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LIFE EXTENSION AND MODERNIZATION OF AMMONIA-UREA COMPLEX

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RESUME

Southern Petrochemical Industries Corporation (SPIC) a son complexe de production d'engrais à Tuticorin, Inde. Cette usine fonctionne depuis 1975. Le coefficient d'utilisation de la capacité des unités était faible les premières années pour différentes raisons. Les goulots d'étranglement et certains équipements peu efficaces du point de vue énergie ont été identifiés et des modifications ont été apportées au fil des années. Il en est résulté une amélioration de l'utilisation de la capacité des unités de plus de 100 %. L'exposé met en lumière les différentes mesures mises en oeuvre et les programmes de réhabilitation de SPIC pour améliorer la performance des unités.

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INTRODUCTION

SPIC fertilizer complex has the following production facilities:

Ammonia plant	1100 TPD
Urea plant	1600 TPD
Sulphuric acid plant	470 TPD
Phosphoric acid plant	165 TPD
DAP plants	1350 TPD
Aluminium fluoride plant	8 TPD

The ammonia plant is based on ICI steam-naphtha reforming process designed by M/s. Davy McKee, U.K. The urea plant is based on Mitsui-Toatsu C improved process designed by M/s. TEC, Japan.

During early years, capacity utilization of ammonia plant was low due to various problems and hence the capacity utilization of urea plant was also low. The problems were analyzed and solutions were found to improve performance of plant.

The initial hurdles in reaching higher on-stream efficiencies were overcome by adopting better maintenance and condition monitoring techniques. Strategic actions like major equipments replacement programmes enabled sustained operation of the plant over the years. Consistent capacity utilization and improvement in on-stream efficiency have been achieved. Now a major revamping programme is on the anvil to further improve the performance.

The emphasis in recent years has been on revamping existing plants with low cost retrofit schemes which have short pay back time on account of reduced energy consumption. Increasing the capacity by revamping is an attractive alternative to installing a grassroot plant. In view of this, to improve the plant reliability and productivity in the coming years, SPIC plants are being revamped in a phased manner. The principal objectives of SPIC modernization schemes are to increase the plant capacity, life expectancy and reducing the energy consumption from the prevailing levels.

IMPROVEMENTS CARRIED OUT IN AMMONIA PLANT

DESIGN CHANGE IN REFORMED GAS BOILER AND ITS TRANSITION PIECE

This boiler located at the outlet of secondary reformer is of water tube type for generation of steam at 106 KSC pressure. Hot spots developed at secondary reformer to RGB neck, due to distortion of incolloy liner at the expansion joint damaging the refractory casting at the secondary reformer outlet nozzle. This was rectified by modifying the support system of the incolloy liner housing the tube bundle. Also, thermodynamic seal system with an expansion joint consisting of a diffuser and venturi was provided to the incolloy liner to avoid bypassing of hot gases and damage to the refractory. Thus the hot spots were totally avoided.

Since commissioning, significant portion of down time of plant was due to failure of tubes in the above boiler. One possible reason was deposition and overheating of tubes. Also, the tubes had a combination of carbon steel at low heat flux area and 1 Cr - ½ Mo steel at high heat flux area. The inspection of the failed tubes revealed extensive hydrogen embrittlement of carbon steel tubes. The material of construction of the tube sheet was changed to 1¼ Cr - ½ Mo steel and that of tubes to 1 Cr - ½ Mo steel for the entire length of the tubes. Subsequently the frequency of tube failures was reduced.

MODIFICATION OF REFORMER BURNERS

SPIC reformer is a top fired furnace with 8 rows of tubes (33 in each row) and 9 rows burners (7 in each row). Tubes in outermost row were getting overheated due to radiation from the wall. The overheating was avoided by down rating the end row burners to 70% of normal capacity.

Originally the reformer burners were provided with metallic air cones which were deformed due to radiation from furnace in service. The performance of the burners had been affected because of this. The air cones have been replaced with refractory lined cones improving the performance of burners.

REFORMER COFFIN BOX MODIFICATION

The poor distribution of flue gas caused poor flame condition and also wide variation in pigtail temperature. This was solved by modifying the coffin box to have proper distribution of flue gas. This modification has brought down the standard deviation of reformer tube skin temperature from 40°C to 28°C. This has helped to increase the life of reformer tubes.

IMPROVED MATERIAL OF CONSTRUCTION FOR REFORMER TUBES

The reformer tubes which were originally of HK 40 material were replaced with tubes of 25 Cr - 35 Ni - 1.5 Nb material. In view of higher creep strength, tubes of reduced wall thickness could be used giving the advantage of lesser temperature gradient across the wall. The reduced wall thickness also enabled higher catalyst loading by about 7%.

REPLACEMENT OF CRITICAL HEAT EXCHANGERS TO OVERCOME DESIGN DEFICIENCY

Some of the critical heat exchangers with cooling water on shell side had been designed with triangular pitch of tubes. The deposit on the tubes could not be cleaned properly, which led to process limitation and failure of tubes due to under deposit corrosion. These exchangers were replaced with square pitched tubes to facilitate effective cleaning. Some other exchangers having mechanical design deficiencies such as flow induced vibration were replaced with exchangers of better design and reliability.

IMPROVED PACKING FOR CO_2 ABSORBER AND REGENERATOR

Ceramic saddles were used as tower packings in the CO_2 absorber and regenerators. Leaching of the saddles caused sludge accumulation and high pressure drop, which limited the plant load and also resulted in plant shutdown for change of packings. These saddles have been replaced with stainless steel pall rings avoiding the sludge problem. SS pall rings have also improved mass transfer characteristics.

MODIFICATIONS ON THE AMMONIA CONVERTER

Ammonia synthesis converter is of quench type having 3 catalyst beds. The converter was found to have high pressure drop within few years of operation limiting the plant load. The lozenge sealing assembly was suitably modified to prevent catalyst entering the lozenge and creating additional pressure drop. Further an additional support grid was provided by splitting the lengthy III bed to avoid any possibilities of catalyst crumbling due to self weight and increasing the pressure drop.

ENERGY CONSERVATION MEASURES

1. RETUBING OF SURFACE CONDENSERS

   Poor vacuum in these condensers was resulting in excess steam consumption and restriction of plant load on some occasions. These condensers were retubed with aluminised carbon steel tubes to prevent deposition tendency on the cooling water side and to improve vacuum.

2. REPLACEMENT OF BFW HEATER IN SYNTHESIS LOOP

   The preheater was less efficient due to bypassing of feedwater (the shell side fluid across the longitudinal baffle) and also because of inadequate design. This was replaced with a new exchanger of better design, resulting in increased feed water temperature and lower energy consumption for steam production.

3. IMPROVEMENTS IN COOLING TOWER

   The cooling tower fan blades have been changed from cast aluminium to hollow fibre reinforced plastic (FRP). This has brought down the power consumption by 20% for the same air flow.

   The cooling tower cells were renewed with PVC fills and improved drift eliminators which have considerably reduced the drift loss.

4. UTILIZATION OF HYDROFINER OFF-GASES AS FUEL

   Off gases from hydrofining section which were being flared, are used presently in raw naphtha vapouriser as fuel. The naphtha burners for the vapouriser were replaced with oil and gas combination burners to reduce consumption of fuel naphtha.

5. RECOVERY OF SOUR OIL GASES FROM SYN GAS COMPRESSOR

   Sour oil mist separators have been provided to recover vent gas from sour oil traps of syn gas compressor. By this modification, production has increased by 7 TPD.

FUTURE REVAMP PLANS IN AMMONIA PLANT

Development of energy efficient technology and effective catalysts is continuously taking place. When this newer developments are chosen selectively and suitably adopted in the older ammonia plants, the energy efficiency and reliability of the plant are vastly improved. Our revamping plan aims at reducing the energy consumption and increasing the plant capacity. For this, the steam/carbon ratio at primary reformer will be reduced. To maintain the reformer efficiency, shaped catalyst will be loaded to the tubes. The CO_2 removal section will be operated with lower heat input. The synthesis section will also be modified to process the increased plant throughput.

MODIFICATIONS IN REFORMING SECTION

1. INSTALLATION OF ADDITIONAL BURNERS IN REFORMER

The heat release per burner is quite high at 1.9 Gcal/Hr. The flame is also lengthy and in some of the burners the flame impinges on the nearby tubes. The heat distribution in the furnace is also not uniform because of the lesser number of burners. These problems will intensify when the plant capacity is increased after revamping. Hence it is decided to increase the number of burners from 63 to 90 reducing the heat liberation per burner by 25%. Better heat distribution, longer tube life and increase in plant throughput are the anticipated advantages.

2. FURNACE INSULATION REPLACEMENT

The furnace is insulated with refractory. The roof is made of hanging bricks and lot of air is leaks into the furnace through the gap between the furnace roof and tubes. The furnace shell refractory panels are being repaired during major turnarounds. However the heat loss from the furnace is always more than the design norms. It is planned to change the roof bricks with ceramic fibre insulation. The side walls and the floor refractory of the furnace will be relaid. Heat loss and air ingress into the furnace are expected to come down.

3. COMBUSTION AIR PREHEATER

Presently a rotary air preheater is used in the reformer flue gas duct to preheat the combustion air to the reformer furnace. The air leak in the preheater is as high as 20 to 25%. This higher air leakage results in wastage of energy and the load on the ID/FD fans is more than the design.

After detailed analysis of the alternatives available, it has been decided to install static air preheater.

4. REFORMED GAS BOILER

The present boiler is a water tube boiler and we still experience tube failures in spite of the improvements done in the material of construction. Addition of surface active agent to avoid the deposit formation of metals inside the tubes could not bring down the tube failures. A twin compartment fire tube boiler will be provided in the next turnaround. Adequate care has been taken while sizing fire tube boiler with respect to fouling of the tubes since potash promoted catalyst is used in the primary reformer and potash dust and refractory debris from the secondary reformer is normally reported to foul the tubes of the fire tube boilers.

MODIFICATIONS IN CO_2 REMOVAL SECTION

The present CO_2 removal system is based on hot carbonate solution with arsenic trioxide as corrosion inhibitor and mass transfer promoter. Choking of absorber bottom bed occurs due to sludge formation. The plant needs to be stopped once in a year to change the packings in the bed.

Two stage regeneration is the new energy efficient technology being offered nowadays. Dual activated solution with glycine and diethanolamine along with vanadium as corrosion inhibitor is considered to be an efficient solution. It is proposed to change over to this system in the ensuing turnaround. This system change over will have the following advantages.

a. Cleaner solution and less deposit formation.
b. Substantial reduction in energy consumption.
c. Environmentally safe solvent operation.

CONVERTER RETROFIT

SPIC's ammonia converter is of early seventies axial flow design with interbed quenches. The quench type is not energy efficient and conversion per pass is also less. The pressure drop is also high compared to radial flow converters. Moreover, when the plant production capacity is increased by revamping the present converter will not be able to handle the entire gas. Hence it has been decided to go in for radial flow converter basket. The existing high pressure shell will be retained. Preliminary study shows there will not be any change to the other synthesis loop equipments. The radial flow converter offers lower pressure drop and high conversion per pass. Increased conversion per pass results in the following improvements.

- Reduction in circulation rate and loop pressure.
- Reduction in refrigeration load.

MODERNISATION OF INSTRUMENTATION TO DDCS

Distributed digital control system is the state of art in the field of process control and it is being used in all the modern plants. This system enables accurate, reliable and fast control along with the facilities for process optimisation and problem diagnosis. It is planned to change the existing pneumatic instrumentation of ammonia plant to the distributed digital control system. The expertise obtained in planning and execution of urea instrumentation system conversion to DDCS is helpful in the process of ammonia plant instrumentation system conversion.

APPLICATION OF PINCH TECHNOLOGY

The energy is being lost in several exchangers in the plant. Pinch study has been applied to find out how this heat loss can be avoided. Two principal sources with higher grade heat energy have been identified to be the heat loss in the final cooler at the synthesis gas compressor suction and synthesis loop cooler condenser. The modifications required in the boiler feed water circuit is also identified and some additional exchangers are required in this process.

When the revamping is completed the plant capacity is expected to be increased by 10%. The energy consumption per tonne of ammonia is expected to come down by 1 GCal.

IMPROVEMENTS CARRIED OUT IN UREA PLANT

REPLACEMENT OF UREA REACTOR

Since commissioning in the year 1975, the urea reactor has been in continuous service and had produced 8.5 million MT of urea before its replacement in 1993. This reactor, a multilayer vessel with 153 mm thickness and titanium lining for corrosion protection, operates at 230 kg/cm^2 and 200°C.

Rigorous inspection and repair works carried out during turnarounds ensured trouble free operation. However in the year 1982, a downtime of 7 days resulted due to leak at the ammonia inlet nozzle area. In the year 1986, a downtime of 12 days resulted due to leak in the shell course weep hole patch plate area. During the turnaround 1988, CO_2 inlet nozzle and reactor outlet nozzle were replaced along with pad plates. In the turnaround-1990, ammonia and recycle carbamate nozzle pad plates, patch plates in the shell course and patch plates of a few weep holes were renewed. In view of the reduction in lining thickness and hydrogen absorption in titanium, it was decided to replace the reactor.

At the design stage of new reactor certain improvements based on operating experience were incorporated. Developments in the fabrication technology over the years have enabled incorporation of improved construction features. The improvements are detailed below:

1. The original reactor had titanium lining thickness of 5 mm at the bottom, 4 mm at the middle and 3 mm at the top. The new reactor is provided with 6 mm thick cladded titanium lining at the bottom head, 5 mm thickness in the 2nd course and top head, 4 mm thickness in the other shell courses.

2. The CO_2 ammonia and carbamate inlet nozzles at the bottom of reactor are projected by 200 mm inside. This change was done to increase the service life of the nozzles.

3. The original reactor shell was made of 12 layers of 12 mm thickness and one layer of 9 mm thickness. The new reactor has only 10 layers with a uniform thickness of 15.3 mm.

4. As against 18 shell courses of titanium lining, the new reactor has only six courses. Three segments of lining are full penetration welded outside with 100 % DP test and radiography and thus the number of shell course welding to be done inside the reactor has been reduced.

   The new reactor is in service since 1993.

DISTRIBUTED DIGITAL CONTROL SYSTEM

There are various methods of implementing DCS in a running plant:

1. Implementing loop by loop conversion.
2. Implementing sectionwise conversion.
3. Implementing the conversion for the total plant during a plant shut down.

After discussing the pros and cons of the above methods, it was decided to implement the conversion for the entire plant during a turnaround.

A study of electromagnetic and power line interference effect was conducted at the proposed new control room area to ensure troublefree operation. To provide clean air environment for the electronic components chemical filters have been installed and integrated with the packaged air conditioning system.

Erection of the system hardware in the new control room was done and the system cables including HF bus communication cables between stations were laid and terminated. Pre-fabricated sections of cable ducts were erected before the shut down and field junction boxes were installed and cables were laid. Current to pneumatic converters were installed for control valves and cables terminated.

The plants were shut down for turnaround during April,1993. The pneumatic transmitters in the field were replaced with electronic transmitters and connected to the same impulse piping with minor modifications wherever required. Termination of cables at field transmitter end was carried out. Loop check was carried out and the field transmitters were hooked up to DCS system.

The plant interlock system was checked for proper performance. The system was hooked up in total and the plant was started with DCS.

ADDITIONAL CO_2 COMPRESSOR:

CO_2 from ammonia plant is compressed by CO_2 booster compressor from 0.06 kg/cm^2 g to 14 kg/cm^2 g. This is a two stage compressor with a first stage discharge pressure at 3.4 kg/cm^2 g. The CO_2 is further compressed to 230 kg/cm^{2}g by CO_2 reciprocating compressors and then fed to the reactor. As per design, a part of CO_2 required for 1600 MT/day urea production is fed in low pressure decomposer operating at 2.5 kg/cm^2 g pressure for effective ammonia stripping. This gas is fed from first stage discharge and there is also a provision to feed from second discharge.

A separate reciprocating compressor was hooked up at the main CO_2 line from ammonia plant and CO_2 was directly fed to low pressure decomposer. With the separate compressor, the additional CO_2 realised was around 1000 nm^3/hr which was over and above the CO_2 drawal capacity of the booster compressor. By providing an additional compressor, the production increase was around 60 MT/day of urea with effective stripping of ammonia reducing the ammonia loss in the system.

FUTURE REVAMP PLANS IN UREA PLANT

Replacement of recycle carbamate plunger pumps with centrifugal carbamate pump

There are four recycle carbamate plunger pumps out of which one is kept as standby. These pumps incur regular maintenance like plunger packing failures and cylinder replacements. At times unpredicted failures lead to load restriction in the plant. Hence as a part of life extension and modernisation program, to avoid frequent maintenance and to increase the reliability of the system, it is planned to replace the recycle carbamate plunger pumps with a centrifugal carbamate pump.

Replacement of urea centrifuges

The existing centrifuges are in line right from the commissioning of the plant. With stiff maintenance schedule, the equipments are being utilised to the maximum output level. Of late, due to over-aging of centrifuges, frequent failures are noticed increasing the frequency of maintenance. Hence to improve the reliability, it is planned to replace the urea centrifuges one by one.

CONCLUSION

With the modifications carried out and future plans for revamp in ammonia-urea complex, the following advantages are envisaged:

1. Increase in plant capacity with higher capacity utilization in forthcoming years.
2. Reliability improvement of equipments with lesser maintenance.
3. Reduction in energy level sustaining high level of performance of the plants.
4. Extended life of the plants ensuring continuous operation for the next 15 years.