MITIGATION OF CORROSION IN ACID PLANTS – THE IJC WAY

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Preamble

Indo Jordan Chemicals Company (IJC) is a joint venture company promoted by M/s Southern Petrochemical Industries Corporation Ltd (SPIC), India, M/s Jordan Phosphate Mines Company Ltd (JPMC), Jordan and The Arab Investment Company (TAIC), Saudi Arabia. The Industrial Complex has been set up in a Special free zone in Eshidia, Jordan adjacent to the Phosphate mines of JPMC.

IJC operates a Phosphoric acid plant, based on Hydro Agri's Single stage Hemi hydrate process with a name plate capacity of 2,24,000 MT per annum, a Sulphuric acid plant with Monsonto's DCDA process with a name plate capacity of 6,60,000 MT per annum and associated utilities and Off-site facilities.

Due to the basic corrosive nature of the chemicals / raw materials handled, the equipments and pipelines in Sulphuric & Phosphoric acid plants are vulnerable to different types of corrosion attack and premature failures.

IJC's way of fighting corrosion follows the principles of effective monitoring and timely action. The plant sections / equipments that are susceptible to corrosion attacks are identified, the probability for occurrence of specific types of corrosion in these areas are analysed in detail and methodologies are worked out to have an adequate & effective monitoring of these areas. Corrective / Preventive actions are taken in time to extend the service life of the equipments and to avoid unforeseen plant outages. All the corrosion failures are analysed in detail to identify the root cause of the problem so as to avoid the recurrence of the same.

This paper enumerates some case studies on IJC's experience with corrosion problems in Sulphuric & Phosphoric acid plants and the corrective actions taken there in.

This paper also presents some of the material changes carried out in IJC plants over the period of 10 years operation to combat corrosion.

Corrosion in SA Plant Furnace

Construction

The Furnace in IJC's Sulphuric acid plant is a Carbon steel vessel lined with 2 layers of refractory bricks, 114 mm thk insulating brick layer and 220mm thk High Alumina refractory bricklayer. The furnace is provided with 3 nos of baffles, built with refractory bricks (Fig 1).

Molten Sulphur is fired in the furnace and hot SO_2 gas, at about 1125ºC, flows through an integral Waste heat boiler (WHB) of Shell & tube design and then to SA Converter. WHB has a bypass arrangement and the bypass nozzle is located at top of the furnace, just ahead of the boiler. Bypass control is effected by means of an automated plug type control valve.

Problem

The furnace has been in service since plant commissioning in 1997. Combined inspection of the furnace is carried during every Annual turnaround with experts from M/s SGL Technik.

After 5~6 years in service, gap was observed between insulating & refractory bricklayers at the bypass valve nozzle area. The opening width of the gap kept increasing every year and in year 2006 the maximum gap was around 60mm (Fig 2).

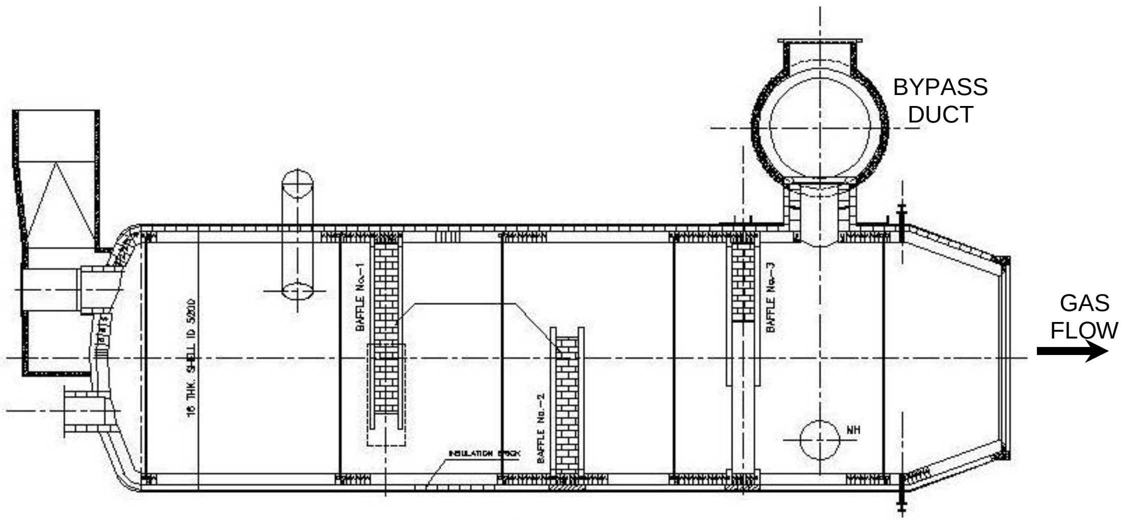

Fig 1 SULPHUR FURNACE – GENERAL ARRANGEMENT

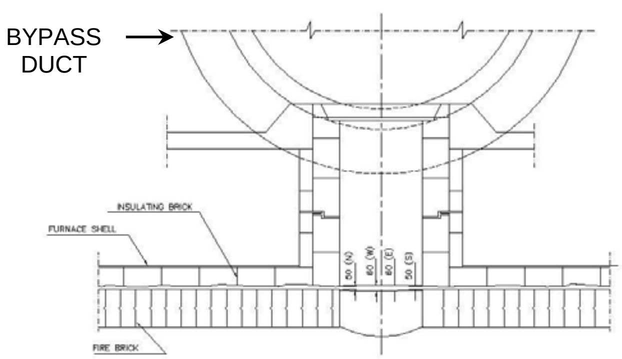

Fig 2 Sulphur Furnace – Gap in Bricklining

Fig 3 Sulphur Furnace – Accumulated Sludge

The impact of this gap was analysed in detail to finalise the need & mode of repair. It was found that this gap will facilitate free passage of gas between the bricklayers and also between the shell and the insulating bricklayer.

Since the furnace is not insulated, the gas reaching the shell will condense into acidic sludge, resulting in possible corrosion of shell. Sagging of bricklining, observed around the bypass valve nozzle, also confirmed this possibility.

To ascertain the condition of the shell, ultrasonic thickness scanning was done for top half of the furnace shell during a short shutdown opportunity.

Thickness reduction was observed to the tune of around 30~40% of the original thickness for $1/6^{th}$ of the circumference at top. In the lower areas, thickness values were satisfactory.

Remedial Action Taken

Based on the inspection, it was confirmed that corrosive Sulphur sludge has got accumulated beneath the shell Bricklining at top. The corrective action was planned on two modes.

1. To repair / strengthen the already corroded area of the shell - Carbon steel patch plates were welded over the corroded areas of the shell, identified by ultrasonic thickness scanning.

2. To arrest the source of gas entry – The sagged Bricklining around the bypass nozzle was replaced with new bricks for an area of around 2.2m x 4.5m.

After removal of bricks, sludge accumulation was observed between insulating brick layer and shell plate for a max thickness of 110mm, confirming our analysis (Fig 3)

Action plan for the future

Sludge accumulation has spread over a wider area along the length and circumference of the shell. This sludge has not been removed completely. Only the gas entry point has been repaired. Further corrosion of the shell is likely, due to the accumulated sludge. The following plan of action is planned for the future.

- Regular thickness monitoring of the shell will be done during every shutdown. Patch welding will be carried out in stages wherever thickness reduction is observed.
- Condition of Shell Bricklining will be monitored during every shutdown. If any further sagging / detachment of bricklayers is observed, then Bricklining replacement will be carried out in these areas in stages.

Corrosion in Interpass Absorption Tower

Construction

In Interpass Absorption tower (IPAT) in SA plant, 98% Sulphuric acid is circulated to absorb SO3 in converter 3rd bed outlet gas. Material of construction for the tower is carbon steel and the acid distribution headers and distribution troughs are made up of Sandvik SX material.

The tower is equipped with 34 nos of Inverted candle type Mist-Eliminators to remove acid mist from the gas. These candle filters were fitted over a SS316L tubeplate. The lower portion of the tower in contact with flowing acid is lined with Rephanol + Acid proof bricklining. In the top portion of the tower, above the tube plate, there will be only acid free gas and hence it is free of any lining.

Problem & Analysis

In June 2005, a leak was observed in the IPAT shell just above the candle filters fixing tube plate. As a temporary measure, plant was stopped for a brief period and the leaking area was patch welded from outside with SS316L plates. Subsequently, between June 2005 & Mar 2006, leaks were observed in 3 occasions in the nearby areas and all these areas were patch welded from outside. Based on thickness scanning, preventive patch welding was also done in the nearby areas wherever thickness reduction was observed.

The problem was analysed in detail. The acid free gas is not corrosive to Carbon steel. Corrosion of shell is possible only if there is acid mist carry over above the tube plate. The probable scenarios could be any or all of the following

- Damage to candle filters
- Gasket failure between candle filter flange & tubesheet
- Corrosion & puncture of SS316L tubesheet

Since, corrosion of SS316L tubesheet is unlikely, it was concluded that damage to candle filters or the gasket failure had caused acid mist carry over & shell corrosion.

Remedial Actions

Annual turnaround of SA plant was planned in end March 2006. During this turnaround, Replacement / Patch welding of punctured area of the shell was planned.

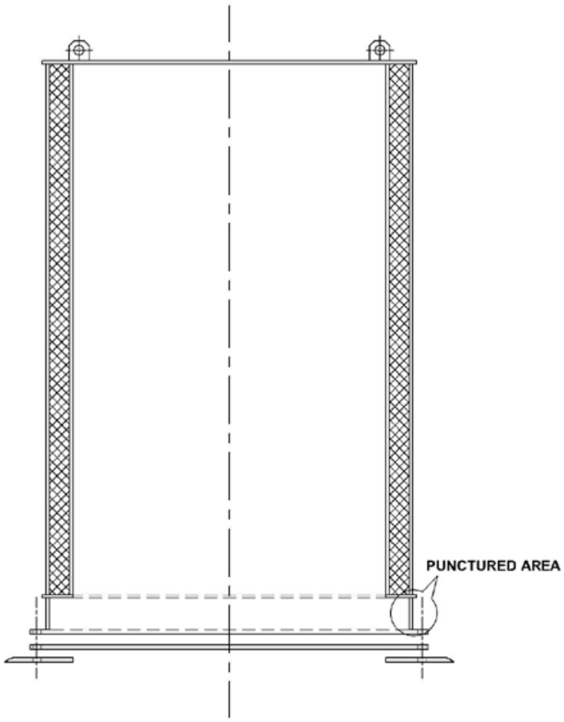

Fig 4 IPAT Candle Filter

During Turnaround 2006, internal inspection of the tower was done and following were the observations

- 4 Nos of candle filters, near to the shell leak area were found heavily corroded / punctured in the bottom collar portion, just above the seating flange (Fig 4).
- Gaps were observed between the candle filter flanges and the fixing tubesheet surface.
- At the leaky area of the shell, the shell plate was found completely corroded for a wider area.

From these observations, it was inferred that splashing of acid mist through the openings in the candle filters had caused shell corrosion / leak. Corrosion resistance of Carbon steel in the concentrated Sulphuric acid environment is mainly contributed by the formation of adherent Iron Sulphate film in static & low velocity conditions. The high velocity splashing of acid mist would have not only damaged this protective film and also prevented further formation of the same.

All the candle filters were replaced. Adequate seating of candles over the tubesheet was ensured by light passing test.

Thickness scanning was done for the shell. Additional SS316L, outside patch welding was done over the corroded area of the shell. To avoid acid entrapment between the original shell and the outside patch plate, the shell plate edges were seal welded to the patch plate from inside.

Action plan for the future

- Periodical on-line thickness monitoring of shell will be done every 6 months
- During every shutdown, in addition to routine inspection of Mist-Eliminators, thickness scanning will be done for the bottom collar portion.
- If any anomalies are detected in above inspections, further course of action will be decided.

Since the repairs jobs in Apr 2006, no problems have been observed so far.

Interchanging of Acid ports in Acid Coolers

IJC operates 6 nos of Plate heat exchangers in SA plant for cooling 98% Sulphuric acid.

The material of construction for the heat transfer plates is Hastalloy C 276 with VITON B gaskets.

The heat transfer plates in the acid cooler are subjected to uniform corrosion due to acid flow. Corrosion rate will be more at the acid inlet nozzle area due to the combined effect of Erosion - corrosion. Due to impingement action of incoming acid, the protective layer gets damaged enhancing corrosion susceptibility.

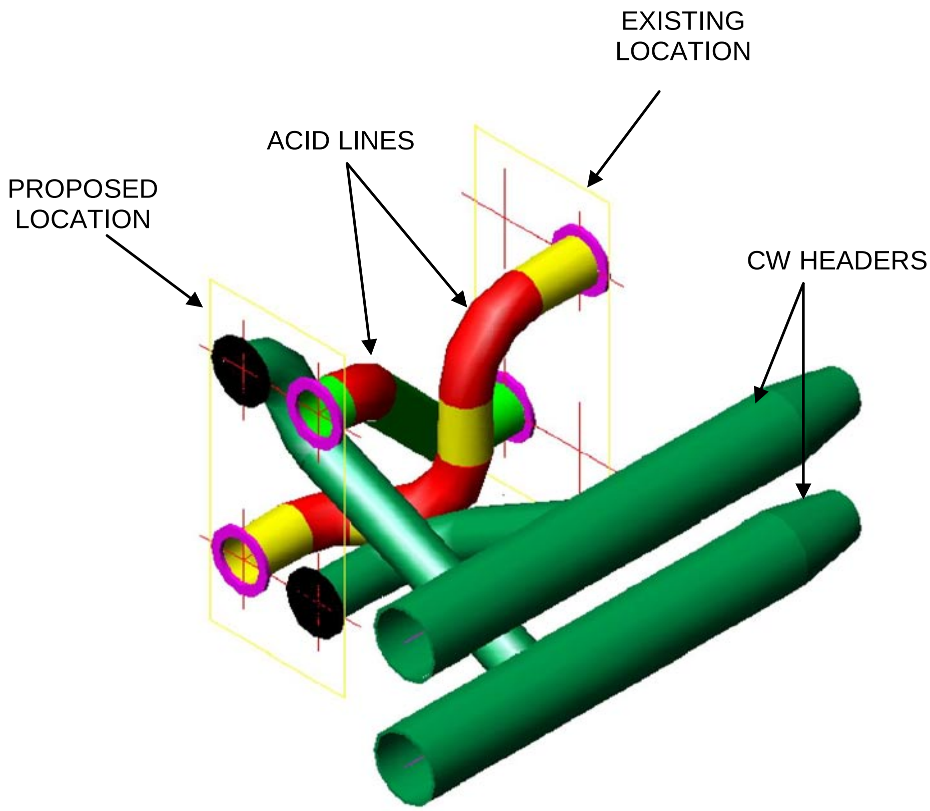

Fig 5 Scheme for interchanging Acid ports in Acid coolers

The plates normally fail (thinned down and punctured) at the acid inlet nozzle area, necessitating replacement of the entire plate pack though the other areas of the plates still have useful service life left in them.

In IJC, the average service life of the coolers is only 4~5 years. To enhance the service life of the coolers, it is proposed to interchange the acid inlet & outlet ports in the coolers which is the common industrial practice. By this way, the total amount of corrosion at acid inlet area over the entire service life is distributed over two nozzles instead of getting concentrated in one nozzle.

Another problem faced in these coolers is blockage of acid channels by the broken pieces of ceramic packing, carried over from the acid towers. These blockages resulted in low heat transfer coefficient.

As per the recommendations of the supplier, Alfa Laval, the most effective method to remove these blockages is by back flushing the coolers with 100% acid flow. Interchanging acid inlet & outlet ports will facilitate this back flushing too.

But the problem with port interchanging is that in IJC, Material of construction for the acid lines is Sandvik SX. These lines are all-welded construction with minimal no. of flanges. Any such port interchanging involves extensive cutting & welding in the SX lines. These SX lines have been in service for around 10 years. Over this period, the material has lost its weldability and attempts to carry out repair welding in these lines were not successful in the past. Any welding in these old lines resulted in numerous cracks in Heat affected zone. Introduction of more flanged joints in Sulphuric acid line is also not preferred.

Hence, a novel scheme has been worked out wherein the coolers will be shifted backwards by about 2m. The gap between the existing acid line flanges and the new position of cooler nozzles will be bridged by 2 nos of flanged spools, routed in such a way to effect the port interchange (Fig 5).

In future, acid port interchange in the coolers can simply be done by relocating the coolers and installing or removing these additional spools. Since the nozzle size in 5 out of 6 coolers is same, these spools can be maintained as common spare for all these 5 coolers. Fabrication of these spools is an one time expenditure.

This modification is planned for next ATA 2008. Thickness of the heat transfer plates at the acid inlet port in all the coolers will be checked with Micrometer. The original thickness of the plates is 0.6mm. If the measured thickness is less than 0.4mm, port interchanging will be carried out by introduction of these prefabricated flanged spools. By carrying out this modification, a permanent & simple system for interchanging of acid ports in Sulphuric acid coolers will be made available.

Interchanging of CW – Acid ports is not considered at present. As per the manufacturer's recommendation, interchanging of Acid – CW channels will result in swelling of gaskets necessitating replacement of gaskets.

Changes in Material of Construction in IJC

Selection of right material for a given service plays a prominent role in ensuring availability and reliability of the plant equipments. There are many variants in the operating parameters in actual plant operation that the designer has not foreseen in the design phase of the project. In addition, advancement in material science engineering has thrown open a wide range of materials for selection.

The industry has an excellent history of operating experience with different materials, which will form the basis for selection of materials suitable for any specific application.

In IJC, over the years of existence, several changes were made in material of construction for the plant equipments and pipelines.

The basis for effecting change in material of construction in IJC are

- Changes in operating parameters & raw material quality
- Improved service life
- Improved reliability
- Ease of maintenance &
- Ease of cleaning

These changes have paid rich dividends in maximizing the On-stream efficiency of the IJC's acid plants.

Some of such changes carried out in IJC are as follows

Demisters for Air drying tower in SA plant

Drying tower in SA plant has two decks of demisters, Primary & Secondary. Original material of construction for both the demisters is SS316 Ti.

To improve the service life of the demisters, Alloy 20 demister pads were tried in both Primary & Secondary deck. But these demisters have failed within a year of service.

Then, demisters with ‘Lewmet’ meshes were installed as Primary demisters and the performance was relatively satisfactory.

Recently, both Primary & Secondary demisters were replaced with ‘ZECOR’ demisters, supplied by Monsonto Envirochem. Zecor is an Austenitic stainless steel with higher Silicon content that has excellent corrosion resistance in Strong Sulphuric acid.

Zecor meshes have been in service since Nov 2005 in Secondary demister and since Apr 2006 in Primary demisters. The performance so far, is satisfactory.

<u>Process vessels in PA plant</u>

Process vessels handling Phosphoric acid in differing concentrations in the Filtration section were originally Carbon steel vessels lined with Butyl rubber. These are vertical cylindrical vessels equipped with agitators and fitted with rubberlined baffles.

In these vessels, often rubberlining damages and leaks were observed in the baffles fixing area of the shell due to more erosion at these areas. During manual cleaning, the vessel rubberlining gets damaged resulting in leaks.

In order to improve the reliability of these vessels, all the rubberlined tanks were replaced with all metallic tanks. The materials of construction for the Metallic tanks were Sanicro 28, SS316L & SS304L based on the concentration of acid being handled. The high capital cost for this modification has been justified by reduced maintenance and improved availability of these tanks.

<u>Pumps for acid & Slurry service in PA plant</u>

Originally these pumps had rubberlined CI impellers with rubber liners for the casing. The life of these impellers and the liners was about 3 months only. After detailed analysis and in discussion with OEM of these pumps, the rubberlined impellers were replaced with metallic impellers of specifically developed Duplex stainless steel material, suitable for the service conditions.

Service life of these metallic impellers is around 12 months and the performance of these pumps is satisfactory.

<u>Process pipelines in Phosphoric Acid plant</u>

Suction & discharge lines of Concentrator circulation pumps in Concentration section were originally Ebonite rubberlined Carbon steel lines. Frequent leaks were observed in the pump discharge lines especially at the reducer in the pump immediate discharge, severely hampering the reliability of these pumps. Hence these reducers alone were replaced with flanged Sanicro 28 spools and the performance since then was satisfactory.

For handling process acids of various concentrations in filtration section, originally Butyl rubberlined carbon steel pipelines were used. However due to maintenance and cleaning problems faced with these lines, these lines were changed in a phased manner to Poly propylene (PP) lines with 10 bar pressure rating. Once these PP lines are well supported as per the specifications, they give a better service life. PP lines also have relatively less scaling tendency as compared to CSRL lines. Cleaning is also easier.

650 NB slurry re circulation line, from Flash cooler to Reactor, in Reaction section was originally Carbon steel line with 65mm thk carbon bricklining. Frequent scaling build up problem was experienced in these spools. Cleaning was also difficult in bricklined piping. After a detailed analysis, these spools were replaced with flanged Sanicro 28 spools. Since then, the scaling build up was less and cleaning was also easier resulting in improved reliability.

All liquid piping in gas scrubbing section were originally PVC reinforced with GRP (RPVC). The performance of the material was good. However, repair of RPVC pipelines is difficult and also the weld joints in these lines are unreliable. Hence, RPVC lines are being replaced with PP / FRP lines and the results are satisfactory.

Gas ducts in SA plant

Material of construction for Interpass absorption tower gas exit duct in SA plant was originally Carbon steel. Due to occasional acid mist carry over from the tower during plant upset conditions, frequent leaks were observed in the duct in the lower horizontal portion leading to stoppages of the plant.

To improve the reliability of the duct, the portion of the duct experiencing frequent leaks has been changed with SS304 MOC. Since then, no leaks were experienced in this duct.

Conclusion

Corrosion mitigation in IJC is an On-going continuous process. By effectively implementing several corrosion control measures, reliability of the equipments has increased a lot since the days of plant commissioning.