out to be 0.03 GCal/MT of ammonia. The procurement and erection for this additional coil was done in-house by IFFCO. The installation of this coil was completed during the annual turnaround of June 1996.

3.6 Improved Vacuum in Surface Condenser

In order to improve the vacuum in surface condenser of ammonia plant, an additional surface condenser has been installed in parallel to the existing condenser. Old surface condenser of old CO2 compressor turbine of the urea plant, which was lying idle had been used for the purpose.

A complete survey of the condensing system was carried out. Air infiltration points were identified and corrective measures have been taken. A periodic checking and monitoring of the condensing system have been incorporated in the operation schedule. which was resulted in an improved vacuum of 680-700 mm Hg on consistent basis.

This was commissioned in May 1998 and energy savings of 0.03 GCal/MT of ammonia is achieved.

3.7 Replacement of Vent Valves

Three vent valves namely, HTS Inlet vent, absorber Inlet vent and methanator inlet vent were of leakage Class - IV and therefore were not providing tight shutoff. Any leakage through these valves results in loss of valuable process gas and therefore higher energy of ammonia. These vent valves were replaced by the new valves of leakage Class - V in place of existing Class - IV. Replacement of these valves completed in 1999.

3.8 Additional Coils in Hydrotreater Heater (201-b) and Desulfurizer Heater (103-b)

Hydrotreater heater (201-B) and desulfurizer heater (103-B) are natural draft furnaces. The flue gases was leaving these furnaces at temperatures in the range of 500 to 550 deg C. This resulted in lot of heat loss and poor efficiency of these furnaces. In order to reduce the heat loss and thereby saving of the naphtha fired in these furnaces additional coils in these furnaces have been installed in April 2000. Energy savings achieved is 0.04 GCal/MT of ammonia.

3.9 DCS Installation

In April 2000, the old pneumatic control system has been replaced by DCS. This will increase the quality of controls and thereby more efficient operation can be achieved. However, energy savings achieved cannot be quantified. However, due to minimum fluctuations in operating parameters, operating parameters can be maintained at optimum level. Thus any loss of energy due to fluctuations in operating parameters like venting, letdown of steam etc., are minimized to a great extent.

In order to conserve energy, regular monitoring of insulation, steam traps, vent valves etc., is being carried out and remedial measures are taken whenever required. These measures have helped to a large extent in keeping the energy consistently at low level.

4.0 IMPACT OF ENERGY SAVING SCHEMES INCORPORATED IN AMMONIA - I OF PHULPUR UNIT

	Scheme	Year	Energy Saving, GCal/MT
1	Purge gas recovery unit	1985	0.11
2	Revamping of primary reformer	1988	0.50
3	Synthesis converter retrofit	1993	0.20
4	LO-Heat Benfield retrofit in CO2 removal system	1995	0.14
5	Additional rows of LT steam superheater coil in primary reformer	1996	0.03
6	Improved vacuum in surface condenser	1998	0.03
7	Additional coils In hydrotreater heater(201-B) and desulfurizer heater (103-B)	2000	0.04