Notes

Chapter - 10

Fertilizer

10.1 Introduction

The Indian fertilizer industry made a very humble beginning in 1906, when the first manufacturing unit of Single Super Phosphate (SSP) was set up in Ranipet near Chennai with an annual capacity of 6000 Tonnes of Rock Phosphate (P_2O_5). The Fertilizer & Chemicals Travancore of India Ltd. (FACT) at Cochin in Kerala and the Fertilizers Corporation of India (FCI) in Sindri in Bihar (now Jharkhand) were the first large sized fertilizer plants set up in the forties and fifties with a view to establish an industrial base to achieve self-sufficiency in food grains. Subsequently, the Green Revolution in the late sixties gave an impetus to the growth of fertilizer industry in India and the seventies and eighties witnessed a significant addition to the fertilizer production capacity. However, there has not been any substantive addition to fertilizer production capacity during the last 15 years.

10.1.1 Production of Fertilizers

Production of Urea, which was 186 lakh Tonnes in 2002-03, increased to 201 lakh Tonnes in 2005-06 and further to a record level of 203 lakh Tonnes in 2006-07. Production of Diammonium phosphate (DAP), however, declined in 2006-07 at 47 lakh Tonnes after reaching a peak at 52 lakh Tonnes in 2002-03, mainly because of feedstock problems and shift of phosphatic capacity towards production of complexes. Decline in production of phosphatic fertilizers has been due to constraints in availability of phosphoric acid and high prices of sulphur. Requirement of Muriate of Potash (MOP) is met fully by imports. The production of Urea, DAP and complexes during the last five years and during the current year up to December 2007 are given below: -

Table 10.1

(In lakh Tonnes)

Product	2002- 03	2003–04	2004-05	2005-06	2006-07	2007-08
Urea	186.21	190.38	202.39	200.85	202.71	198.39
DAP	52.36	47.09	51.72	45.54	47.13	42.11
Complexes	48.61	45.07	52.59	67.65	73.13	58.33

Source: FAI and Department of Chemicals & Fertilizers

10.1.2 Installed Capacity

As on 31 March 08, the country has an installed capacity of 122.84 lakh Tonnes of nitrogen and 58.59 lakh Tonnes of Phosphate. Presently, there are 59 large size fertilizer plants operating in the country manufacturing a wide range of nitrogenous, phosphatic and complex fertilizers. Out of these, 31 (as on date 28 are functioning) units produce urea, 19 units produce DAP and complex fertilizers, 2 units produce Calcium Ammonium Nitrate (CAN) & Ammonium Chloride and the remaining 10 units manufacture ammonium suplhate as product. Besides, there are about 78 medium and small- scale units in operation producing SSP. The sector - wise installed capacity is given in the table below: -

Table 10.2

Sector-wise & Nutrient - wise Installed Capacity Of Fertilizer Manufacturing Units as on 31.03.2008

(In lakh Tonnes)

SNo.	Sector	Nitrogenous		Phosphatic	
		Capacity	% Share	Capacity	% Share
1	Public	35.92	29.24	3.87	6.60
2	Cooperative	31.69	25.80	17.13	29.24
3	Private	55.23	44.96	37.60	64.16
	Total	**122.84**	**100.00**	**58.59**	**100.00**

Source: FAI and Department of Chemicals & Fertilizers

10.1.3 Per Capita Consumption

The per capita consumption of fertilizer of agricultural population in India, which was a meager 1 kg in the early 50's, has increased substantially to about 32.7 kg in 2004-2005.

The per capita fertilizer consumption of agricultural population in different countries is highlighted in the table below:

Table 10.3

Country	Fertilizer Consumption (kg Per capita)*	Fertilizer Consumption (kg/ha)**
India	32.7	108.4
China	52.9	289.1
Japan	438.9	363.0
Egypt	78.4	555.1
Bangaladesh	23.1	197.6
Pakistan	42.7	146.2
France	2492.0	210.5
Russian Federation	131.8	14.4
UK	1814.7	305.2
USA	3463.0	113.5
World	59.7	101.0

*of agricultural population ** of arable land and land under permanent crops

Source: FAI and CII-IREDA

10.2 Raw Material Profile

The basic raw materials for the production of fertilizers are ammonia for nitrogenous fertilizers, phosphate for straight phosphatic fertilizers, and potash for potassic fertilizers. Out of the three fertilizer types, production of ammonia is most energy and resources intensive.

10.2.1 Nitrogenous fertilizers

Domestic raw materials are available only for nitrogenous fertilizers. For the production of urea and other ammonia-based fertilizers, methane is the major input. Methane is obtained from natural gas/ associated gas, Naphtha, fuel oil, low sulfur heavy stock (LSHS) and coal. Of late, production has switched over to use of natural gas, associated gas and Naphtha as feedstock. Out of these, associated gas is most hydrogen rich and easiest to process, due to its lighter weight and fair abundance within the country. However, demand for gas is quite competitive since it serves as a major input to electricity generation and provides the preferred fuel input to many other industrial processes.

10.2.2 Phosphatic fertilizers

For production of phosphatic fertilizers, most of the raw materials have to be imported. India has no source of elemental sulfur, phosphoric acid and rock phosphate. Some low-grade rock phosphate is domestically mined and made available to rather small- scale single super phosphate fertilizer producers. Sulfur is produced as a by-product by some of the petroleum and steel industries.

10.2.3 Ammonia production

The most important step in producing ammonia (NH_3) is the production of hydrogen, which is followed by the reaction between hydrogen and nitrogen. A number of processes are available to produce hydrogen, differing primarily in type of feedstock used. The hydrogen production route predominantly used worldwide is steam reforming of natural gas. In this process, natural gas (CH_4) is mixed with water (steam) and air to produce hydrogen (H_2), carbon monoxide (CO) and carbon dioxide (CO_2). Waste heat is used for preheating and steam production, and part of the methane is burnt to generate the energy required to drive the reaction. CO is further converted to CO_2 and H_2 using the water gas shift reaction. After CO and CO_2 is removed from the gas mixture ammonia (NH_3) is obtained by synthesis reaction. Another route to produce ammonia is through partial oxidation. This process requires more energy (up to 40-50% more) and is more expensive than steam reforming. The advantage of partial oxidation is high feedstock flexibility; it can be used for any gaseous, liquid or solid hydrocarbon. In practice partial oxidation can be economically viable if used for conversion of relatively cheap raw materials like oil residues or coal. In the partial oxidation process, air is distilled to produce oxygen for the oxidation step. A mixture containing among others, H_2, CO, CO_2 and CH_4 is formed. After desulfurization CO is converted to CO_2 and H_2O. CO_2 is removed, and the gas mixture is washed with liquid nitrogen (obtained from the distillation of air). The nitrogen removes CO from the gas mixture and simultaneously provides the nitrogen required for the ammonia synthesis reaction.

10.3 Energy Profile

Production of nitrogenous fertilizers is highly energy intensive. Ammonia is used as the basic chemical in the production of nitrogenous fertilizer. Production of ammonia itself involves almost 80% of the energy consumption in the manufacturing processes of a variety of final fertiliser products. Therefore, ammonia is considered a key intermediate for determining the overall energy efficiency of fertiliser production. Besides air as the source of nitrogen, the ammonia-manufacturing process have choice of using raw materials such as water, natural gas, naphtha, fuel oil, coal, coke oven gas. Natural gas is the best feedstock for ammonia production. However, the use of natural gas in India for urea production is constrained due to its scarce availability.

Better feedstock and process technologies, together with improved operation and maintenance practices, retrofitting, and so on have resulted in significant amount of energy savings during ammonia production. The average specific energy consumption for ammonia production in India has improved significantly from 57.35 Giga Joules (GJ)/tonne in 1985-86 to 37.53 GJ/tonne in 2007-08. The average energy consumption of 25% of the most efficient Indian ammonia plants is 32.7GJ/tonne in 2007-08.

10.3.1 Energy Intensity

The fertilizer industry is one of the major consumers of hydrocarbons. The fertilizer sector accounts for 8% of total fuels consumed in the manufacturing sector. Energy costs account for nearly 60 to 80% of the overall manufacturing cost. The absolute energy consumption by this sector has been estimated at 628 million GJ annually. The specific energy consumption per ton of urea varies between 21.59 GJ for the most efficiently operating plant to 52.38 GJ for the most inefficient plant during 2007-08. Energy intensity in India's fertilizer plants has decreased over time. This decrease is due to advances in process technology, better stream sizes of urea plants and increased capacity utilization.

Energy is consumed in the form of natural gas, associated gas, Naphtha, fuel oil, low sulfur heavy stock and coal for process. LDO, LSHS, HFO and HSD are also used in diesel generators. Large fertilizer plants generate part of their own power through cogeneration mode in Turbo Generator (TG) sets, while smaller plants depend exclusively on purchased power or power from DG sets. With the ever-increasing fuel prices and power tariffs, energy conservation is strongly pursued as one of the attractive options for improving the profitability in the Indian fertilizer industry.

The feedstock mix used for ammonia production has changed over the last decade. The choice of the feedstock is dependent on the availability of feedstock and the plant location.

The shares of feedstock's in ammonia production are as follows:

Table 10.4

Feedstock	1997-1998	2007-2008
Natural Gas	60.4 %	78%
Naphtha	21.2%	11%
Fuel oil	15.0%	11%

Source: FAI

The shift towards the increased use of natural/associated gas and Naphtha is beneficial as this feedstock is more efficient and less polluting than heavy fuels like fuel oil and coal.

The production of phosphatic fertilizer requires much less energy than nitrogenous fertilizer. Depending on the fertilizer product, energy consumption varied from negative input for sulfuric acid to around 1.64 GJ/tonne of fertilizer for phosphoric acid. For sulfuric acid the energy input is negative since more steam (in energy equivalents) is generated in waste heat boilers than is needed as an input.

10.3.2 Specific Energy Consumption (SEC)

Ammonia is the intermediate product in Urea production. Out of total energy consumed for the production of Urea, 80% is consumed in Ammonia production. Hence, efficient production of Ammonia has greatest impact on Specific Energy Consumption.

Hence, efficient production of Ammonia has greatest impact on Specific Energy Consumption.

The specific energy consumption comparison of Indian fertilizer industry with the World and China is as follows:

Table 10.5(a)
Specific Energy Consumption by Feedstock Type (GJ/tonne NH_3)

Feedstock based Plants		India Average (2001)	India Best (Improvement Potential)		World Average (1998)	World Best	China Average (2000)
Gas based plants	Ammonia	36.5	30.3 (17%)	TCL Babrala	36.6	28.0	36.7
	Urea	26.5	22.5 (15%)	TCL Babrala	25.8	20.9	26.3
Naphtha based plants	Ammonia	39.9	34 (15%)	CFCL Kota			38.7
	Urea	29.1	24.3 (16%)	CFCL Kota			28.3
FO based plants	Ammonia	58.4	47.9 (18%)	GNFC Bharuch			
	Urea	40.5	31.3 (23%)	GNFC Bharuch			

Note: The urea figures include the embedded energy in the production of ammonia
Source: LBNL

Table 10.5(b)
Feedstock-wise Capacity and Energy Consumption in Operating Ammonia Plants

Feedstock	Energy Consumption (GJ/Tonne)	
	Ammonia	Urea
Gas	35.54	24.99
Naphtha	41.23	30.01
Fuel Oil	49.06	33.45
Total	37.55	26.33

Source: FAI

10.4 Potential for Energy Efficiency Improvement

The biggest drawback of the Indian fertilizer industry is its reliance on non-natural gas-based plants. If we consider only the natural gas based plants, Indian plants compare favorably with international practices (Table 10.5a). The figures in brackets are the improvement potentials if plants were to reach best practices available in India. The highest energy saving potential is observed with fuel oil based plants.

The best practice energy intensity worldwide is 28 GJ/Tonne of ammonia, and is a result of auto-thermal reforming technology process. Auto thermal reforming process is a mixture of partial oxidation and steam reforming technology. According to the European Fertilizer Manufacturing Association (EFMA), two plants of this kind are in operation and others are at the pilot stage.

Tata Chemicals owns and operates one of the more energy-efficient plants for the production of ammonia and urea in India with an energy intensity of 30.3 GJ/Tonne of ammonia and 22.5 GJ/Tonne of urea. These energy intensity values are among the lowest recorded internationally. Manufacturing facilities at Babrala comprise an ammonia plant of 1520 TPD and a urea plant of 2864 TPD capacity which were implemented and commissioned in December 1994. Even though the plant currently uses natural gas, it has been designed for full flexibility in the use of natural gas and naphtha as a feedstock and fuel.

When only natural gas-based plants are considered, India appears to maintain very competitive plants compared to the world average (Table 10.5a). However with latest changeover of number of plants from naphtha to natural gas, India has now 80% ammonia capacity based on natural gas as of 2007.

India's national average figures of specific energy consumption for ammonia plants are close to the world average but there is wide variation in energy consumption of various plants. It varies from 32 GJ/Tonne to 63 GJ/Tonne with a weighted average of 37.55 GJ/Tonne. This wide variation is mainly because of the operation of Naphtha & fuel based plants, which have higher energy consumption than gas-based plants. In a competitive environment, with energy cost representing between 60% to 80% of total production cost depending on the type of plant, companies will be compelled to gradually switch over to natural gas in order to have an energy consumption per ton of output closer to world average and become more competitive in the international market.

10.4.1 Categories of Energy Efficiency Improvement

Over the past 30 years, induced by major technological improvements and by a better energy management, the energy used to produce each ton of ammonia has declined by 30 to 50%. Technology-wise, three different process stages can be distinguished where energy improvements are possible:

Steam reforming phase: This is the most energy intensive operation, with the highest energy losses. Different methods are available to reduce losses that occur in the primary reformer, viz., installing a pre-reformer, shifting part of the primary reformer load to the secondary with installation of a purge gas recovery unit, and upgrading the catalyst to reduce the steam/carbon ratio. It is possible to reduce energy losses by 3-5 GJ/Tonne of NH_3.

CO_2 removal phase: The removal of CO_2 from the synthesis gas stream is normally based on scrubbing with a solvent. A reduction of the energy requirement for recycling and regeneration of the solvent can be achieved by using advanced solvents, pressure swing absorption or membranes. Energy savings are in the order of 1 GJ/Tonne of NH_3.

Ammonia synthesis phase: A lower ammonia synthesis pressure reduces the requirement for compression power, and also reduces production yield. Less ammonia can be cooled out using cooling water so more refrigeration power is required. Also the recycling power increases, because larger gas volumes have to be handled. The overall energy demand reduction depends on the situation and varies from 0-0.5 GJ/Tonne of NH_3. Another type of catalyst is required to achieve the lower synthesis pressure. Furthermore, adjustments have to be made to the power system and the recycle loop.

Additionally, energy price escalation and growing concerns regarding pollution have intensified the attention on energy conservation at all levels. Improving energy efficiency does not necessarily require investment and can result from a better balancing of energy flow along the process. The optimization of operations and maintenance practices, by reducing waste heat and capturing excess heat to channel it back into the system, allows a better energy distribution and constitutes major energy efficiency improvements.

Some plants in India have realized considerable energy savings by increasing awareness at all levels in the plant, monitoring energy consumption during production, and identifying potential energy-savings opportunities

Some Technologies that can be adopted by fertilizer plants for energy efficiency improvement are briefly described below:

10.5 Technologies & Measures for Energy Efficiency Improvements

10.5.1 Haldor Topsoe Exchange Primary Reformer (HTER-p) (Ammonia Production)

Technology Description

HTER-p is introduced reforming section in ammonia plant to reduce size of the primary reformer and at the same time reduce the HP steam production. HTER-p is a new feature, initially developed for use in synthesis gas plants. In ammonia plants this is operated in parallel with the primary reformer, and that is why the name is HTER-p. The exit gas from the secondary reformer heats the HTER-p, and thereby the waste heat normally used for HP steam production can be used for the reforming process down to typically 750-850°C, depending upon actual requirements. The technology was implemented in a synthesis gas plant in South Africa in the year 2003.

Advantages

Operating conditions in the HTER-p are adjusted independently of the reformer in order to get the optimum performance of the primary overall reforming unit. In this way, up to around 20% of the natural gas feed can by-pass the primary reformer.

10.5.2 Uhde Dual Pressure Ammonia Technology (Ammonia Production)

Technology Description

At present, reducing the cost of plant by increasing the plant capacity is a major thrust in conventional ammonia process. To overcome the constraints in increasing the plant capacity beyond 2000 metric tons per day, Uhde has developed Dual Pressure technology. Dual Pressure process focuses on the de-bottlenecking of the conventional synthesis loop. A synthesis reactor has been introduced at an intermediate pressure level in the synthesis gas loop, which makes synthesis, and separation of ammonia possible in between compressor casing and the synthesis gas volume flow to the high-pressure loop is significantly reduced.

Advantages

The production can be raised by about 65%. Gives a superior hydrogen yield. Energy consumption is reduced by up to 4%. Cost of production is reduced by 10% to15%.

10.5.3 Megammonia (Ammonia Production)

Technology Description

The Megammonia technology is designed in the year 2003 jointly by M/s Lurgi and M/s Ammonia Casale for large scale production capacity of 4000 TPD Ammonia. Using natural gas, steam and air as feedstock, following five principal steps as below produces ammonia:

i. Air separation: 95% oxygen and 99.99% pure nitrogen is produced from air.

ii. Catalytic Partial Oxidation: Desulphurised natural gas, after addition of steam is first preheated in a fired heater and then reformed over a nickel oxide catalyst to CO, H_2 and CO_2 following partial oxidation.

iii. CO-Shift: Reformed gas is passed through two beds of conventional HT shift catalyst (Copper promoted Iron / chromia based) in series to convert remaining CO to H_2 and CO_2.

iv. Gas Purification: CO_2 is removed by absorption in cold methanol and other impurities like CO, CH_4 and Ar are removed by washing the gas with liquid nitrogen.

v. Ammonia Synthesis: The extremely high purity of ammonia synthesis gas results in higher conversion of gas per pass, lower circulator duty and lower refrigeration duty.

Advantages

Reduction in the capital cost by 18-20%. Operating cost is expected to be lower around 12 -15% over the most advanced conventional technology. CO_2 emission is expected to reduce by around 30% as compared to other conventional technologies.

10.5.4 HydroMax Technology (Ammonia Production)

Technology Description

Alchemix Corporation U.S.A developed the Hydromax technology. The technology is used for production of hydrogen using either relatively cheaper coal or using inexpensive fuels like municipal waste, biomass and petroleum coke etc. in presence of metal like iron. The technology involves a two-step process. In the first step, steam reacts with molten iron to form iron oxide and hydrogen and in the second step, iron oxide is reduced back to pure metal by adding carbon. Iron simply acts as a carrier for oxygen. In both steps, hydrogen production and reduction of iron oxide back into iron occur in the same reactor at the same temperature of 1250°C.

Advantages

Carbon dioxide and hydrogen are produced in separate compartments and do not require CO_2 removal system. Cost of production is almost four times less than Steam Methane Reforming (SMR) production cost. Emission of greenhouse gases is 34% less than SMR process.

10.5.5 Feedstock conversion from Naphtha to Regassified Liquified Natural Gas (R-LNG) in Ammonia-Urea plants

Technology Description

The type of feedstock has a major influence on energy consumption in an Ammonia-Urea plant. Hydrogen to carbon ratio increases as we move from liquid hydrocarbons (Naphtha, FO, LSHS, etc.) to gaseous hydrocarbons (Natural Gas). Besides, associated impurities namely sulphur, etc. are present only in traces in the case of gas. With the steep rise in the cost of liquid hydrocarbons in the last five-to-six years, Ammonia- -Urea production from liquid hydrocarbons plants has become very costly. Most significant difference between Naphtha and Natural Gas based Ammonia plants are in the Desulphurization Section. Since gas does not contain much sulphur unlike in Naphtha, hence pre-desulphurization section need not be operated. Other important aspect is in the hydrogen to carbon ratio, which is high in case of gas. As a result, less steam is consumed in the reforming section and less CO_2 is generated. After the reforming section, plants operating on Naphtha or gas are identical except in the quantum of generation of CO_2.

Advantages

Natural gas is ideal feedstock for ammonia production. It has several advantages besides being cheaper and easy to handle. It allows easy and shorter start up of the plant, thereby lesser unproductive consumption. The burners choking phenomena is completely solved and CO_2 emission from furnace has reduced. Plant also runs trouble free and the catalyst life is also increased

10.5.6 Carbon Dioxide Recovery (CDR) Plant

Technology Description

With the steep rise in the cost of liquid hydrocarbons, Ammonia -Urea production from liquid hydrocarbons plants has become very costly. As major disadvantage of RLNG conversion is lesser CO_2 production due to lower C/H ratio in RLNG as compared to Naphtha. CO_2 generated with lean RLNG is not adequate to convert total Ammonia produced to Urea. One of the possible options to overcome this problem is the recovery of CO_2 from flue gas from various furnaces. CDR plant is basically a low pressure CO_2 removal section in which CO_2 present in flue gases is absorbed & then regenerated to produce CO_2 having 99.93 % purity. CO_2 recovery from flue gases is a new concept in fertilizer industries.

Basic steps involved in CDR plant are:

a) Flue gas Pretreatment
b) Low pressure CO_2 absorption in special solution KS-1
c) CO_2 regeneration
d) CO_2 compression to desired level

Advantages

Though regeneration energy is very high in comparison to that of any normal CO_2 removal section of ammonia plant, the cost effectiveness of the plant is very attractive because of the use of costlier Naphtha (as feed to balance the CO_2 for Urea production) shall be stopped completely. There is substantial reduction in CO_2 Emission as well.

10.5.7 Parallel S-50 Converter

Technology Description

The S-50 converter is a single bed radial flow converter, which is added downstream of the main converter to increase the ammonia conversion and at the same time improve the steam generation.

Advantages

The converter allows ammonia synthesis loop to operate at lower pressure with increased conversion per pass.

10.5.8 Conversion of Single Stage GV System to 2-Stage GV System for CO_2

Technology Description

Ammonia is manufactured by steam reforming of natural gas. During the process, CO_2 is formed in the gaseous mixture and the same is removed from the gaseous mixture in the CO_2 Removal Section designed by M/s. Giammarco Vetrocoke (GV) of Italy. The process gas containing CO_2 enters the CO_2 absorber where major amount of CO_2 is absorbed in the lower portion of Absorber in semi-lean GV solution. Rest of the CO_2 is absorbed in top portion of Absorber in lean GV solution. The process gas, with around 300 ppm of CO_2, leaves the Absorber from top.

The main feature of original single stage GV system are (1) Absorption by only lean GV solution and (2) Stripping only in one Regenerator. The heat of regeneration is provided by vapours generated in GV Reboilers heated by Process gas and live LP steam. Full quantity of GV solution is sent to flash tank after GV Reboilers to remove maximum amount of vapour and CO_2. This lean GV solution goes to GV Absorber in two parts, the hot solution to the middle to absorb major amount of CO_2 and cold GV solution to the top of GV Absorber to absorb the residual CO_2.

The main features of the modified 2-stage GV process are (1) Absorption by lean & semi lean solutions in GV absorber (2) High pressure & low-pressure stripping in HP Regenerator and LP Regenerator. The heat of Regeneration is provided by vapours generated in GV Reboilers heated by Process gas, steam generated in LP Steam Boiler heated by process gas and live LP steam. Partially regenerated GV solution (Semilean Solution) from Regenerators goes to GV Absorber to the middle to absorb major amount of CO_2 and strongly regenerated cold GV solution (Lean Solution) to the top of GV Absorber to absorb the residual CO_2.

Advantages

The features result in better absorption of CO_2 in Absorber and lower energy consumption for regeneration of the solution in Regenerators. Major benefits of the modification are:

- Reduction of CO_2 slip through Absorber by around 600 ppm, which has resulted in:

- Higher availability of CO_2 for urea production.
- Decrease in hydrogen consumption in Methanation Section.
- Decrease in LP steam consumption in CO_2 Removal System from 38 T/hr to 15 T/hr.
- By this, an energy saving of around 1GJ/Tonne of ammonia can be achieved.

10.5.9 LTS Guard Reactor & BFW Preheater

Technology Description

The reformed gas from Reforming Section flows to HT Shift Convertor after cooling in HP Waste Heat Boiler from 988°C to 380°C. The carbon monoxide content of the process gas is reduced from 12.96% to 3.46% in HT Shift Converter through shift reaction, which takes place in the reactor in presence of Iron-chromia catalyst. Process gas temperature of around 444°C at the outlet of HT Shift Convector is reduced to around 210°C by heat recovery in a Waste Heat Boiler and Boiler Feed Water Preheater.

Installation of a new LT Shift Guard Reactor before LT Shift Converter reduces the CO slippage from the Shift Conversion Section. The CO slip gets considerably lowered with the LT Shift Guard in line. Lower CO slip in turn, results in additional Ammonia production due to reduction in the consumption of hydrogen in Methanator. Considerable energy saving can be achieved by installation of a BFW Preheater down stream of the new LT Shift Guard Reactor.

Advantages

Reduction of CO slip through Shift Conversion Section by around 300 ppm. This gives higher availability of CO_2 for urea production. Hydrogen consumption in Methanation Section can also be considerably decreased. Installation of the BFW Preheater results in considerable energy savings.

10.5.10 The Poolcondenser concept (Urea Production)

Technology Description

The Poolcondenser concept is introduced to de-bottleneck very large capacities indeed. In case a stripping plant is considered in urea plants, the Poolcondenser is installed with a parallel-operated stripper. Conventional urea plants are revamped by using this concept to change the plant into a stripping unit. In this way the plant capacity is increased and the utility consumption is decreased drastically. The Poolcondenser is a horizontal high-pressure vessel in which reaction volume and condensing including retention time, which is needed to produce urea, is already in this Poolcondenser. The technology is implemented at PIC in Kuwait.

Advantages

Very large capacities are de-bottlenecked.

10.5.11 Modified trays in Urea reactor

Technology Description

Due to advancement in technology and current fertiliser scenario, it is necessary to upgrade the plant equipments to reduce energy consumption. One new development is new modified tray design for Reactor in place of conventional design. Installation of these modified trays have further improved plug flow and reduced back mixing in the reactor and hence conversion of Ammonium Carbamate to Urea in the Reactor is enhanced.

Advantages

Conversion efficiency in Reactor is increased with considerable saving of medium pressure steam per tonne of production. Materials of construction of new trays are more corrosion resistant and have more life as compared to material used for conventional trays.

10.5.12 Use of Advanced Process Control (APC) with Distributed Control System (DCS)

In control theory, Advanced process control (APC) is a broad term composed of different kinds of process control tools, often used for solving multivariable control problems or discrete control problem. APC are often used for solving multivariable control problems or discrete control problem. APC makes it possible to control multivariable control problems. Since these controllers contain the dynamic relationships between variables, it can predict in the future how variables will behave. Based on these predictions, actions can be taken now to maintain variables within their limits. APC is used when the models can be estimated and do not vary too much. Normally an APC system is connected to a distributed control system (DCS). The APC application will calculate moves that are send to regulatory controllers. Historically, the interfaces between DCS and APC systems were dedicated software interfaces. Nowadays the communication protocol between these system is managed via the industry standard Object Linking and Embedding (OLE) for process control (OPC) protocol.

Advantages

The key advantages of APC with DCS are:

- Safer plant operations
- Avoiding unnecessary plant trips
- Better plant performance and maximized production

10.5.13 Simulation of Absorption and Desorption Columns for CO_2 Removal

Technology Description

A computer programme has been developed which simulates the performance of an absorption column for CO_2 removal by using chemical solvents such as DEA promoted carbonate solution. The computer predictions have been validated by using industrial column data from fertilizer industries. In addition, another computer program has also been developed to simulate the performance of steam desorption of bicarbonate solution for solvent regeneration in the CO_2 removal systems of fertilizer plants.

Advantages

The modeling equations are rigorous as they take into account point to point variation of all important transport and physical parameters, heat effects, gas and liquid temperature profiles, enhancement in gas absorption due to mass transfer with chemical reaction, etc.

10.6 Case Studies

Case Study 1: Installation of a Pipe Reactor in Complex Plant

Brief

Before Improvement	***After Improvement***
In a phosphatic fertiliser complex, producing Ammonium sulphate and Mono-ammonium phosphate, the phosphoric acid, sulphuric acid and ammonia are reacted in a tank reactor to produce a melt of 85 % solids.	*The plant replaced the existing tank reactor with a pipe reactor.* *The implementation of this project resulted in operation of the reactor at higher concentration. The outlet of the reactor was directly inserted into the granulator. Hence the concentration of the melt was maintained at about 95 %, as against < 85 % earlier. The increase in concentration of the melt reduced the drying requirement in the dryer. The furnace oil consumption came down from 20 liters/ton of product to 5 liters/ton of product.*

Energy savings

Annual savings : Rs. 21.0 Million
Investment amount : Rs. 80.00 Million
Payback period : 45 months

Case Study 2: Replacing Reformer Tubes with Tubes of HPNb Material Stabilised with Micro-Alloys

Brief

Before Improvement	***After Improvement***
In a 357 TPD Ammonia plant involved in production of Urea and other Phosphatic fertilisers, the reformer tubes were made of conventional material with 25 % Chromium & 20 % Nickel.	*The Reformer tubes were replaced with 'modified HPNb materials stabilised with micro-alloys' with higher Chromium & Nickel and stabilised with Niobium (25 % Chromium, 35 % Nickel, 1.5 % Niobium and traces of Zirconium).* *The replacement of the reformer tubes with modified superior material resulted in the following benefits:* • *Reduction in thickness of tube from 20 mm to 10 mm* • *Increase in internal diameter of tubes from 100 mm to 120 mm –it aided in packing additional catalyst to the extent of 35 %* • *Increase in capacity of the plant by 15 %* • *Reduction in Reformer tube skin temperature* *The above benefits together resulted in reducing the energy consumption for production of Ammonia by 0.63 GJ / Tonne of Ammonia.*

Energy savings

Annual savings : Rs. 15.0 Million
Investment amount : Rs. 50.0 Million
Payback period : 40 months

Case Study 3: Modernisation of the Ammonia Converter Basket

Brief

Before Improvement	***After Improvement***
In a 357 TPD Ammonia plant, the Ammonia converter basket had a conventional axial type basket. This needed an operating synthesis loop pressure of 300 bar. The catalyst used was Topsoe supplied of 10 mm size with a pressure drop of 5 bars. The conversion per pass was around 16 %. In 1992, the bottom exchanger developed a leak, leading to further reduction of ammonia conversion and increased loop pressure. The total production loss was around 30 %.	*The converter basket was modified to an axial-radial type system.* *The replacement of the old axial type converter basket with the modern axial-radial system resulted in the following benefits:* • *Loop pressure reduced to 250 bar – reducing compression energy* • *Lower pressure drop in converter beds – 3 bar as against 5 bar before* • *Higher Ammonia production (about 10 TPD)* *The above benefits resulted in the reduction of energy consumption by 1.47 GJ / Tonne of Ammonia*

Energy savings

Annual savings : Rs. 20.0 Million
Investment amount : Rs. 50.00 Million
Payback period : 30 months

Case Study 4: Installation of Waste Heat Boiler (WHB) at the Inlet of LTS Converter in Ammonia Plant

Brief

Before Improvement	After Improvement
In an Ammonia plant, the Low Temperature Shift Converter (LTSC) was designed to operate at a inlet temperature of 238°C.	*A Waste Heat Recovery Boiler (WHRB) was installed to reduce the temperature of the gases entering the LTSC to about 210°C.* *The installation of the WHRB resulted in the following benefits:* • *Reduction of LTSC inlet temperature to about 210°C and generation of 2 TPH of steam at 14 kg/cm^2* • *Prolonged life of LTSC catalyst* • *Increased process efficiency – Resulting in higher Ammonia production by 0.9 % (about 3 TPD)* *The above benefits resulted in the reduction of energy consumption by 0.34 GJ / Tonne of Ammonia.*

Energy savings

Annual savings : Rs. 8.20 Million
Investment amount : Rs. 4.50 Million
Payback period : 7 months

Case Study 5: Installation of Make-up Gas Chiller at Suction of Synthesis Gas Compressor at Ammonia Plant

Brief

The compressor is the heart of nitrogenous fertiliser plant and is used for various purposes such as compressing the synthesis gas, air, re-cycle gas and ammonia. The compressor capacity is also one of the important parameters controlling the capacity of the plant.

Hence, the design of the compressor and its effective utilisation is essential for achieving higher production and lower energy consumption.

Before Improvement	AfterImprovement
A ammonia fertiliser complex producing 900 tons per day of Urea was operating at about 920 TPD of ammonia production. The synthesis gas was entering the compressor at about 39°C.	*The plant installed a vapour absorption refrigeration system with LP steam for cooling the synthesis gas.* *The implementation of this project resulted in a saving of 117355 GJ per year, which amounted to 0.38 GJ / Tonne of ammonia*

Energy savings

The implementation of this project resulted in the following benefits

Parameter	*Units*	*Before Implementation*	*After Implementation*
Ammonia Production	*TPD*	*920*	*944*
Syn. gas temperature	*°C*	*39*	*13*
Syn. gas compressor speed	*RPM*	*13,142*	*13,071*

Annual savings : Rs. 9.80 Million
Investment amount : Rs. 22.00 Million
Payback period : 27 months

Case Study 6: Replacement of Air Inter-coolers in the Ammonia Plant

Brief

Before Improvement	After Improvement
In a 1,00,000 ton per annum capacity Ammonia plant, the air requirements of the Ammonia converter were being met by two numbers of oil lubricated 4 stage reciprocating compressors. The compressors were provided with inter-coolers with finned tubes and were laid in a horizontal fashion. The oil in the air from cylinders used to plug the gap between the fins and reduce the heat transfer. The exit air from the inter-cooler used to be at 55 – 58°C as against the design of 42°C. The capacity of the subsequent stages was getting reduced leading to loss of Ammonia production.	*The inter-coolers for the compressor was replaced with finless tubes and laid in a vertical fashion.* *The replacement of horizontal fin type cooler with vertical finless coolers resulted in reduction of exit air temperature to around 45°C. There was a reduction of power to the extent of 45 kW.*

Energy savings

Annual savings : Rs. 0.85 Million
Investment amount : Rs. 2.00 Million
Payback period : 28 months

Case Study 7: Routing of Ammonia Vapours from Urea Plant to Complex Plant

Brief

Before Improvement	After Improvement
In a Urea & Phophatic fertiliser complex, ammonia is compressed from vapour to liquid form by compression to 19 kg/cm^2 in two reciprocating compressors and then condensed while in the other part of the plant, the liquid Ammonia (about 6 TPH) at 0°C was drawn from the storage spheres and vapourised at 6 kg/cm^2 . Both these operation demand energy in the form of electricity for compression and steam for vapourisation.	*The system was modified as below:* ▪ *Ammonia was compressed to only 6 kg/cm^2 in the Urea plant.* ▪ *The hot vapours were exported from the Urea to the complex plant.* *The implementation of this project resulted in the following benefits:* • *Reduction of electrical energy consumption for compression of Ammonia in the Urea plant.* • *LP steam saving in the Complex plant* *The above benefits resulted in the reduction of energy consumption by 6 lakh units per year and 2000 T of LSHS.*

Energy savings

Annual savings : Rs. 4.00 Million
Investment amount : Rs. 0.50 Million
Payback period : 2 months

Case Study 8: Replacement of Pellet Type Catalyst with Ring Shaped Catalyst in Sulphuric Acid Plant

Brief

Before Improvement	*After Improvement*
In a sulphuric acid plant, which was a part of the larger fertiliser complex plant, pellet shaped V_2O_5 catalyst was being used. The plant was frequently facing problems of dust accumulation and increase in pressure drop. Additionally the plant had to be shut down once every six months for screening and re-charging the catalyst.	*The pellet shaped catalyst was replaced with ring shaped catalyst of the same material composition.* *The replacement of the pellet type catalyst with ring type catalyst resulted in the following benefits:* • *Reduction in the pressure drop build up of the converter* • *Reduction in the load of the main air blower* • *Shut down (for screening and recharging catalyst) frequency reduced from two per year to once per year* *The above benefits resulted in the reduction of energy consumption by 900 tonne of LSHS and additional production of 10,000 tonne of sulphuric acid per year*

Energy savings

Annual savings : Rs. 7.80 Million
Investment amount : Rs. 40.0 Million
Payback period : 62 months

Case Study 9: Installation of High Efficiency Turbine for Air Blower in Sulphuric Acid Plant

Brief

Before Improvement	*After Improvement*
In the sulphuric acid plant (1200 TPD capacity) of a huge fertilizer complex, the sulphur furnace blower was driven by a single stage turbine operating between 35 kg/cm^2 and 3.5 kg/ cm^2. The turbine had a specific steam consumption of 16.9 tons per MW. The turbine was consuming about 27 TPH of steam during normal operation. There was also a mis-match of LP steam generation and requirement, resulting in an average venting of LP steam (pressure of 3.5 kg/cm^2) of about 4 TPH.	*The single stage turbine was replaced with a new multi-stage steam turbine of higher efficiency. The improvement in efficiency was about 15 % resulting in reduction of steam consumption by about 3 TPH, even when operating at higher load.* *The implementation of this project resulted in the saving of about 3 TPH of steam (35 kg/cm^2).*

Energy savings

Annual savings : Rs.9.60 Million
Investment amount : Rs.15.0 Million
Payback period : 19 months

Case Study 10: Installation of Variable Frequency Drive (VFD) for Sulphur Pump

Brief

Before Improvement	*After Improvement*
In the sulphuric acid plant (1200 TPD capacity) of a huge fertiliser complex, the sulphur pump was being driven by a steam turbine with inlet steam at 35 kg/cm^2. The pump was of 10.2 m^3/h capacity and 265 m head and was being controlled by re- circulation. Also, the turbine driving the pump was a small one consuming a maximum of about 0.7 TPH of steam. Since the quantity of steam was less, the exhaust was let out into the atmosphere.	*The steam turbine was replaced with a motor of 22 kW with a variable frequency drive. There were two pumps and one was operated continuously. The replacement was done for one of the pumps and other turbine driven pump was kept as a stand-by.* *The implementation of this project resulted in the saving of about 0.4 TPH of steam. The motor installed along with VSD was consuming about 15 kW*

Energy savings

Annual savings : Rs. 0.75 Million
Investment amount : Rs. 0.50 Million
Payback period : 8 months

Case Study 11: Optimisation of Vacuum Pump Operation

Brief

Before Improvement	*After Improvement*
In a phosphatic fertiliser unit, which is part of a bigger fertiliser complex involved in production ofβ complex fertilisers, a long belt filter was being used for final filtration of the slurry of silica and AlF_3. Two vacuum pumps of 500 m^3/h capacity and 0.3 kg/cm^2 vacuum were being used for creating vacuum. One of the vacuum pumps was being operated with valve throttling. *The detailed study of the system revealed the following:* *There were leaks in the vacuum line joints close to the belt filter.* *The capacity of the vacuum pump was reduced due to uneven wearing of the pump*	*During a maintenance stoppage of the plant, the leakages were arrested and a trial was taken to operate the filter with one vacuum pump. The trial was satisfactory and the operation of one vacuum pump per filter was made into a standard operating procedure.* *The power saving was about 15 kW, which annually amounted to 1,20,000 units* *(8000 hrs/year operation)*

Energy savings

Annual savings : Rs. 0.37 Million
Investment amount : Minimal
Payback period : Immediate

Case Study 12: Coating of Pump Impeller and Casing with Composite Resins

Brief

Before Improvement	*After Improvement*
In a sulphuric acid plant of 600 TPD capacity, there were 4 cooling water pumps of 2700 m^3/h capacity and 50 m head driven by a 500 kW motor. The pumps were operating at an efficiency of 64.5%, consuming about 430 kW.	*The casing of the pump was coated with epoxy resin coating.* *Consequent to the coating the efficiency of the pump had improved and there was a reduction of about 16 kW in the power consumed by each pump. The total saving was about 0.13 million units.*

Energy savings

Annual savings : Rs. 0.7 Million
Investment amount : Rs. 0.5 Million
Payback period : 9 months

Case Study 13: Installation of Hydraulic Turbine in the CO2 Removal Section

Brief

Before Improvement	*After Improvement*
In a particular nitrogenous fertiliser plant of about 1,00,000 tons per year capacity, the aqueous mono ethanol amine (MEA) process was being used for CO_2 removal. This MEA absorbed in the CO_2 absorber which is at a pressure of 24 kg/cm^2, enters the CO_2 stripper operating at a lower pressure of around 0.4 kg/cm^2. This pressure reduction is effected through a pressure-reducing valve.	*A Hydraulic Power Recovery Turbine (HPRT) was installed to recover the pressure energy being lost across the valve.* *The implementation of this project resulted in reduction of the load on the steam turbine driving the lean MEA pump. The steam saving on the steam turbine amounted to 2.5 TPH of high-pressure steam, which annually amounted to about 600 tons of LSHS. The reduction in specific energy consumption amounted to about 0.06 Gcal / Tonne of ammonia.*

Energy savings

Annual savings : Rs. 3.80 Million
Investment amount : Rs. 1.10 Million
Payback period : 4 months

Case Study 14: Replacement of steam ejectors with vacuum pumps

Brief

Before Improvement	**After Improvement**
In one of the complex fertilizer-manufacturing units, there were five evaporators for concentration of phosphoric acid. The evaporators were operated under vacuum using 2-stage steam ejectors. These ejectors consume about 1.5 TPH each of 27-kg/cm^2 pressure steam.	*All the five steam ejectors in evaporator section were replaced with water ring vacuum pumps.* *The steam saved by replacement was equivalent to about 7.5 TPH of 27-kg/cm^2 pressures. This can generate additional power equivalent to about 50 units/ ton of steam, thereby offsetting equivalent power drawn from the grid*

Energy savings

Annual savings : Rs. 10.00 Million
Investment amount : Rs. 7.50 Million
Payback period : 9 months

Case Study 15: Re-processing of Purge Gas for Ammonia-fertiliser

Brief

Before Improvement	**After Improvement**
The 10,000 TPA methanol plant based on natural gas reforming is designed with a purge of 5, 000 Nm^3/ hr from methanol synthesis section, which is used as a part of fuel in reformer. The purge stream is having 70 percent of hydrogen, which is having low heating value.	*Productive use of this stream containing about 3,500 Nm^3/ hr available hydrogen was thought of to produce ammonia. The compatibility of the stream was established in ammonia plant upstream of rectisol wash unit after boosting the pressure from 54 to 75 bars by using a recycle compressor. After implementing the scheme, ammonia production could be increased to the tune of 40 T/ day on consistent basis.* *Also part of purge gas is reprocessed to pure hydrogen after installing pressure swing absorption unit. The hydrogen is supplied for producing aniline (20,000 TPA) at 54 BAR*

Case Study 16: Reprocessing of CO waste gas for ammonia/ methanol

Brief

A stream of gas generated in gasification unit, containing mainly CO + H_2 is used for 50,000 TPA acetic acid plant. This gas stream is purified to remove impurities of CO_2 and H_2S, followed by CO enrichment. This 99.5 percent pure CO is used for production of acetic acid. In the process of CO enrichment, a waste CO + H_2 stream is generated. The hydrogen of this stream is reprocessed in nitrogen wash unit for enhancing ammonia production as in-built feature. However, CO content of the stream is lost in tail gas stream of nitrogen wash unit.

Energy savings

A scheme to use this stream in methanol plant is made which will spare hydrogen for increasing ammonia production by 7 TPD.

Case Study 17: Re-use of Condensate Streams from Different Locations

Brief

In the CO-shift reaction 50 T/hr of water is consumed from the saturated gas generated by gasification. Grey water circuit of carbon extraction unit supplies this water. Also about 20 Tonne/ hr of water is required to blow-down from the grey water drum to maintain chloride and TDS in the system. This 70 Tonne/ hr of water requirement is met by make-up of BFW or condensate to grey water drum as per design. This being very high consumption of BFW the use of waste streams available was thought of and the following streams were identified and connected with grey water circuit.

1. *Urea plant hydrolyser effluent : 30 Tonne/ hr is recycled to grey water drum through a control valve. The contaminants limits are fixed at 100-ppm ammonia and 50 ppm urea.*
2. *Formic acid plant : 10 Tonne/ hr condensate of stream is taken to grey water drum by pump.*
3. *Methanol plant : 20 Tonne/ hr condensate containing about 5 ppm methanol is diverted to grey water drum.*

Energy savings

Load on DM water and BFW system is reduced by about 60 Tonne/ hr giving considerable savings.

Case Study 18: Installation of modified trays in Urea reactor

Brief

A major plant had modified the old Reactor trays of 11 & 21 units of Urea Plant-I with new design trays .M/S Snamprogetti, Italy (technology supplier for Urea Plant) have developed a new modified tray design for Reactor. In place of 10 Nos. of identical sieve trays of conventional design (each having 363 nos. holes of 8 mm each on square pitch), 15 Nos. trays of modified Snamprogetti design have been installed. Each set of 5 new trays has 1922, 1281 & 941 holes of 8 mm dia. each on triangular pitch. Installation of these modified trays have further improved plug flow and reduced back mixing in the reactor and so conversion of Ammonium Carbamate to Urea in the Reactor is enhanced.

Energy savings

Saving of around 30 kg of medium pressure steam (24 ata) per tonne of fertliser produced has been achieved due to increased reactor efficiency. Material of construction of new trays is 2-RE-69, which is more corrosion resistant and shall have more life as compared to SS 316 LM material used for conventional trays.

Energy Saving Achieved: 0.0063 GJ/Tonne of urea.

Case Study 19: Conversion from Naphtha to R-LNG as feedstock

Brief

A major plant initiated the task of executing RLNG conversion along with Energy Saving Project. As the availability of indigenous natural gas was limited, the only possible alternative was to go for RLNG which was to be sourced from outside andmade available to the unit as per the requirement. The unit held discussions with *the concerned parties and finally an agreement was reached between the gas supplier and the unit for gas supply. A separate 140 KM pipeline was laid from Thulendi of District Rai Barelly to the Unit from the existing HBJ gas pipeline.*

Energy savings

- *Easy and shorter start up of the plant, thereby lesser unproductive consumption*
- *No burners choking problem*
- *Reduced CO_2 emission from furnace*
- *Trouble free running of plant*
- *Increased life of catalyst*

Case Study 20: Installation of Carbon Dioxide Recovery (CDR) Plant

Brief

A major unit has installed a Carbon Dioxide Recovery (CDR) Plant, to recover CO_2 from flue gases of Ammonia plant primary reformer furnace. The capacity of the plant is 450 TPD of CO_2 and M/s MHI, Japan has provided the basic engineering for it. M/s TICB was engaged as turnkey contractor for detail engineering, procurement, erection and commissioning. CDR plant is basically a low pressure CO_2 removal section in which CO_2 present in flue gases is absorbed & then regenerated to produce CO_2 having 99.93 % purity.

Energy savings

- *Cost effectiveness of the plant is very attractive because the use of costlier Naphtha as feed to balance the CO_2 for Urea production shall be stopped completely. This offsets higher conversion costs.*
- *Reduced CO_2 Emission*

References

1. Annual Report 2007-08, Ministry of Chemicals & Fertilizer, Department of Fertilizers, GoI.
2. Technology Assessment Report - Fertiliser Sector: Fertiliser Association of India
3. "Energy Efficiency Gains in Indian Ammonia Plants Retrospect and Prospects", Sachchida Nand, Manish Goswami; 2006 IFA Technical Symposium, 25-28 April 2006, Vilnuus, Lithuania.
4. LBNL - 57293; Assessment of Energy use and energy savings potential in selected industrial sector in India, August 2005.
5. Indian Journal of Fertilizers, Vol - 4, No.9, September 2008 (ISSN 0973-1822)
6. Compendium of Workshop - "Adoption of Energy Efficient process technologies & practices and implementation of Energy Conservation Act 2001 in Fertilizer Sector" by BEE at New Delhi on 1st September, 2008.
7. TERI Energy Directory and Yearbook 2007
8. LBNL-41846: India's Fertilizer Industry: Productivity and Energy Efficiency; Katja Schumacher and Jayant Sathaye; Earnest Orlando Lawrence Berkley National Laboratory, Environmental Energy Technologies Division, July 1999
9. Statistical Abstract 2007 - CSO
10. CII - IREDA Publication: "Investors Manual on Energy Efficiency".
11. Japan Energy Conservation Directory
12. LBNL - 62806; World Best Practice Energy Intensity Value for Selected Industrial Sectors, February 2008
13. LBNL - 54828: Emerging Energy Efficient Technologies in Industry case studies of selected technologies - May 2004
14. National Energy Map of India: Technology Vision 2030
15. Report of the working group on Power for 11th Plan (2007-12)
16. Report of the working group on R&D for the Energy Sector for the formulation of the 11th Five Year Plan (2007-12)
17. BP Statistical Review, June 2008
18. http://fert.nic.in
19. www.energymanagertraining.com
20. www.faidelhi.org
21. www.eeii.org.in