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Energy Efficiency and Productivity Improvement in Indian Fertiliser Plants

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India stands at the second largest producer of nitrogenous and complex fertilisers in the World. The major fertilisers produced in India include urea, di-ammonium phosphate (DAP), NP/NPK Complex fertilisers and single super phosphate. Urea is the most produced fertiliser and consumed in the country. During 2024-25, 30.64 million metric tonne (million MT) urea was produced against a production of about 52.0 million MT of total fertiliser products. During the year, production of DAP, NP/NPK complexes, SSP and other fertilisers was 3.77, 11.34, 5.24 and 1.01 million MT, respectively. There has been significant improvement in the fertiliser production over the years. Capacity of urea plants increased from 0.02 million MT in 1960s to 21.1 million MT in 2000. The plants underwent series of revamp exercise from time-to-time to increase the capacity. As a result of such debottlenecking exercise, urea capacity increased by 4.0 million MT in the last one a half decade. Post 2019, commissioning of six new urea plants further augmented the production capacity by 7.6 million MT to reach 31.3 million MT in 2023-24. However, there were some reductions in production due to closure of two plants in mid-2023. The DAP and NP/NPK product capacity is around 16.2 million MT while that of SSP is 12.8 million MT. In terms of P_2O_5, capacity is 7.5 million MT in 2023-24 but capacity utilization was only 66.7%.

Productivity refers to maximizing output while minimizing resource input and downtime. Higher productivity ensures that the plants meet increasing demand of fertilisers while optimizing resources. Urea accounts for 95% of the energy intensity in the fertiliser sector. Ammonia synthesis phase, which forms the basis for urea and other nitrogen-containing fertilisers, consumes about 80% of energy as its uses fossil resources as feedstock and fuel. Hence, the foundational elements of energy efficiency in urea production is the optimization of the ammonia production process. Ammonia production process is the net generator of waste heat due to exothermic reactions. The key to enhance the energy efficiency is to effectively utilise the waste heat within the plant for pre-heating of process streams, feedstock, process air, boiler feed water, etc.

Ammonia and corresponding urea production in India had a modest start with small sized multi-stream plants and variety of feedstock like natural gas, naphtha, fuel oil and coal. As the technology developed, capacity moves to larger size, single stream plants with in-built high-energy efficiency features. These plants were commissioned during late 1980s and 1990s, having capacity of 1350 MTPD ammonia and 2200 MTPD urea. These plants expanded their capacities through debottlenecking to more than 2000 MTPD ammonia and more than 3000 MTPD urea. The latest plants commissioned after 2019 are having ammonia and urea capacity of 2200 MTPD and 3850 MTPD, respectively. Two coal-based plants were closed down in 1998 and other ammonia-urea plants based on naphtha and fuel oil switched over to natural gas under the directive of pricing policy. The older plants reduced the energy efficiency gap by retrofit and revamp of the plants from time-to-time with better catalysts, improved heat exchanger designs, high-efficiency burners in reformer, use of low-level waste heat in vapour absorption machines and retrofits of compressors, turbines & pumps. The power supply and electrical system is also an important element of operation. Modernization and upgradation of electrical equipment and systems provide flexibility, reliability and safety of electrical networks. Furthermore, integration of process simulation and real-time optimization tools enabled plant operators to continually monitor performance and optimise the plant operation and energy input. Conversion to natural gas and energy conservation

Fertiliser plants reduced the efficiency gap by retrofit and revamp of the plants from time to time and achieved a very high level of efficiency comparable to the best plants in the world

efforts resulted in improvement in energy efficiency and reduction in emissions of carbon dioxide.

Energy efficiency gains in ammonia plants reflect directly in the urea energy consumption. Urea plants also made interventions to reduce steam and power consumption needed to convert ammonia to urea. The prominent measures such as increasing efficiency of urea reactor by replacement of old designed trays with better design high efficiency trays, introduction of additional trays, additional stages for decomposition, concentration and pre-heating of ammonia were invariably adopted by all plants. The new plants adopted such features at the design stage itself. The weighted average energy consumption of ammonia plants improved from 12.87 Gcal MT^{-1} in 1987-88 to 7.76 Gcal MT^{-1} ammonia in 2023-24. The energy efficiency of old plants has improved significantly. The weighted average energy efficiency of urea plants improved from 8.87 Gcal MT^{-1} to 5.71 Gcal MT^{-1} urea during the corresponding period. This also resulted in reduction in generation of carbon dioxide emissions from ammonia plants from 3.6 MT MT^{-1} in 1987-88 to 1.9 MT MT^{-1} ammonia in 2023-24. Considering the carbon dioxide used for making urea, the net emissions from integrated ammonia and urea plants is estimated to be about 0.6 MT MT^{-1} urea during 2023-24.

Phosphatic and potassic (P&K) fertiliser plants are highly dependent on import of raw materials and intermediates like rock phosphate, sulphur, ammonia, sulphuric acid and phosphoric acid. The productivity of this sector is impacted by the availability and pricing of raw materials & intermediates in the international market. Dependency on import often affects quality of raw materials and intermediates, which in turn affects operations of complex fertiliser plants. Sulphuric acid, used for production of phosphoric acid, is the power house for complex fertiliser plants. The exothermic heat of sulphuric acid is utilized to produce electricity, which helped in replacing use of coal as a fuel for generation of power; thus reducing GHG emission. The productivity of phosphatic fertiliser plants are determined by use efficiency of raw materials. Most of the complex fertiliser plants as a result of process optimization and improved scrubbing systems are able to improve the nitrogen recovery efficiency and P_2O_5 recovery efficiency from the level of 93-94% in 1990s to more than 99% at present.

Energy audit is an essential tool for identifying inefficiencies and benchmarking performance against best-in-class standards. The audit helps in uncovering hidden losses, such as leakages in steam systems, sub-optimal performance of equipment or over-design in pumping and compression systems. Based on audit findings, plants can implement energy conservation measures that yield measurable improvements. Energy management systems and certification schemes such as ISO 50001 provide a structured approach to monitoring, analysing, and improving energy performance on a continuous basis. Most of the major energy intensive fertiliser plants have implemented energy management systems along with other environment management systems for quality, environment and safety.

The efforts of the industry resulted in a very high level of efficiency comparable to the best plants in the world. The plants of all vintages have carried out modifications to improve the efficiency and productivity. The technology suppliers are also assessing the plant performance and proposing schemes to improve efficiency of fertiliser plants. Industry is also exploring such options to further improving efficiency.

The Technology Special Issue covers 8 articles from fertiliser plants and a leading technology supplier sharing experience of improvement in urea, acids and complex fertiliser plants. Article reviewing the industry performance over last four decades is also included. We hope that the readers would find the Journal useful and a valuable reference material. ■