

Recent Efforts in Energy Conservation in Ammonia and Urea Plants

Ammonia and urea plants have improved their energy efficiency over the years. Improvement in energy efficiency is a result of concerted efforts of the industry by implementing various energy saving schemes and adopting efficient technologies for the new plants. The declining trend in weighted average energy consumption of ammonia and urea plants over the years is the testimony to these efforts. The weighted average energy consumption of all ammonia and urea plants in 2007-08 was reduced by about 30% from the level of 1987-88. The article reviews the development in ammonia and urea industry and the energy conservation efforts so far. The recent energy conservation efforts of the industry are covered in more detail.

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1.0 INTRODUCTION

INDIAN AMMONIA AND UREA INDUSTRY has been in existence for more than half a century. Initial period of development emphasized on indigenisation since foreign exchange was a scare commodity and also there was emphasis on self-reliance. The next phase of development witnessed the efforts for improving reliability and operating factors. Spiraling energy costs in the decade of 1970's shifted the attention to improvement in operating efficiency in the energy intensive industry. Energy is a major cost item in the cost of production of ammonia and urea and hence the efforts for energy conservation intensified in 1980's and continued to the present time. FAI has been monitoring the energy efficiency of ammonia and urea plants since mid-1980's. Status papers were published at regular intervals reviewing the energy conservation efforts of the industry and results obtained. Two of these reviews published were in 2003 (1) and 2006 (2). This paper traces the developments in ammonia and urea industry in brief from the old times and reviews the major efforts for energy conservation impacting the energy intensity of the industry. The most recent efforts of the industry in this area are covered in more detail.

2.0 DEVELOPMENT OF AMMONIA INDUSTRY

HISTORY OF DEVELOPMENT OF AMMONIA industry in the country runs parallel to the

development of fertiliser industry in India. Commercial production took off in 1951 with first large scale ammonia plant using coke oven gas as raw material. It was only after a decade that another ammonia plant came up in 1961 at Nangal using electrolysis of water as source of hydrogen. Major nitrogenous fertiliser products initially were ammonium sulphate and calcium ammonium nitrate. It was only in 1959 that first urea plant of 70 tonnes per day (tpd) based on once through process was commissioned at Sindri.

In the beginning, capacity of both the ammonia and urea plants was less than 500 tpd. These plants used turbo compressors for high pressure reactions. Capacity leap frogged with the advent of centrifugal compressors. A 600 tpd ammonia and matching urea capacity was the norm for several projects in India. Centrifugal compressors not only enabled large capacity in single stream, but also used waste heat of the plant in form of steam as motive force. This made a significant improvement in the energy efficiency of ammonia production. Subsequently developments in technology, catalysts and equipments allowed the capacity to increase to 900 and 1350 tpd. Industry is now operating a large number of ammonia plants with capacity of more than 1500 tpd and urea plants of almost 3000 tpd. The build of ammonia capacity in recent times is shown in **Table 1**.

Table 1 – Capacity build-up of ammonia plants (for selective years)

Year	Ammonia capacity(MMT)
1987-88	8.6
1990-91	10.0
1993-94	10.1
1996-97	11.3
1998-99	12.7
1999-00	12.0
2000-01	13.7
2002-03	13.4
2005-06	13.2
2006-07	13.2
2007-08	13.2

In the initial phase of development of the fertiliser industry world wide, energy efficiency was not a focus area in design of plants. This was due to the fact that energy in various forms viz. natural gas, naphtha, electricity, etc. was very inexpensive. However, then came the oil shock of the year 1973 when energy prices trebled in short time. Designers of the plant paid attention to the energy efficiency as a parameter in addition to the capital cost of the plant.

A few modern energy efficient ammonia plants were commissioned in 1984-85 with specific energy consumption figures close to 7.0 GCal/MT of ammonia. These plants of about 1000 tpd each included one at Court right, Ontario in Canada, Sluiskil in Netherlands and at Ludwigshafen in Germany. Large scale ammonia plants of 1350 tpd using gas as feedstock also came up in India around the same time. However,

energy consumption of these plants was higher than the plants mentioned above. This was due to the fact that Indian project owners wanted plants with proven technology and equipment. This was after the experience of poor performance of plants commissioned in 1970's with emphasis on experimentation in technology and indigenization of the equipment. Local environmental conditions (hot and humid) and configuration of plants also increases the energy consumption by 2-3%.

3.0 DEVELOPMENT OF UREA INDUSTRY

DEVELOPMENT OF UREA INDUSTRY RUNS parallel to build up of ammonia in the country. Urea being the main product for supply of nitrogen, urea plants were installed along with all ammonia plants with a few exceptions. First large scale (500 tpd) urea plant based on total recycle process was commissioned in 1966 at Neyveli. It was part of ammonia-urea complex using gasification of lignite as source of hydrogen for making ammonia. A number of plants with total recycle process were commissioned in the decade of 1970's. Stripping processes were developed by Stamicarbon and Snamprogetti. Most plants commissioned in 1980's and 1990's adopted Snamprogetti ammonia stripping process with lower steam and power consumption. These plants consumed steam and power equivalent to about 1.0 GCal/MT of urea compared to energy consumption of earlier total recycle plants equal to or higher than 1.5 GCal/MT of urea.

4.0 ENERGY CONSERVATION EFFORTS

IT IS EARLIER STATED THAT LATER generation plants were designed with low energy consumption in view of escalating energy prices in the 1970's. However, older plants needed to modernize and reduce energy consumption to remain competitive. Continuous developments in process technology, catalyst and design and materials of construction of

equipments offered opportunity to all existing plants old and new to improve energy efficiency. Therefore, revamp/ retrofit/replacement measures were implemented as an ongoing exercise.

4.1 Energy Conservation Efforts in Ammonia Plants

4.1.1 Phase I (1980's)

Production of ammonia is the most technologically complex and energy intensive process. Ammonia production takes about 80% of total energy required for production of urea and other fertilisers. Hence, there has always been sharp focus on the energy conservation efforts in ammonia plants. The first phase of energy conservation measures in 1980's included installation of Purge Gas Recovery Unit (PGRU) for recovery of hydrogen from the purge gas. All these units were based on cryogenic separation of hydrogen which was recycled back to the synthesis loop. Till then, the purge gas was burnt as fuel in the reformer. This measure alone reduced specific energy consumption by 0.15-0.25 GCal/MT of ammonia.

The second most significant development was availability of reformed tubes of better metallurgy than that of HK-40 or equivalent used in most reformers. The new metallurgy like IN519 had higher strength and it was possible to use thinner wall tubes for the same operating condition of temperature in the reformer. This allowed larger inner space for packing of catalyst and hence higher throughput. This not only increased the reformer capacity but also helped to save energy consumption.

Other measures included use of solvent promoters in CO₂ removal section, more heat recovery in the convection zone of reformer furnace, etc.

4.1.2 Phase II (1990's)

In reformer section, while change to better metallurgy of reformer tubes

continued even in 1990's in various units, there was renewed emphasis on recovery of additional waste heat from the off-gases of reformer furnace. The temperature of off-gases was brought down to as low as 150-160°C from more than 200°C earlier in the relatively new plants. Along with other heat integration steps in the ammonia plant, these steps reduced energy consumption by 0.1-0.2 GCal/MT of ammonia. There was also revamp of CO₂ removal system by way of change to better solvent, better packing in absorption and desorption towers for higher mass transfer efficiency. For example, in one of the units, energy consumption was reduced from 36,000 KCal/Mol CO₂ to 26,000 Kcal/Mol CO₂ with change of solvent from ammine to MDEA.

The next generation efforts in energy conservation included a number of significant measures. The highlight of these efforts were change of internals of synthesis converter in old plants from axial flow to radial-axial or radial flow which allowed the use of more active catalyst of finer particle size without increasing the pressure drop through the reactor. This in turn resulted in increase in conversion per pass and thus reducing the energy consumption in recycle of synthesis gas. This measure alone saved 0.20-0.25 GCal/MT of ammonia.

Almost all ammonia and urea units changed from analog to digital instrumentation with screen based controls. Installation of Distributed Control Systems (DCS) and Programmable Logic Controllers (PLC) became the norm in the decade of 1990's. Ammonia plants designed for 8.0-8.2 GCal brought down their energy consumption to 7.7-7.8 GCal/MT ammonia.

Major energy conservation measures implemented in the decades of 1980's and 90's helped to bring down the energy consumption in existing plants. **Table 2** shows the level of energy consumption of ammonia plants in 1987-88 and than of the same plants in 1999-2000. Further improvement in energy efficiency in the

existing plants is possible only in small increments.

Feedstock	1987-88	1999-2000
Gas	9.96	9.60
Naphtha	12.26	10.56
Fuel oil	13.92	13.71
Total	11.70	11.31

4.1.3 Phase III (2000 onwards)

Energy prices witnessed a steep climb during last 5-6 years. At the same time cost of revamp and retrofit measures have also increased multifold during last decade or so. Increasing cost and lack of incentives in the pricing policy in general slowed the investment in debottlenecking and energy saving schemes. Nevertheless, improvement continued to occur with technical innovations in operation and maintenance and projects with small investment. However, there are a few units which made large investment in energy saving projects with significant energy saving.

Low Temperature Shift (LTS) guard with additional heat recovery to preheat boiler feed water helped to reduce CO slip from 0.20 to 0.10 % mole percent at the exit of LTS convertor resulting in energy saving of order of 0.02 GCal/MT in a number of units. In carbon dioxide removal section, change from single to two stage regeneration allowed better heat integration. Changing of single stage flash vessel system in regenerator section with 5-stage flash vessel with ejectors including a mechanical steam compressor was carried out by another unit. One of the units has also installed hydraulic turbine to recover energy from high pressure process gas in a recent revamp.

There have also been some process modifications in the synthesis loop. Installation of S-50 converter with MP waste heat boiler is reported to have given energy saving of the order of 0.13 GCal/MT. Additional converter has increased conversion from 14% to 19% resulting in saving in recycle energy. Similarly one of the units has installed S-300 converter with energy saving of 0.34 GCal/MT.

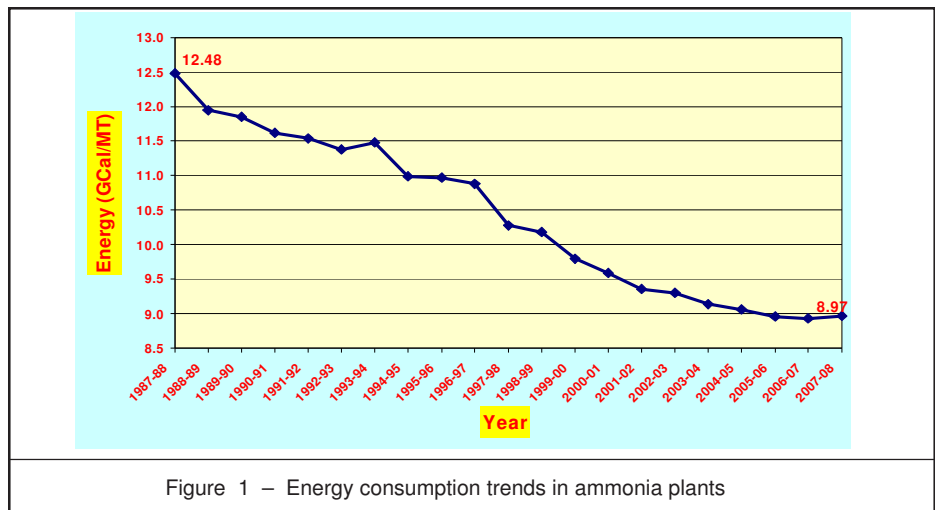


Figure 1 – Energy consumption trends in ammonia plants

Liquid ammonia wash of synthesis gas has helped to remove impurities of CO₂ and moisture. Discharge from synthesis gas compressor was originally going to 1st stage ammonia separator via chillers and then to convertor. After additional purification, it is going directly to the convertor and thus saving energy in chillers. In a separate measure in some units, chilling of make up synthesis gas has helped to save the compression energy in the synthesis compressor.

There are numerous small measures implemented by a large number of plants. For example, even feed gas saturation with process condensate has helped to conserve energy. Most plants are operating with the DCS and take full advantage of automation. A number of units have installed Advanced Process Control (APC). While energy savings are small of the order of 0.05-0.1 GCal/MT ammonia, operation of plant becomes very smooth with control of most operating parameters within the narrow range. APC also enables the optimization of plant operation to minimize energy consumption and / or maximize production. The result of recent energy conservation efforts are shown in **Table 3**.

Company	Savings GCal/MT of ammonia	Percentage improvement (%)
A	0.837	9
B	2.26	> 20
C	0.255	> 3

As a result of the energy conservation efforts of the industry and addition of capacity through more efficient plants, the weighted average ammonia energy consumption of ammonia plant was reduced from 12.48 GCal/MT in 1987-88 to 8.97 in 2007-08. The best plant achieved energy consumption of 7.70 GCal/MT of ammonia during 2006-07. **Table 4** gives the feedstockwise energy consumption of ammonia plants during 2007-08. **Figure 1** shows the trends in energy consumption of ammonia plants over a period of 20 years.

Feedstock	Production (MMT)	Energy consumption (GCal/MT)
Gas	9.86	8.49
Naphtha	0.94	9.85
Fuel Oil	1.43	11.72
Overall	12.24	8.97

4.2 Energy Conservation Efforts in Urea Plants

Urea reactor has been revamped by almost all units by replacement of old trays with hydro-dynamically more efficient trays. This measure improved conversion in the reactor. Installation of vacuum pre-concentrator and pre-decomposer helped to reduce energy consumption and improve product quality in a number of units. Installation of pre-concentrator reduced the heat load on the first stage evaporator resulting in steam saving. Pre-decomposer reduced the load of stripper

and MP/LP sections improving reliability of these equipments. In one of the units commissioned in 1984-85, a saving of 120 kg/MT urea was realised in all the four streams. In a 1981 plant, 200 kg LP steam/MT was saved with installation of pre-concentrator. In the same plant replacement of urea old stripper with new bimetallic stripper resulted in saving of 0.05 MT steam/MT. In yet another unit of 1984 vintage, vacuum pre-concentrator, MP pre-decomposer, additional trays in urea reactor, steam booster ejector for utilisation of surplus LP steam in MP decomposer and new bimetallic stripper saved 120 kg/MT of steam.

Carbon dioxide compressor is major energy consumer in urea plants. Refurbishing the compressor with better design impellers and change of motor has improved the efficiency of compressors. Similarly revamp / refurbishing of turbines helped to reduce the consumption of steam. A few units have replaced the turbine and / or compressor for large energy savings and improvement in reliability.

Change of cooling tower fans, replacement of insulation, steam trap management, etc. have helped to save energy. A number of units have modified internals of pumps (e.g. trimming of impeller) to match the load and reduce the steam / power consumption. Installation of more efficient impellers also reduced the steam consumption. For smaller duty pumps (1 MW) motor drives are more efficient than steam drives. Wherever, there are both types of drives (including stand by), mere operational changes has saved energy. Elsewhere, even replacement of drives has been found to be an attractive measure. There has been emphasis in recent years to save energy in various pumps by way of modification of pumps to improve efficiency to optimize their operation to reduce energy consumption. Changes in operational philosophy and minor changes in hardware are also helpful. One of the units has installed a small booster cooling water pump and now run only 3 regular pumps along with a booster pump instead of running 4 regular pumps.

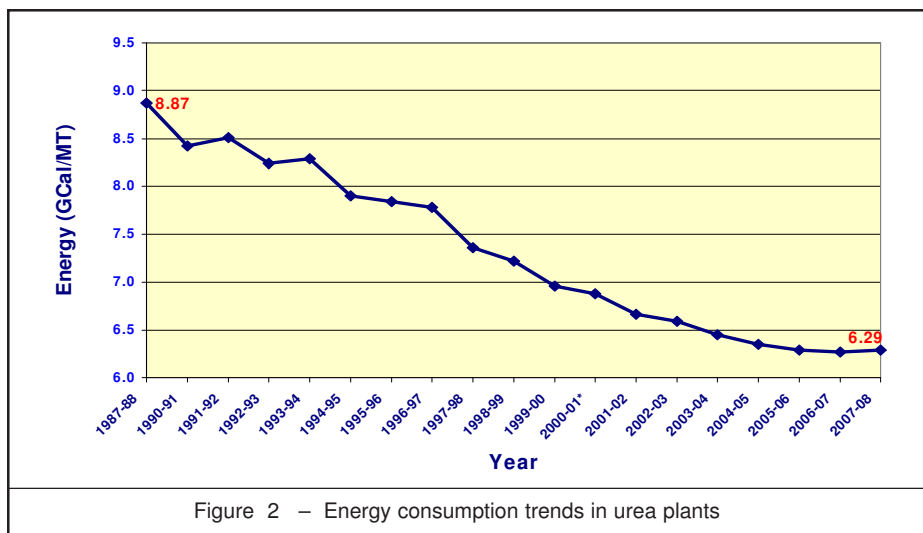


Figure 2 - Energy consumption trends in urea plants

The weighted average energy consumption of the urea plants in the country for the year 2007-08 is given in **Table 5**. The best plant achieved energy consumption of 5.16 GCal/MT urea for the year 2007-08. **Figure 2** shows the trend in energy consumption of urea plants reflecting about 30% improvement in energy over a 20-year period.

Feedstock	Production (MMT)	Energy consumption (GCal/MT)
Gas	16.12	5.97
Naphtha	1.60	7.17
Fuel Oil	2.17	7.99
Overall	19.89	6.29

5.0 FUTURE DEVELOPMENTS

THE PLANTS WOULD CONTINUE TO CARRY out the measures to improve their efficiencies. Revamp and retrofit measures are under implementation in a number of units. According to an estimate the demand for urea production is expected to reach 28.8 million tonnes by 2011-12 i.e. a short fall of about 2.8 million tonnes from the 2007-08 production level. Part of the demand would be met by de-bottlenecking the present capacities and the rest to be met by expansion and greenfield projects. The de-bottlenecking projects are expected to be bundled with energy efficiency schemes. One of the companies has already implemented the energy saving schemes in all its units to improve energy efficiency as well as increase in

capacity. New projects would be based on the most efficient process technologies. Further, fuel oil based plants accounts for about 10% ammonia production capacity. These plants are expected to convert to gas in near future. This will improve the energy efficiency of these plants significantly

6.0 CONCLUSION

AMMONIA AND UREA INDUSTRY HAS COME a long way in terms of capacity expansion and improvement in energy efficiency. Modernization of old plants and installation of new plants with better feedstock and technology have helped to reduce the energy intensity of the industry. The energy consumption was reduced from 12.48 GCal/MT in 1987-88 to 8.97 GCal/MT in 2007-08 for ammonia plants. For the same period the energy consumption of urea plants came down from 8.87 GCal/MT (1987-88) to 6.29 GCal/MT (2007-08). Revamp and retrofit projects are under way in a number of units. This alongwith conversion of non-gas plants to gas would help to further increase the efficiency of this energy intensive segment of the fertiliser sector.

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