## CHALLENGES & INNOVATIONS IN TECHNOLOGY OF AMMONIA UREA PLANTS

## INTRODUCTION

The nature has its own nitrogen fixing bacteria in the soil to rejuvenate the fertility of the soil for the growth of the plants in different crop pattern known as nitrogen cycle. Organic manures through the natural biodegration used to enhance the fertility further. But the human population growth has been much faster needing larger and larger food grain for its living, necessitating higher and higher food grain output. Invention and use of chemical fertilizers played a key role in this area. Chemical fertilizers provides the three primary nutrients i.e. nitrogen (N), phosphorous (P2O5) and potash (K2O).

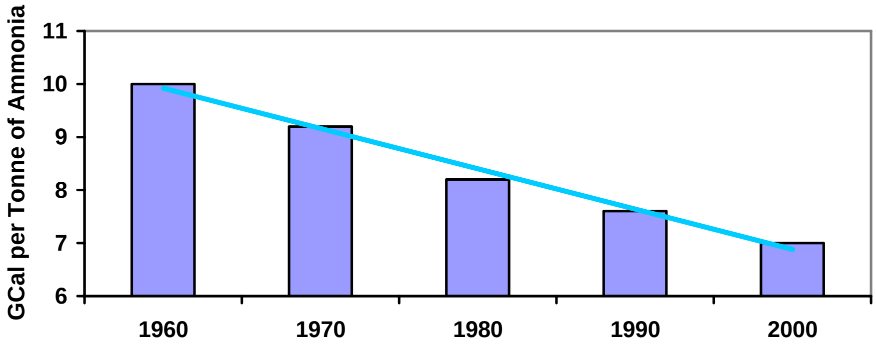
In the use of Nitrogenous fertilizers starting from Ammonium Sulphate, Ammonium Chloride, Ammonium Nitrate etc. the inventions of urea made a revolutionary change. The technologies have undergone tremendous developments and because of improvements energy consumption has reduced considerably and there is noticeable reduction in cost of production and in capital cost.

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

## Technology

The first commercial production of Ammonia from nitrogen and hydrogen was carried out successfully in Germany in 1913.However, the size of the plant was very small, 25-30 tpd and cost of production was very high. During the latter half of the 20$^{th}$ century, successive improvements in ammonia production have lowered the cost of production which resulted in liberal use of fertiliser in crop production. The use of centrifugal compressors, staring in the 1960s, made possible large, single train ammonia plants of 1000-or even, 1500-tpd capacity. Development of special alloys reduced the size and weight of equipment also resulting into capacity enhancement of the plants. This lead to a marked reduction in the capital cost and energy requirements of around 7.0 Gcal/tonnes of Ammonia from earlier 10 GCal/tonne.

By incorporating the latest technologies, up to 7.0 GCal/tonne of Ammonia has been achieved in latest plants. The reduction in specific energy consumption of Ammonia Plants over the past 40 years is shown below:




It is becoming more and more difficult to reduce the energy requirement further in cost effective manner, as the theoretical energy requirement is 4.5 Gcal/t.
The various available Technologies for ammonia are mentioned below:

1. Haldor Topsoe (HTAS)
2. Kellogg Brown Root (KBR)
3. ICICF Braun
4. Uhde

The thrust area for future process technologies are:

1. Low specific energy consumption
2. Innovative, yet proven technology
3. Superior economic performance
4. Reducing the emission of Green Houses Gases(GHG)
5. Looking for various cost effective feed stock.
6. Automation

**CHALLENGES BEING FACED BY FERTILISER INDUSTRY:**

Today, fertilizer industry is facing a lot of challenges. The major challenges are availability of feed stock and reduction in Specific Energy Consumption.
India is an Energy deficient and is dependent on imports to meet its energy requirements.

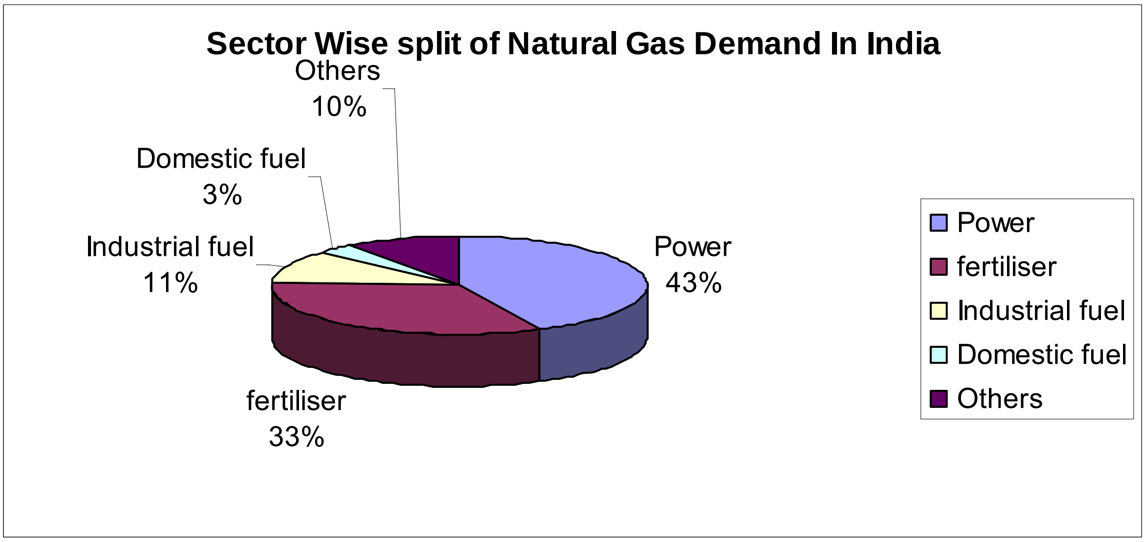
Natural gas is the most efficient fuel available for fertiliser production. In the manufacturing of Ammonia both Energy value and the Chemical value of Natural Gas is used unlike in other Natural Gas uses e.g. in the Power generation only Energy value of the gas is utilized.However,the allocation of Gas to the fertiliser sector is less than the requirement. Another major challenge is reduction of energy to reduce cost of production. Fertiliser being subsidized product, Govt. of India is tightening the norms of Specific Energy Consumption of the fertiliser plants to reduce the subsidy outgo. Therefore, industry has to constantly endeavor to reduce the energy consumption in order to remain competitive.

## 1. <u>Availability of Feed Stock</u>

The availability of feed stock and its price is most important for efficient production of fertilizer and its competitive cost. Natural Gas is preferred Feed Stock because it is a clean and efficient feed / fuel as compared to liquid fuels.

More than 70% of the World production of Urea is based on Natural Gas. In India about 67% Urea capacity is based on Natural Gas and balance 33% on Naphtha and Fuel Oil. There are limited reserves of oil in the world which are estimated to be 3 trillion barrels at present. With the present reserve to production ratio the oil is estimated to last for 40 years. No major discoveries of oil could be made in last few years. The total reserves of Natural Gas in the world are 6040 TCF. With the present reserve to production ratio the reserves will last upto 70 years. In India, the total proven Natural Gas reserves are 26 TCF. Further, exploration has been made by M/S GSPCL in KG basin and M/S Reliance is also adding to its reserves. With the present production rate the gas reserves will last upto 27 years.

In India, the Natural Gas supply has been limited to the availability of Domestic Gas. At present, the supply of Natural Gas is around 75 MMSCMD to various industries. Sector-wise split of Natural Gas demand in India is as below:



The present allocation of Natural Gas to Fertiliser Industry is around 29 MMSCMD against which the demand of 33MMSCMD.To meet the shortfall of Natural Gas in Gas based plants, to convert the Naphtha/FO/LSHS based plant to Gas based and additional requirement for proposed expansions, the Fertiliser industry needs around 35 MMSCMD additional Natural Gas which can either be met by importing LNG or sourcing the gas from recent Gas discoveries.

The recent major discoveries of Gas by Reliance and Gujarat State Petroleum Corporation (GSPC) Ltd. In Krishna Godavari (KG) basin in Bay of Bengal is expected to produce around 80 MMSCMD Gas from 2008 onwards. Additionally, a number of other small discoveries of Gas have also been announced from time to time.

Exploration of Gas is being carried out in various parts of the country and results are encouraging. It is important that availability of Gas for fertilizer industry will improve considerably from 2009 onwards.

However, keeping in mind the depleting reserves of Natural Gas, we should look forward for other different feedstock alternatives like Coal Bed Methane (CBM), Coal Gasification Technologies (both above & underground) and Gas Hydrates etc. for the production of Urea.

**<u>Coal Bed Methane:</u>**

The Coal Bed Methane is a gas similar to natural gas which contains more than 90% methane. The CBM gas can be also utilized as a feed stock for the Ammonia/ Urea fertilizer complex. However, it is a bit premature to depend on this source unless more information on production of CBM from these blocks is available. The potential CBM blocks are geographical wide spread spanning from Rajasthan to AP or in MP. So far in India sixteen blocks have been awarded through two rounds of bidding and in 3$^{rd}$ round 10 more blocks has been awarded. The likely production volumes of CBM – I & CBM-II blocks is of the tune of 21 MMSCMD and production is likely to start in 2007-08. The approximate cost of CBM gas is 5.5 US$ / MMBTU.

**<u>Coal Gasification:</u>**

With the improved technology and the equipment available to handle poor quality of Indian Coal this has very high ash content of 32-35%. Today technologies for reducing the ash content in a cost effective manner are available. This opens up opportunities for using the established coal gasification technologies which has been successfully used in China.

Coal gasification is a viable option for urea production with delivered coal prices being around US$ 2.5 / MMBTU as against US$ 9 for spot LNG and US$ 14 for naphtha. However, serious effort in this direction has to be made.

India is endowed with huge reserves of coal and lignite. Out of the total coal reserves a large quantity exists at un-mineable depth**. Underground Coal Gasification (UCG)** is a process which burns coal/Lignite in-situ in the seam in presence of air/oxygen to produce gaseous mixture consisting of $CO_2$, CO, $CH_4$, H2, and $N_2$ etc. The gas in turn can be used for generation of power, generation of Liquid Hydrocarbon fuel or in the production of Ammonia & Urea.

The lignite reserves in the state of Rajasthan, Gujarat and Tamil Nadu are ideally suited for UCG. The recoverable energy from coal reserves of Mehsana-Ahemdabad block in the state of Gujarat alone (63 billion tonnes) alone in the form of gas is estimated to contain 15,000 Billion cubic meter of Natural Gas. The successful trial run of UCG project has been carried out in Chinchilla, Australia and the viability has been proved in Angren, Uzbekistan. In India ONGC has taken up pilot studies in the state of Gujarat to prove the viability.

## Gas Hydrates

Natural Gas hydrates are another alternate of cleaner and future fuel. Naturally occurring gas hydrates are ice like compounds in which gas molecules, methane in most cases, are there in crystallized form held between hydrogen and water bond occurring at a water depth of 650-750 meters where pressure and temperature conditions are favorable for the formation of Gas Hydrates.

Gas hydrates occurrences are proven through samples in Pacific Ocean, Indian Ocean, Atlantic Ocean, Artic Ocean and others. With the work in last 10-12 years the world estimates have converged on a consensus value of about 21000 trillion cubic meters of methane in natural gas hydrates. These reserves are more than the 100 times proven world reserves of Natural Gas. However, technology is yet to be developed to exploit these reserves on commercial basis. Russia, USA and Japan have taken up projects to exploit Gas hydrates reserves. In India potential areas for gas hydrate occurrence includes the area of Andaman-Nicobar, Krishna-Godavari, Konkan and Kutch offshore. ONGC, GAIL alonwith Directorate General of Hydrocarbons are involved in working the techno-economic feasibility.

Research work in Russia, USA & Japan is under progress to design safe, economical and environmentally acceptable process to exploit Gas Hydrates commercially.

## 2. Reduction in specific energy consumption :

There is shortage of energy sources in India. The country has to import huge quantity of oil and gas to meet its energy requirements. Because of limited availability, the prices of feed / fuel are much higher. Therefore, it is imperative for Indian Fertiliser Industry to reduce specific energy consumption to remain competitive. Various technological improvements have helped to reduce the Energy Consumption in the production of Ammonia Urea. IFFCO Kalol plant which was commissioned in 1975 was having designed energy consumption of 10.2 Gcal per tonnes of Ammonia. New technologies were incorporated time to time to modify the equipments and machinery. As a result even after 31 years of commissioning, the plant is operating continuously at more than 100% capacity utilization and energy consumption has reduced to a level of around 8.2 Gcal per tonnes of Ammonia. IFFCO has always endeavored to implement latest Energy Savings Schemes in its plants. Because of this, IFFCO plants are among the most efficient plant in India and even in the world. Some of the Energy Savings Schemes implemented by IFFCO are as below:

### a. Advanced CO2 removal system

Till 1990 most of the plants were having the Benefield CO2 removal system with full regeneration of all the solution in two parallel operating CO2 strippers. With the introduction of aMDEA technology with two stage CO2 removal the CO2 slip has reduced to 10~ 50 ppm from a level of 600-700 ppm in the Benefield system and also resulted in energy saving to the tune of 0.21 Gcal/MT.

### b. Process Condensate Stripper using MP process steam

This process eliminates the emissions to the atmosphere completely with the added benefit of process water, CO2 and Ammonia recovery into the system which yields energy saving as much as 0.06 Gcal/ton of ammonia

**c. Installation of Process Steam Superheater**

Conventionally the process steam Superheater was fired type. Replacing this with process steam Superheater eliminated environment emissions and energy savings to the tune of 0.024 Gcal/ton of ammonia is achieved. Operation flexibility is an added advantage of this scheme.

**d. Introduction of Mixed Feed and installation of Pre-reformer, Dual feed and fuel capability**

To provide flexibility in the feed stock and to overcome the limitations in NG supply Naphtha Pre-reformer was installed in Kalol Unit which was Gas based plant. Further, during expansion of Aonla-II Plant, Naphtha Pre-Reformer was installed to reform Naphtha to meet upto 50% of feed requirement. This provide flexibility to use Naphtha to supplement shortage of Gas.

**e. High Efficiency turbines for all critical drives**

In the last 20 years there has been huge improvement in the design technology of rotating machines. With the improvement in Technology the specific energy consumption for production of Ammonia has reduced considerably. To take advantage of new technology, various rotating machines of IFFCO have been modified / replaced.

**f. High efficiency catalysts**

Catalytic performance plays a vital role in the production of ammonia. In the past 20 years there has been marked improvement in Catalyst technology which has resulted in the reduction in specific energy consumption and increased service life of catalyst.

**g. Accelerated start up techniques**

With the improvement in the material of construction, the process and utility interconnections together with higher degree of most advanced control system has facilitated in the accelerated ammonia plant start-ups. This has time saving and in turn cost savings.

### h. Introduction of Distributed Control System

Initially the ammonia plants were based on Pneumatic based control system. The Introduction of new generation Distributed Control System the various parameters in the plant are being controlled efficiently. IFFCO has installed DCS system in all its plants including Kalol Unit which was commissioned in 1975.

### i. Addition of S-50 Converter

For energy reduction in the ammonia synthesis loop, installation of a HTAS S-50 ammonia synthesis converter with a lower heat exchanger and an internal electrical heater has resulted in the saving of around 0.13 Gcal/MT of Ammonia. The S-50 converter is located downstream the existing converter. The S-50 will increase the conversion and reduce the circulation and thereby the pressure drops in the loop. Savings are then seen on the power consumption of the synthesis gas compressor. Furthermore, it is foreseen to install a medium pressure waste heat boiler downstream the S-50 for utilization of the heat produced in the new converter.

The reason for choosing an MP steam boiler is to reduce the flow of HP steam to the extraction part of the synthesis gas compressor turbine along with the reduction in shaft power caused by the revamp schemes.

The above schemes have been implemented in almost all the ammonia plants of IFFCO and resulted in huge saving of energy.

## 3. Innovations expected in Existing Ammonia Plants

With the advancement of technology, the Specific Energy Consumption in modern ammonia plant has come down to around 7.0 Gcal per ton of Ammonia. Further research is being carried out to reduce the specific energy consumption and it is likely that with the implementation of new improvements, the energy will be reduced upto 6.5 Gcal per ton of Ammonia. Some of the improvements on which work is in advance stage are as below:

## a. Advanced Instrumentation, Computation and Control

- The use of Computational Flow dynamics (CFD) enable the study of complex fuel, flue gas and process gas flow patterns.

- Enabling advanced reactor and reformer designs as well as piping network design

- Technology is being improved to make the instrument control system of Ammonia Urea Plant wireless. The wire less instrumentation would eliminate the cumbersome CAPEX of cables, and will also eliminate various faults, which takes place due to problem in wiring from field to control panel.

- The Optical Fiber Cable (OFC) network today promises to give data updation speeds of upto 10 ~ 40 milli seconds, on a mega project having more than 10000 input/output parameters.

- Completely Integrated Control System (ICS) and emergency shutdown systems are already in place. This system has been installed in one of the largest fertilizer plant at OMIFCO. The scan time of the emergency shutdown system is considerably low in compare to the DCS system which has given in an efficient control system of Ammonia plant.

- The use of most advance LOPA (Layers of Protection Analysis) analysis and the application for the critical equipments control system with the help of Triple module redundancy has yielded very high reliability and availability of the critical machineries, resulting in high on stream efficiency for the operating units and better monitoring of the process.

- All the critical rotating equipments of Ammonia Plants are having online vibration monitoring system. The higher vibration readings are used to trip the rotating machines in order to save guard from any mechanical failures. Presently, a system has been developed by M/s Bentley Nevada which offers a complete package of most sophisticated online vibration analysis with self diagnostics and decision making tools which will not only save the critical machines from any major failures but also the accuracy of the system will result in less number of faulty trippings.

### b. The Primary Reformer

The future Primary Reformer is designed to eliminate to a large scale the CO2 emission caused by fuel firing, as such the reformer is being re-scaled and designed either as a auto thermal reactor (Topsoe and KBR) or as heat exchanger (Topsoe and KBR) using the heat of secondary reformer gases.

### c. Synthesis Loop

After the successful era of Casale and Topsoe low pressure converter modifications and the installation of add-in of S-50 and similar type, we are now on the threshold of new and advanced catalysts (the Amomax-10 and Ruthenium-Fe catalyst) which are presently in operation and claim to deliver more than 50 % extra catalyst activity.

### d. Burners

After the initial proven Dry-LO-NOx burners, the FLOX (flame less oxidation) type of burners is under development. In the Low-NOx burners internal flue gas recirculation is used to lower peak temperatures in flames. However, the rate of flue gas recirculation can only be increased to a certain value above which flame becomes unstable and eventually extinguishes. At wall temperatures $850^0$C together with an appropriate recalculating flow pattern, the flameless oxidation technique extends the limit for stable combustion to much higher recirculation rates. These burners are expected to emit still lower NOx as the conventional flame front is replaced by a diluted volumetric reaction zone, without temperature peaks. These types of burners shall be useful in Gas Turbines.

### e. Primary Reformer Tube

With the innovation in the metallurgy, there has been continuous improvement in the material of primary reformer tubes. After introduction of stabilized micro alloy (Ni and Ti stabilized), we are now moving to special Oxide Dispersion Stabilized (ODS) alloys with higher creep resistance. Apart from increasing the life of the tube, it has become possible to increase the primary reformer temperature thus helping to improve the reforming of the feed.

**f. Fuel cells as a source of electrical energy**

Fuel Cells are an electrochemical energy conversion device which produces electricity from an external supply of fuel an oxidant. In an ammonia urea plant, there is huge consumption of electricity to drive various rotating machines. The requirement of electricity is met by either Captive Power Plant or import from the grid. Further improvements in overall efficiency and reduction in capital cost is required to commercialize fuel cells in near future. With the development of this technology, fuel cells may replace the captive power plant in Ammonia/urea Plant.

## 4. FUTURE INNOVATIONS IN AMMONIA TECHNOLOGY

A lot of research and development are being carried out in the conventional technologies for the production of Ammonia. A number of new unconventional technologies are also being developed which are at different stages of research. With the development of these technologies, it is expected that specific energy consumption can be reduced upto 6.0 Gcal per ton of Ammonia.

### *4.1 Innovation in Conventional Technologies of Ammonia*

Today's state of art capacity of a world scale of ammonia plant is about 2000 mtpd.With the improvement of plant energy efficiency already reaching the optimum, at present the major thrust is to reduce the cost of plant by increasing the plant capacity. In the conventional ammonia processes and technologies there are certain constraints when capacities are increased beyond 2000 metric tons/ day. To overcome these constraints, Uhde has developed Dual Pressure Technology and Lurgi & Casale developed MEGAMMONIA Technology in which capital cost / ton of Ammonia has been reduced considerably.

### a. Uhde's Dual Pressure Ammonia Technology

Uhde first commercial ammonia plant got commissioned in the year 1928.In 2001 they presented Dual Pressure Process. Dual Pressure process focuses on the debottlenecking of the conventional synthesis loop. The main features and benefits of this process are as under:

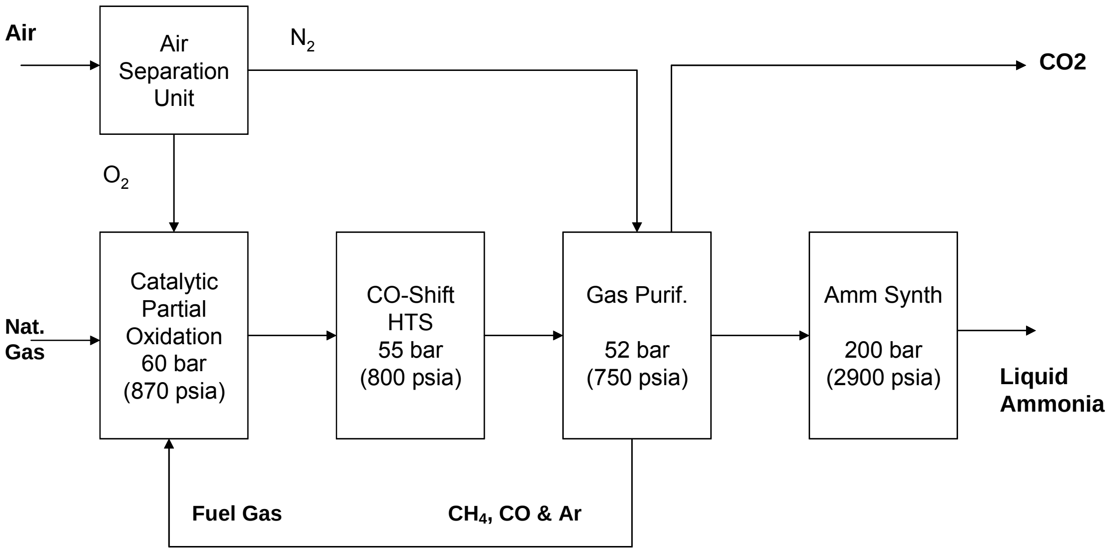
- A once through synthesis reactor has been introduced at an intermediate pressure level in syntheses gas loop. With this ammonia synthesis and separation takes place in between the compressor casing and the syntheses gas volume flow to the hi-pressure loop is significantly reduced and the production capacity can be raised by around 65% still using proven equipment. With the increase in capacity of the plant, the capital cost is reduced by 10% to 15%.

- The Hydrogen yield is superior
- Significant increase in plant capacity (+65%)
- Reduction of scale-up risk by use of referenced equipment
- Energy consumption decreased by 4%
- Specific production cost per ton of ammonia reduced considerably.

**b. MEGAMMONIA**

M/s Lurgi and M/s Ammonia Casale have jointly designed large scale Ammonia Plant MEGAMMONIA with the production capacities 1.4 million metric tons of ammonia/year which is ready for commercialization. The process comprises of five principal units:

1. Air Separation Unit (ASU)
2. Catalytic Partial Oxidation Unit (CPox)
3. CO-Shift Unit
4. Gas Purification Unit
5. Ammonia Synthesis Unit




In an ASU the pure Oxygen produced (95% oxygen) is used in the Auto thermal Reformer and a stream of 99.99% pure nitrogen for use in the Gas Purification Unit.

In the Catalytic Partial Oxidation Unit, feedstock natural gas is preheated and desulphrised in the conventional manner over a cobalt molybdenum catalyst followed by zinc oxide. The desulphrised gas is then saturated using condensate recycled from the CO-Shift Unit, preheated in a fired heater and pre-reformed over a nickel oxide catalyst so as to convert all higher hydrocarbons to hydrogen and methane. Steam is added to the pre-reformed gas to adjust the steam to carbon ration. The gas is further preheated in the fired heater, and then reformed to CO, H2 and CO2 in the CPox reactor by partial oxidation with oxygen.
The absence of a pressure limiting steam reformer makes it feasible to raise the pressure of the CPox Reactor to 60 bars.

Within the CO-shift unit, the reformed gas is passed over two beds in series of conventional HT catalyst to convert the remaining CO to H2 and CO2. Gas purification is accomplished in two wash columns, the first removing CO2 and the 2$^{nd}$ removing the remaining impurities i.e. CO, CH4 and Ar. CO2 is removed by absorption in cold methanol, CO, CH4 and Ar are removed by washing the Gas with liquid nitrogen. Pure synthesis gas comprising H2 and N2 is passed to the Ammonia synthesis unit which is of conventional design. The extremely high purity of the ammonia synthesis. gas results in higher conversion of gas per pass, lower circulator duty and lower refrigeration duty.

This new technology has got following major features:

- It will reduce the capital cost by approx 18-20% which will offset the perceived risk of investing in a new technology.
- The operating cost with this technology is expected to be lower by around 12-15% over the most advanced conventional technologies available.
- MEGAAMMONIA has the potential for greater environmental friendliness than the conventional ammonia process. The CO2 emission is expected to reduce by around 30% with this technology as compared to other conventional technologies.

## 4.2 Innovations in unconventional technologies in ammonia production

Apart from innovations in conventional technologies, a lot of research is being carried out to develop some unconventional technologies for the production of ammonia. A large research initiating has focused on developing environmental friendly, efficient and economical production of ammonia. Technologies are being developed to use renewable sources of energy like bio-mass, solar energy etc. Some of the technologies which are in the advance stage of research are as below:

### a. HYDROMAX TECHNOLOGY

In Hydromax technology, hydrogen is produced using either relatively cheaper fuel coal or using the inexpensive fuels like municipal waste and bio-mass. At present the technology is at advance stage of development and pilot plant is being set-up in Canada. However, it is expected that the estimated cost of production of Hydrogen with Hydromax technology will be approximately four times less than the conventional Steam Methane Reforming.

The Hydromax technology is a two-step process. First, steam contacts molten iron to form iron oxide and release hydrogen. Unlike conventional gasification this hydrogen is not co-mingled with carbon monoxide or other gases and separation costs are eliminated. In the second step, iron oxide is reduced back to pure metal by adding carbon, a typical metal smelting method. The only inputs are steam, oxygen and carbon. The outputs are hydrogen, steam, electricity and carbon dioxide. Iron is not consumed in the process and remains molten whether in a metal or oxide form.

The main benefits of this process are as under:

1. The only inputs are steam, oxygen & carbon.
2. Iron is not consumed in the process and remains molten.
3. The feedstock could be inexpensive such as coal, municipal waste, and biomass and petroleum coke.
4. The cost of production of H2 by Hydromax process is almost four times less than Steam Methane Reforming (SMR) production cost.
5. The emission of greenhouse gas by Hydromax is 34% less than SMR process.

## b. BIOMASS PYROLYSIS/GASIFICATION

Biomass like agricultural products, including hardwood, softwood and other plant specifies may be used to produce hydrogen either by direct gasification process or by pyrolysis to produce liquid bio-oil for reforming.

The direct biomass gasification is similar to coal gasification processes and takes place in three steps. In the first step the biomass is treated with steam in an oxygen-blown or air-blown gasifier to produce hydrocarbon gases, hydrogen, CO, CO2, tar and water vapor. The gasification step is followed by shift reaction and purification to produce. CO2 & H2.

Alternatively, the biomass can first be reformed to a liquid Bio-oil (liquid composed of oxygenated organics and water) in a process called Pyrolysis, which is a thermal decomposition of biomass carried out at 450-550 deg. C. The bio-oil produced is steam reformed at 750 – 850 deg. C and the CO produced is converted to CO2 in shift reaction.

Biomass gasification process is well researched. However, thrust is required to remove the bottlenecks in the process by improving the bio-mass feed preparation, non-catalytic bed additives and modifying reactor design parameters to enhance product selectivity and minimizing and amount CO produced during gasification.

## c. Aqueous Phase Reforming

In an ammonia plants major consumption of energy takes place in reforming process. To reduce the specific energy consumption in production of ammonia Aqueous Phase Reforming process is being developed. The major advantage of this process is that renewable bio-mass derived feed stock is used in place of fossil fuels for production of ammonia. This technology can be very useful for a country like India having shortage of fossil fuels.

Aqueous Phase Reforming (APR) produces hydrogen derived from compounds such as glycerol, sugars and sugar alcohols. APR is unique in that the reforming is done in the liquid phase. The process generates hydrogen without volatilizing water.

The aqueous solutions containing 10 wt% glucose is used which is converted to sorbitol which then reformed at around 220 deg. C. in a reforming reactor to $H_2$ and $CO_2$. A gas-liquid separator is used for the removal of high-pressure $H_2$-rich reformate gas.

The pilot project APR is being taken up. As per initial outcome it has got following benefits over the fossil fuel reforming:

- Capability to generate hydrogen from renewable biomass-derived feedstock.
- Capability to provide on-demand hydrogen with low capital requirements.
- Significantly lower operating temperatures (220 °C v 800 °C) enabling easier assimilation into heat sensitive environments.
- Ability to use conventional distribution infrastructure to deliver feedstock's with little or no safety concerns.
- Generation of 10 times more hydrogen per gram of catalyst than steam reforming processes.

## 5. Alternative technologies to source hydrogen

Hydrogen is one of the major constituent in the production of Ammonia. Out of the total world production of Hydrogen, 60% is being used for ammonia production, 24% for refining and desulphurization of oil and balance for production of Methanol and hydrogenation of fats. Presently, the Hydrogen being used for the production of Ammonia is produced after reforming the fossil fuels. Research is being carried out for production of hydrogen from alternate renewable sources which are at difference stages of development. Although, the cost of production of hydrogen from these alternative technologies might be higher at present compared to the conventional technologies, thrust should be given for development of these technologies. With the development of these technologies, not only cost of production will come down, but it will reduce dependence on non renewable energy sources and will also provide cleaner environment.

### a. High Temperature Electrolysis:

Electrolysis has been used in the past for the production of Hydrogen by splitting the water molecule using Electricity. This process was later abandon due to the higher cost of production because of high cost of electricity. With this, the cost of production of hydrogen is around three times compared to NG Reforming process.

In High-Temperature Electrolysis the cost of production reduces considerably as the energy required to break the water molecule decreases with the rise in temperature and the process efficiency increases. The cost of production arrived from a relatively smaller pilot stage units are higher; however, for a large unit with the centralized facility the cost of production may be comparable with the conventional technologies.

### b. Through Sulphur- Iodine Cycle

Sulphur-Iodine cycle is based on Thermo-Chemical reactions and require only external heat source to operate. In this cycle, iodine and sulphur dioxide are added to water, forming hydrogen iodide and sulphuric acid in an exothermic reaction. Under proper conditions, these compounds are immiscible and can be readily separated. The sulphuric acid can be decomposed at about 850 deg. C releasing the oxygen and recycling the sulphur-dioxide. The hydrogen iodide can be decomposed at about 350 deg.C, releasing the hydrogen and recycling the iodine.

The net reaction is the decomposition of water into hydrogen and oxygen. The whole process takes in only water and high temperature heat and releases only hydrogen, oxygen and low temperature heat. All reagents are recycling; there are literally no effluents.

The approximate cost of hydrogen will be around US$ 1.8 to 2.0 per kg of hydrogen while assuming a cost of natural gas of about US$ 6 per MMBTU the cost of hydrogen through steam reformation will be around US$ 1.40 per kg.

### c. Hydrogen from Solar Energy

The unconventional source of energy which is available in abundance is Solar Energy. This source of energy if tapped properly, may meet the whole requirement of energy of the world. On a clear day the amount of solar energy available at the Earth's surface is 1387 $W/m^2$. Taking into account the total surface area of the earth the total power reaching the earth is $1.77 \times 10^{17}$ W. As against this it is estimated that humans use only $12X10^{12}$ W of energy. Presently Solar energy is being used in a number of applications:

- Heat
- Electricity generation
- Desalination of Seawater

**(i)** Hydrogen can also be produced from Solar energy using special titanium oxide ceramics that harvest sunlight and split water to produce hydrogen fuel. As we have abundant sunlight and huge reserves of titanium this technology has got vast potential. This production technique is a clean process without producing harmful gases. However, as economic estimates are speculative due to the process being in the early research stage. To make the process economically viable, efforts have to be made for the development of the cost effective photo catalytic materials.

**(ii)** Photosynthesis in plants is based on Manganese atom within the photo synthesizes core. The precise geometry of this core is vital to the process breaking water into Hydrogen & Oxygen using Sunlight. The precise mechanism is recently discovered by British Scientists and would be utilized for artificial photo synthesizes for generation of Hydrogen using sunlight.

**(iii)** In photosynthetic hydrogen production, hydrogen in produced by the reduction H+ ions in an aqueous solution to H2 + certain type of green algae contributes to the reduction by producing the catalyst for reduction and also providing the electron source required for reduction. As the amount of hydrogen that can be produced depends upon the amount of sunlight penetration through the tank building algae.

Thrust is being given to remove the bottlenecks in the photosynthesis process to improve the efficiency and reduce the cost. With the cost saving from the more efficient photosynthesis process along with the refinements to the bio reactor design and genetically altering Algae could make this technology for hydrogen production from Algae competitive with other conventional methods.

### e. Hydrogen from Nuclear Energy

The Initiative is to demonstrate the economic, commercial-scale production of hydrogen using nuclear energy is being taken. If successful, this research could lead to a large-scale, emission-free, domestic hydrogen production capability to fuel a future hydrogen economy. Nuclear energy has the potential to efficiently produce large quantities of hydrogen without producing greenhouse gases and hence, to play a significant role in hydrogen production.

- **Thermo chemical Water Splitting**

High-temperature heat from an advanced nuclear system could be supplied to a hydrogen-producing thermo chemical or high-temperature electrolysis plant through an intermediate heat exchanger. Such an arrangement could provide high efficiency and avoid the use of carbon fuels.

Significant research and development (R&D) is required in order to complete a commercial-scale demonstration.

## VARIOUS INNOVATION IN UREA TECHNOLOGY

## SNAMPROGETTI UREA TECHNOLOGY

Fertilizer plants based on Snamprogetti Urea Technology came into operation in India in the early eighties. With the passage of time various innovations were carried out in order to reduce energy for Urea Production.

The various innovations in Snamprogetti Urea Technology which have been implemented in various fertilizer industries in the Indian sub-continent are as under:-

- **Installation of Pre-concentrator:-**

  Pre-concentrator is installed in Urea plants to recover the heat (energy) from Medium Pressure Decomposer off gases which is otherwise lost to the cooling water.

  In traditional Snamprogetti Urea plants, Medium Pressure Decomposer off-gases are cooled in Medium Pressure Condenser by using cooling water. To recover a part of this heat, Pre-concentrator is installed in which urea solution going to Evaporation Section is heated for increasing its concentration. With this modification, there is reduction in low-pressure steam used in $1^{st}$ Evaporator.

- **Installation of Pre-decomposer:-**

  In a typical Snamprogetti Urea plant that came up in late eighties, generation of low-pressure steam and its usage were almost balanced. With the installation of Pre-concentrator, low-pressure steam becomes surplus within the Urea plant battery limits. In order to utilize this low-pressure steam, Pre-decomposer is installed in the downstream of High Pressure Stripper (i.e. between Stripper and Medium Pressure Decomposer). With installation of Pre-decomposer, the medium-pressure steam requirement in the Medium Pressure Decomposer decreases which ultimately results in reduction in extraction steam flow from the $CO_2$ Compressor Turbine and hence, reduction in high-pressure steam flow to the turbine of the $CO_2$ Compressor.

**ENERGY SAVINGS:-**

0.09 Gcal per MT of Urea energy saving is estimated in the above modifications (i.e. Pre-concentrator & Pre-decomposer both) in a typical 2 x 1310 MTPD plant (having common Prilling and Waste Water Treatment facilities).

**TOYO ENGINEERING Corporation: ACES 21 Urea Process Technology**

Toyo Engineering Corporation (TEC), a global engineering contractor and urea process licensor, has licensed their technologies to ¼ of world Urea Production since 1961.TEC has completed R&D of its latest urea synthesis technology named ACES 21 in cooperation with PT Pupuk Sriwidjaja, Indonesia. The major features of this technology are as under:

1. It reduces the number of equipment in the Urea Synthesis loop to simplify the system which lessens the construction cost.
2. Installation of the Urea Reactor on the ground in CO2 stripping process.
3. 10% reduction in energy consumption with the optimization of synthesis section at lower operating pressure.

## STAMICARBON MEGA UREA PLANT

Ammonia licensors has developed single line ammonia plants with the capacities more than 2000 TPD.In conjunction with these dynamics in the ammonia world M/S Stamicarbon has developed a single line urea plant of 4500TPD. The process uses Pool reactor/Condenser technology. In Pool reactor/Condenser, condensation and reaction parts of Urea plant synthesis section is in a single vessel. The large pool reactor/condenser plants paves the way for a new 4500 TPD urea plant concept whereby the sizing of the high pressure equipment stays well within the manufacturing limits. To keep the high pressure stripper and the tube-bundle of the pool condenser within acceptable limits, the urea solution leaving the high pressure reactor is partly sent to a medium pressure recirculation add-on section. By applying the pool condenser concept, the great deal of the urea reaction takes place in pool condenser. This makes the required volume for the high pressure reactor medium sized.

The major advantages of this Mega urea plant are following:

- In MEGA plant a relative small high pressure stripper is used, a much higher turndown ratio (around 40%) is allowed in comparison with 60% of standard $CO_2$ stripping plant.
- The investment cost involved for a MEGA capacity concept is 70 to 75% as compared with the standard 2000 TPD Urea Plants.
- The high pressure steam consumption is considerably less in the MEGA Urea Plants.

The process is commercially proven and the process is being implemented at Stamicarbon parent company in the Netherlands.

## CONCLUSION:

The technologies for production of ammonia urea have come a long way. With the improvement in technology, the specific energy consumption vis-à-vis cost of production has reduced considerably over last two decades. Although, the conventional technologies are being improved continuously, but major thrust should be given for improvement of unconventional technologies which promises use of renewable source of energy and are environmental friendly. To improve these technologies, industry and educational institutions should join hands for the brighter future.