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Tel. +33 1 53 93 05 00 - Fax +33 1 53 93 05 45/47 - ifa@fertilizer.org - www.fertilizer.org

LIFE EXTENSION OF A VINTAGE PLANT THROUGH RELIABILITY IMPROVEMENT SYSTEMS (a)

Babu K. Verghese*, V.Jayaraman** and S. Muruganandam***
Southern Petrochemical Industries Corporation Ltd., Tamil Nadu, India

1. Abstract

The plants at the Fertilizer Complex of Southern Petrochemical Industries Corporation Limited, Tuticorin were commissioned in 1975 and running at their best efficiency to date. The company has adopted many methods to improve the plant reliability, safety and environment performance and energy and water conservation. Technology up-gradation, Condition monitoring of equipment, vigilance system, performance monitoring of running equipment, catalyst and heat exchangers, up-gradation of support system like instrumentation and electrical systems, standard operation procedures, Adoption of international standards for quality, safety and environment, technical and management training to the employees, total employee involvement in various functional areas are some of the systems adopted in the Fertilizer Complex to achieve reliability and efficient production in its 3 decades of operation.

2. Introduction

In recent years, the constant dilemma for many producers has been whether to shut down older capacity or revamp it to improve and extend its operating life. This is no easy matter. With a new large-scale plant costing several hundred million dollars, new investments are not taken on lightly. Energy prices themselves have risen, and account for a much greater proportion of manufacturing costs than before.

Many older plants have in fact been closed down, but equally, many others have been successfully operated. In the right circumstances, even very old plants have been kept in profitable operation by a series of reliability improvement measures and modernisation.

The life of the plant equipment and machinery depend upon the operational conditions to which they are subjected to during their course of operation. A proper care and control during the normal operation and reduction in the shocks caused to the plant can substantially improve the life of the plant. During normal operation of the plant, adequate monitoring is to be available to ensure that the equipment and machinery are running with in their specified condition.

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* Managing Director
**Executive Director (site)
*** Chief manager (Operations)
Email : pon_muruga@vsnl.net or muruganandam@spicttn.com
(a) received on: 01/07/02

3. About Southpetro

Southern Petrochemical Industries Corporation Limited is the largest South Indian business congrolomerate and has been operating a fertilizer complex at Tuticorin, India, since 1975. The complex has the following production facilities.

Ammonia	1100 TPD
Urea	1600 TPD
Sulphuric acid	470 TPD
Phosphoric acid	165 TPD
Di-ammonium phosphate	1350 TPD
Aluminium fluoride	8 TPD

4. Plant Equipment Monitoring

Vigilance is an important function in a process plant from the standpoint of ensuring plant reliability, personnel safety and optimization of operating cost. The method of monitoring various parameters at a pre-determined frequency has been well established in SPIC and rigorously followed. The process parameters are monitored through various instruments available in the plant and the analyses done in the laboratory. The condition monitoring of the rotary and static equipment is done through various inspection methods available. The inspection activities generally fall in the categories such as on stream inspection and shut down inspection.

4.1 Plant Online Inspection

4.1.1 Look Listen Feel Technique

The base level inspection method is known as "LOOK-LISTEN-FEEL" monitoring. This method is meant for identifying the defects visually, on observing the noise and by feeling the equipment. The abnormalities such as high bearing temperature, vibration, and leakage are identified by the plant operator and rectified at once.

4.1.2 Vibration analysis

The vibration level of any rotary equipment is a direct indication of the condition of the equipment. For all high power compressors and turbines vibration monitoring is being carried out continuously online and latest software is used to continuously record the vibration and analyse it whenever there is a need. The other equipments are classified based on their criticality and the frequency of measurement of vibration is decided . Accordingly, daily, weekly and monthly vibration measurement schedule is drawn. The vibration data is continuously fed into the computer and trend monitoring is being done. For equipments to which vibration trend monitoring indicates an abnormal condition, vibration analysis is carried out using portable vibration analyser. Such vibration analysis helps in identifying the actual reason for vibration such as unbalance, mechanical looseness, misalignment, defective bearing, cavitations, flow turbulence and bent shaft. Since introduction of the vibration analysis programme, there has been no major equipment break down. All the equipment problems are identified at very early stage and the corrective actions are taken.

4.1.3 Temperature monitoring

Monitoring the temperature of various equipments and their parts can give ample information on the condition of the equipments. The bearing temperature of high capacity turbines, compressors and pumps are provided with temperature indicators having alarm facility. The refractory lined vessels are likely to develop hot spot, which are identified very early by routine measurement of temperature and the required corrective actions are taken. The areas, which are not accessible easily, are scanned using infrared thermometer and the surface temperature is monitored. The surface temperature of the vessels operating below atmospheric temperature and lined with cold insulation is monitored through the thermo-graphic survey and the cold spots are located. These are the spots with poor insulation quality and susceptible for corrosion due to moisture condensation. Strengthening of the insulation eliminates these cold spots.

Electrical equipments and transformers having short-circuiting or local heating up of joints may fail. To identify such areas temperature measurement using infrared thermometer and thermo graphic survey are conducted at periodic intervals.

4.2 Preventive Maintenance Programme

The rotary equipments are scheduled to undergo the preventive maintenance programme, which is based on the past experience. The programme contains the various inspection points for a particular equipment and the periodicity. The preventive maintenance schedule is part of the computerised on line maintenance system and the schedule is automatically generated. Emphasis is given to attend all the jobs as per the preventive maintenance schedule and any default is looked into as serious violation. The electrical modules and motors are also covered under the preventive maintenance programme.

4.3 Engineering Survey

The preventive maintenance, predictive maintenance, condition monitoring and inspection programmes are carried out for all rotary and major stationery equipments in a systematic manner. However, there are large number of stationery equipments, piping and structures in the plant, which are not covered by the above maintenance/inspection programmes. These equipments are inspected and all the abnormalities observed are given in a report called as Engineering Survey, along with the recommended corrective actions. The objective of the Engineering Survey of the plant is to identify abnormal conditions such as inadequate support, corrosion, deterioration in painting, non-compliance of design requirement and other unsafe conditions. These observations may appear to be very minor in nature, but if they are neglected, in due course they may result in a major failure

4.4 Plant Off-Line Condition Monitoring:

During the plant shutdowns and turnarounds, inspection of all the equipments and their parts are carried out. Following non-destructive testing techniques are employed for the condition monitoring.

- Dye penetrant testing
- Magnetic particle Inspection
- Ultrasonic testing
- Radiography testing
- Specific tests
- Boroscopic tests
- Ferrite check
- Creep check
- Magnetic check
- Hardness inspection
- Spark testing
- Replica studies & metallurgical analysis
- Boroscopic inspection
- Pneumatic and hydro testing.

Based on the various inspection results the rectification work is immediately taken up or planned for the future, depending upon the availability of the spares and time during the shutdown period.

4.5 Major Equipment Replacement Programme

Based on the various inspection results and performance parameters of the equipment, the operation, maintenance and inspection teams jointly evolve a programme on the requirement of replacement of major equipments in the plant. Past experience, criticality of the equipment to plant operation, achievement of design life are given due consideration. The programme is constantly reviewed and updated subsequent to all plant turnarounds and/or once in two years. While taking up the replacement programme, due consideration is given to design with latest revision in codes and standards, improved design and materials so as to extend the life of the equipment

5. Minimisation of Plant Shutdowns

Frequent plant shut downs will have significant impact on the life of the plant due to the possible thermal cycling and pressure cycling during the course of the plant shut down and start up. Hence, minimising the plant shut downs will lead to increased life of the plant. The cause for plant shut downs were analysed in detail and the shut downs can be minimized by improving 1) Reliability of process and plant operation 2) Reliability of maintenance 3) Reliability of instrumentation system 4) Reliability of power supply. Attention is given to each area to improve the reliability and thereby to increase the life of the plant.

5.1 Reliability of process and plant operation

Due to the inherent nature of the process, the particular section of the plant needs to be stopped for cleaning or maintenance. For example, while using arsenic based solution in the CO_2 removal section of ammonia plant, the bottom packed bed of the CO_2 absorber used to get choked with arsenic sludge and the plant had to be stopped once in a year to remove the packing for cleaning. This problem had been overcome by modifying the process and replacing the arsenic based solution with glycine based solution.

The plant operation is a carefully performed function and the plant shall never be stressed by wrong operation. Extreme care is taken in training the operators on plant vigilance, equipment operation, panel operation and responding to plant shut down and emergency. The operators are trained in the process simulators located in the training centre, where various emergency situations are created and operators respond to that. Regular trip drills are done, in which the operator is told to assume the emergency situation and perform all the actions required at the specified sequence. To all the operating personnel, standard operating procedures are made available for every possible plant upset situation, so that the real operation is standardized and error free.

5.2 Reliability of equipments

The design inadequacy in certain sections of the plant will lead to stoppage of the total plant. The process and mechanical design of the equipments are reviewed in order to overcome the design inadequacy and the equipment is modified suitably.

The reformed gas boiler in ammonia plant was of horizontal water tube design and the heat flux was found to be very high, which led to frequent tube failure, particularly the tubes at the outer most row had longer tube length and hence, lesser water velocity compared to the inner row tubes. This has been overcome by converting the boiler to fire tube boiler.

The pipelines in various areas of the plant were checked thoroughly for the pressure drop and corrosion problems. Accordingly, the pipe diameter has been increased to save on energy and better material of construction is employed to overcome the corrosion. For example, the CO2 line from ammonia plant to urea plant was changed with increased size to reduce the pressure drop and the material construction of the rich solution line in the CO2 removal section of the same plant was changed from carbon steel to SS 304 to withstand corrosion. The coils of the fired heaters and feed stock header to reformer in the ammonia plant were changed with better material of construction in line with the revised Nelson Curves.

5.3 Reliability of maintenance

The philosophy of maintenance is to improve the reliability of the plant by providing permanent solutions right at the first time. Based on the equipment performance and the recommendation of the supplier, detailed short term and long-term maintenance requirements are planned for every equipment. Checklists have been prepared for overhaul and maintenance of all equipments, which is rigorously followed while carrying out the maintenance. Spares availability, developed based on past experience and supplier recommendation, is ensured for all the equipments for turnaround, regular maintenance and modification jobs. Various innovative methods have also been developed to do on line maintenance in order to avoid a plant shut down due to a leak or some other problem.

5.4 Reliability of instrumentation system

Instrumentation and control system of a fertilizer plant should have the degree of reliability for sustained plant operation. A plant shut down due to malfunctioning of an instrument will result in production loss, as well as, may cause damage to plant equipments. The pneumatic instrumentation system of ammonia plant, urea plant and boilers were modernised to Distributed Digital Control Systems (DDCS) in order to improve the reliability of the control system. While doing the modernisation, based on the past experience, various redundancy levels are provided in the distributed digital control system for higher reliability. The field control stations are duplexed and hence there is a back up for the CPU, power supply and communication system. Redundancy has also been provided for control input / output cards and the main data high way. Dual solenoid valves are provided for critical trip valves, in order to avoid the trip outs due to malfunctioning of the solenoids.

The trip interlock system of ammonia plant is executed in a PLC system, which is configured for 3-2-1-0 degradation, which means that it will continue to operate with two faulty channels. In the event of a fault in the last channel, the system software will initiate a safe shut down of the plant. An event-triggered auto trend-save application software package saves a defined trend block during an occurrence of a specified event. The saved trend files can be selectively retrieved for analysis.

5.5 Reliability of power supply

The unreliability in power supply is a major factor causing considerable loss of production, as well as, damage to machinery and components of the plants. Frequency fluctuations, power failures and power restriction contribute to the loss of production directly or indirectly. Any slight variation in supply characteristics upset the balance and results in trip outs. Such plant trippings, apart from resulting in production loss, are extremely dangerous to the safety of the plant. Thermal shocks due to process interruptions at the time of power failures drastically affect the life of the various equipment and catalysts. To combat the problem of power instability thereby causing loss of production, it is always advisable to have a captive power unit installed at least of the capacity equivalent to the requirement of plants and other utility services to keep the plants running in case of power failure. SPIC installed captive power plant based on turbo generators with a combined capacity of 24 MW, which can cater to the entire requirement of the fertilizer complex. However, the complex power system is run in synchronisation with the state power supply grid for increased reliability. In case of failure of supply from the state grid, a trip selection device suitably alters the power load to match with the captive generation. The power distribution panels were also changed with improved design.

6. Life Extension by Modernisation of the Plant

The condition monitoring of the plant and reliability improvement through better practise in operation and maintenance had resulted in increasing the life of the plant to some extent. However, in order to infuse more life to the plant and also to keep up the plant on par with latest generation plants in terms of efficiency, a modernisation programme was drawn for the entire fertilizer complex. To achieve this objective a team of engineers were formed and they analysed various sections of the plants, identified bottlenecks and phased them out. The modernisation programme emphasised on improving the reliability, reducing the energy consumption and adopting to eco-friendly technology. The various modernisation activities are listed below:

6.1 Ammonia & Urea Plants

- The reformer burners were modified with energy efficient low capacity burners for better heat distribution, longer tube life and increasing plant throughput. The reformer tubes were replaced with better material of construction.

- The reformer flue gas ducting arrangements were modified to have better flue gas flow dynamics and uniform heat distribution across the furnace. The furnace top insulation was renewed with ceramic fibre. The sidewalls and floor refractory were relaid.

- The rotary combustion air preheater was replaced with the plate type heat exchanger to avoid air leakage into the flue gas side and hence to improve the efficiency.

- The CO2 removal system based on hot carbonate and arsenic trioxide was replaced with energy efficient, maintenance free, environmental friendly, reliable two stage regeneration dual activated carbonate solution with glycine, diethanaol amine and vanadium. The packing in the absorber and regenerators were also changed to latest generation.

- The ammonia synthesis converter internals were replaced with the energy efficient axial-radial flow converter.

- Purge gas hydrogen recovery unit was installed to recover the hydrogen from the purge gas from ammonia synthesis loop which helped in enhancing the energy efficiency of the plant.

- The urea reactor was replaced with a new more lengthy reactor, which helped in enhancing the convention efficiency.

- The centrifuges in the urea plant were modified to have improved technology

- Additional reciprocating compressor was provided in parallel to the booster compressor to enhance the urea plant throughput.

6.2 Phosphatic Fertiliser Plants

- The sulphuric acid plant was retrofitted with double contact double absorption process to enhance the life, capacity of the plant and minimise the emissions ($SO2$) from the plant. The irrigation coolers of sulphuric acid plant were replaced with counter current plate heat exchangers.

- A captive power generation plant of 6 MW capacity was installed utilising the steam generated in waste heat boilers of Sulphuric Acid plant and this has improved the power availability to the phosphatic fertilizer plant.

- The diammonium phosphate plant was retrofitted with pipe reactor technology, which helped in enhancing the plant capacity, reducing the energy requirement and down time.

7. Conclusion

The first point to be addressed in any life extension programme is whether the existing plant will operate satisfactorily and safely without replacement or major modification. A thorough analysis has to be undertaken to determine the best combination of condition monitoring, design modifications, modernisation and refurbishment activities. Development of in-house expertise to evolve such strategies can bring the best results. In SPIC, the systematic approach to the life extension programme by our dedicated team of technocrats have resulted in extended life of the plants for the next 15 years, with concurrent reduction in energy consumption and higher capacity utilisation.