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Reliability of Static Equipment in Fertilizer Plants

Production of fertilizers involves processing, handling and storage of hazardous chemicals like sulphur, ammonia, sulphuric acid, nitric acid, phosphoric acid and other hazardous chemicals. Plants also operate under extreme condition of temperature and pressure. Health and integrity of equipment both static and rotating ones are extremely important for safety of man and materials. It is also important that all plant and machinery are maintained in healthy conditions because fertilizer plants operate continuously 365 days a year. The static equipment like reactors, heat exchangers, boilers, storage tanks, valves, piping, etc. are critical to continuous operation. Plant managements monitor the health of equipment even during operation with non-destructive testing techniques (NDT). Similarly, condition of critical equipment is assessed during maintenance shutdown of plants. Maintenance is carried out by repair or replacement based on condition of the equipment without waiting for the breakdown. Forced shutdown of the plants due to failure of any equipment results in huge loss of production and costly repair/replacement. Unhealthy equipment can also result in leak of hazardous chemicals both gas and liquid, fire and explosion. Therefore, it is extremely important that problem is predicted before it occurs. It is done with sophisticated monitoring and analytical tools available to plant operators.

The fertilizer production processes involve reactions that are both endothermic and exothermic in nature. Heat for endothermic reactions is supplied by burning of fossil fuels. Waste heat from flue gases and exothermic reactions is utilized to generate either steam or preheat process gas or air. A number of heat exchangers are used to recover this heat. In addition, boilers are used to generate steam for power generation or supplement process steam. In ammonia plant, waste heat in flue gases in reformer is recovered in convection section with a number of heat exchangers to pre-heat process air, feed gas, or boiler feed water. The reformed gas boiler in ammonia plant is used to recover waste heat from process gas available at 950-1000 ^{o}C from exit of secondary reformer and generate high pressure (HP) steam. The HP steam is used to drive large and critical air and synthesis gas compressors. The operation of reformed gas boiler, therefore, is vital for running of these compressors and hence the ammonia plant. There were incidents when ammonia plants had to take forced shutdown due to failures of RG boilers. The production of ammonia from nitrogen and hydrogen is an exothermic reaction and synthesis loop boiler is employed to generate medium or high pressure steam. It is the critical equipment in the synthesis section of ammonia plant. The waste heat is also available in the process gas at the exit of shift reactor and methanator which is recovered in form of medium pressure steam or to provide heat to inlet process gas stream. Similarly, in sulphuric acid production exothermic reactions take place and heat exchangers are employed to recover the heat to generate HP steam. All the boilers and heat exchangers are susceptible to creep failure, corrosion, fatigue, overheating, tube rupture, hydrogen attack, etc. The reliability of exchangers has been improved by changing material of construction(MOC) from carbon/alloy steels to duplex stainless steel having better corrosion resistance for cooling water.

Primary reformer is the most capital and energy intensive equipment in an ammonia plant. The endothermic reaction takes place in the catalyst filled tubes in temperature 750-850 ^{o}C and pressure of about 40 kg cm^{-2}. Reformer tubes are subject to high temperature, stress, thermal shocks, internal carburization due to process upset, localized overheating, metal dusting or metallurgical degradation. These may result in creep failure, stress corrosion cracking and deformation of reformer tubes. Developments in MOC have helped in improving properties of the tubes to withstand high thermal stress. Life of reformer tubes is also a direct function of operating conditions. Operation of reformer at milder temperature than design can also help in improving its life. Monitoring skin temperature of reformer tubes during operation and measuring thickness of tubes regularly using NDT like H-Scan help in assessing the health and residual life of reformer tubes.

Ammonia converter is another critical equipment in which reaction to convert hydrogen and nitrogen to ammonia takes place at temperature of 450-500 ^{o}C and pressure of 140 to 250 kg cm^{-2}. The converter is prone to internal failures, hydrogen embrittlement and nitriding. The developments in design of internals of converter from single bed to multi-bed and axial

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flow to axial-radial or radial flow have helped in reducing the operating pressure and allowed introduction of smaller size catalysts for higher conversion. Installation of an additional converter also helped to improve the conversion and reduce pressure in synthesis loop. Reliability issue of these converters was solved by modifying their design from hot wall to cold wall.

Corrosion is one of the critical factors affecting the reliability of equipment. Handling of corrosive materials such as ammonium carbamate an intermediate compound produced during production of urea severely affects the life of equipment in urea plants. In spite of precautions such as use of passivation air and special materials, rectors, strippers, decomposers, pipelines etc. which come in contact with carbamate solution are susceptible to corrosion. The corrosion attack is more severe in reactor and stripper which operate at higher temperature. A number of plants have faced leakage problem due to corrosion in reactor and stripper. Reactor liner gets eroded and plants have to often replace the complete liner. Sometimes, leakages have been experienced even after repair work. Therefore, repair and maintenance procedures and workmanship are critical for better results. Leak detection test after repair is essential to ensure that there is no leakage. Some technology suppliers are also providing online leak detection system for reactors. Use of such a system during operation may help in attending to the very small defects before it become severe and affect reliability of the plant. There have been developments in MOC of stripper such as bimetallic or proprietary materials that offer better corrosion resistance. Plants have extended the life of the existing strippers by reversal of stripper after a few years of operation. Shortening of stripper has also been carried out by a plant to improve reliability and save capital investment in a new equipment.

Production of complex fertilizers involves reactions of sulphuric acid, phosphoric, sulphuric and nitric acids with rock phosphate and ammonia. These plants are also prone to corrosion and erosion of material. The equipment needing special attention in sulphuric acid plant are reactor, intermediate and final absorption towers and drying towers. The critical equipment in phosphoric acid plant include digester, flash cooler, recycle acid tank, scrubber and vacuum cooler. These are lined with special and rubber materials to improve the corrosion resistance. The corrosion under insulation is one of the important factors affecting the life of equipment and pipelines. Seepage or damage in insulation may pose threat to safety of plant and manpower. The storage tanks for ammonia and acids and underground pipelines need to be inspected periodically for integrity of insulation.

Reliability of static equipment is dependent on various factors such as design, metallurgy, operating condition, maintenance and inspection practices. The MOC of the equipment is selected based on the process parameters and characteristic of fluid. The design of any equipment takes into account the operating conditions. However, actual operating conditions may differ from design consideration due to process upset or unforeseen shutdown which affects the life of the equipment. Feedback from operation has helped in modifications in design and development of new MOC. Critical process equipment such as pressure vessels and heat exchangers need to be periodically inspected to monitor their condition and to assess their life. There are number of static equipment and pipelines which cannot be inspected on regular basis due to time and resource constraints. A risk based inspection (RBI) plan can help in identifying critical equipment based on its operating condition and past history. Time table for inspection and maintenance can be drawn accordingly. Further, RBI plan can be integrated with process safety management system for improving health and safety of the plant and equipment.

While on the subject, it may be underlined that ensuring reliability and safety of operation requires both revenue and capital expenditure. Inadequate compensation for fixed cost under urea pricing policy does not augur well for the continuous efforts of the industry for reliable and efficient operation.

In view of the importance of health of the static equipment in uninterrupted operation of fertilizer plants, there are continuous improvements in operation, inspection and maintenance practices to ensure a very high degree of safety and reliability. Continuous safe and efficient operation of fertilizer plants in India are testimony to the efforts of the industry. We organize several activities including training programmes, group discussions and workshops in the areas of operation and maintenance of fertilizer plants to bring the information on latest developments in these areas. This is another effort in this direction by devoting entire issue to the subject of reliability of static equipment. Special issue documents the recent efforts made by the fertilizer plants in this area. We hope that all those engaged in design, operation, maintenance and problem diagnosis of fertilizer plant & equipment will find the content of the issue useful. ■