Urea Reactor Pro-Active Modification & Repair:
GPIC Experience

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1. INTRODUCTION TO GPIC

GPIC is a world class producer of Ammonia (1200 metric ton/day), Methanol (1200 metric ton/day) and granular Urea (1700 metric ton/day), a key company in Kingdom of Bahrain's drive toward the diversification of its industrial sector and a model of co-operation between GCC countries.

The company was established in 1979 as a joint venture equally owned by the Government of Kingdom of Bahrain, Petrochemical Industries Company (PIC) of Kuwait and Saudi Basic Industries Corporation (SABIC) of the Kingdom of Saudi Arabia, and in just over two decades it has grown to become a major petrochemical venture contributing to international growth and development in its field.

GPIC 1700 MT/day granulated urea plant was commissioned in 1998. The plant was constructed by Mitsubishi Heavy Industries utilizing SNAMPROGETTI process.

The high level of consideration given to Quality, Health, Safety and care for the environment is testified by the certification of the Company's Quality System Management to ISO 9001 since 1995 (ammonia and methanol) and 1999 (urea), the certification of its Environment Management System to ISO 14001 and the accreditation of its HSE Management System to the American OSHA Process Safety Management and the British Occupational Health and Safety Assessment Series (OSHAS) 18001.

This care has led GPIC to reach top-of-the class results in reliability with ammonia, methanol and urea plants operating continuously for more than 730 and 930, and 941 days respectively.

In HSE, GPIC was the first Company outside Europe and North America to win the prestigious Sir George Earle Trophy, which is awarded for the Highest Performance of the Occupational Safety and Health Worldwide from the Royal Society for the Prevention of Accidents (RoSPA), UK. The prize adds up to a number of others won at local and regional level.

The reliability, HSE and management system achievements are a measurable evidence of the skill and expertise of the operating, maintenance and technical staff of the company, and also of the structured management approach toward its objective and key Performance Indicators (such as operation and maintenance reliability).

2. INTRODUCTION TO AXO WELDING

AXO WELDING is an Italian company specialized in servicing, repairing and modifying static equipment on site.

The company is young and dynamic, rapidly expanding to become an internationally recognized supplier of on-site services to some of the most important chemical, petrochemical and fertilizer producers in the world. among which GPIC, SABIC in Saudi Arabia, PETRONAS in Malaysia, YARA and ENI in Europe.

AXO WELDING operates on reactors, vessels, power boilers, furnaces and heat exchangers made of materials ranging from carbon steel to low and high alloyed steels, stainless steel, nickel alloys titanium and zirconium. The typical services offered take place during scheduled plant turnaround, a fact that has made the ability to strictly follow a tight schedule one of the main features of the company.

AXO WELDING has been fruitfully co-operating with GPIC almost from its foundation date.

3. UREA REACTOR CONSTRUCTION

The GPIC urea reactor was fabricated in 1997 by a European manufacturer. Its main features are:

- ✓ **Overall dimension and access:**
  Height 45m
  Internal Diameter 2.011mm
  External spiral stair
  510mm ID manway on top head.
- ✓ **Pressure part shell:**
  Single wall construction
  Thickness 74mm
  Carbon Steel (Vd TÜV 440/1)
- ✓ **Hemisferical heads:**
  Single wall construction
  Thickness 39mm
  Carbon Steel (Vd TÜV 440/1)
- ✓ **Corrosion resistance liner:**
  Thickness 7mm
  ASTM A240 TP 316 L Urea Grade.
- ✓ **Trays:**
  Total No. 14, equally spaced.
  Thickness 5mm
  ASTM A240 TP 316 L Urea Grade.
- ✓ **Tray supports:**
  No. 8 per tray.
  Double gusset support arrangement.
  Thickness 7mm.
  ASTM A240 TP 316 L Urea Grade.
- ✓ **Urea over flow pipe:**
  Fabricated from rolled plates.
  Diameter 6"
  ASTM A240 TP 316 L Urea Grade.

In consideration of the extremely high rate at which ammonium carbamate corrodes carbon steel at the process' pressure and temperature, the necessity to immediately detect any leak that may find its way through the stainless steel liner has been taken care of by the solution commonly employed on all high pressure urea equipment, that is, a net of No. 92 weep holes positioned near the liner welds and arranged as in figure 1.

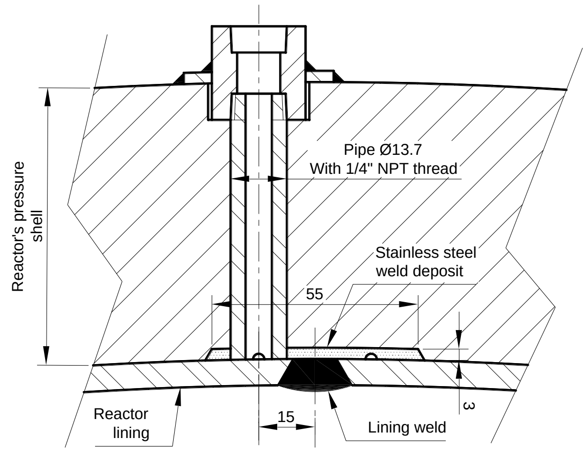


Figure 1: typical weep hole scheme

Figure 2 shows the tray support design as originally supplied with the reactor.

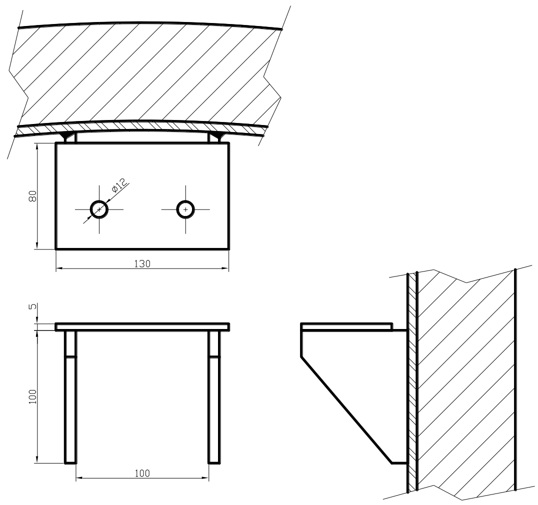


Figure 2: original tray support design

Control and assurance of the quality of the design and manufacturing process of the reactor was performed through the involvement of:

1) The Equipment manufacturer.
2) The QA/QC representative of the main contractor for the urea plant and all associated equipment.
3) The QA/QC representative of the owner of the urea plant and all associated equipment.
4) The Code authorized inspector.

4. APPROACH TO EQUIPMENT RELIABILITY

Up to the date of this paper the urea reactor has gone through nine internal inspections. Since the first inspection, when the unit was received and erected, the workmanship was evidently not up to the high standard required for HP urea equipment.

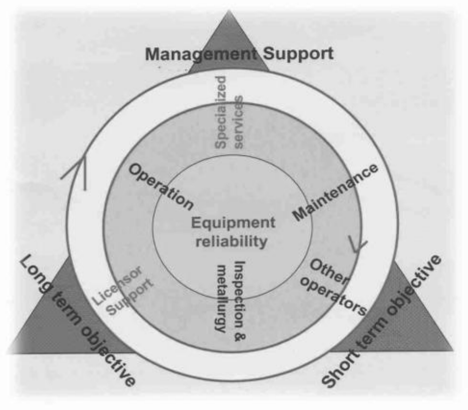
Discussion with the manufacturer, the main contractor and the licensor inspection engineers led to the preparation of some general guidelines for inspection and repair of the equipment:

1) Thickness check and random ferrite check should be carried out upon each internal inspection.
2) Only qualified and skilled manpower should work on repair activities.
3) Although the liner and support material was 316L urea grade, all repair should be carried out with 25Cr-22Ni-2Mo welding consumables.
4) When repairing the liner welds, no grinding should be made to a depth of more than 4mm.
5) All repairs should be subject to liquid penetrant (PT) examination and ferrite check.

These guidelines were effective in granting the basic and most important reliability target, that is, having no leak through the stainless steel liner.

In addition, another factor that contributed significantly to enhancing the reliability is the operational control and the monitoring of the process parameters, along with the sharing of knowledge with other urea operators. The former have ensured strict control day in day out over the oxygen content in the process, influencing significantly the corrosion rate. The latter have contributed with practical experience in inspecting, repairing and highlighting possible locations of future corrosion impact, based on the knowledge gained through the inspections and repairs carried out on reactors and other equipment in the HP synthesis section in other urea plants throughout the world.

The diagram below propose a dynamic network of interlink relationship between the concerned parties, which in the opinion of the authors are the owner, the licensor and the other operators. If the network is effectively utilized it can significantly enhance the life & reliability of any HP equipment in the urea process.



5. REACTOR INSPECTION HISTORY

From 1997 to 2002 the reactor underwent 4 inspections, each one followed by a number of minor repairs:

- In November 1997, the first inspection before the plant commissioning.
- In 1998, the warranty inspection after one year in operation.
- In 1999 a non-scheduled inspection when the plant was shut down due to operation upset in the decomposition medium pressure section.
- In 2000, the first planned plant turnaround.

What emerged was a general condition that, starting from a level of quality and workmanship not up to the desired standard, was progressively deteriorating towards a situation of seriously uncertain reliability.

The findings of the four inspections and the corrective actions undertaken are summarized in table 1.

Table 1: summary of inspection findings.

	Liner plates	Liner welds	Trays and tray supports	Overflow pipe	Corrective actions	Conclusions
1997	- Sharp chisel grooves and Smooth concentric marks at tray #10	- High ferrite content in the top dome liner welds. - Weld spatter marks and arc strikes.	- Contact between tray and liner in some areas. - Some points of contact between tray and liner.	- Contact between top elbow and dome liner. - High ferrite content (7.0÷8.5) in the pipe longitudinal welds.	- Weld spatter and arc strikes smoothed out - Defective welds ground and re-welded - Tray bolt holes enlarged - Overflow pipe cut and re-positioned	*Quality not up to the high standard required for urea HP equipment*
1998	- Slightly rough surface above tray #5	- Rough surface, predominantly in the HAZ (area from top to tray No. 10). - Corrosion marks in the stop/start spots - Shallow undercut in the HAZ.	- 90% of gusset welds partially or fully corroded. - Some corrosion on the support-to-liner welds. - Some corrosion in the tray welds.	- Welds between brackets and liner badly corroded.	- Worst corrosion spots in welds ground and re-welded. - Undercut recorded for further observation (no correction performed)	*Beginning of a worrying corrosion phenomenon in the most sensitive areas.*
1999		- Localized corrosion cavities.	- Localized corrosion cavities in the welds between the tray support and the liner, mostly on the top 9 trays but with some isolated spots below tray #14		- Same as 1998	*More progress in the corrosion of the welds*
2000			- Severe corrosion on 90% approximately of support-to-liner welds.	- Severe corrosion on pipe longitudinal weld and HAZ. - Severe corrosion on bracket-to-liner welds.	- Extensive repair of support welds. - Removal of ½ of a support on tray #13, due to a defect that was not possible to remove	*Corrosion rate apparently increasing.* *Current support design may hinder inspection and repair.* *Examination of removed ½ support raised suspicion that support-to-liner welds might not be full penetration.*

Correction of the defects found in these first four inspections was aimed to solve the immediate problem. After the first planned turnaround in 2000, though, the possibility of a more comprehensive action, directed to markedly increase the reliability of the equipment, started to be taken into consideration.

In January 2001, an extensive study was carried out in house to this purpose. The study included literature review on case history, other plant operation input, maintenance & inspection approach, and Licensor approach and philosophy on relining and repair. The study concluded the following:

1) All tray support gussets and solution outlet pipe brackets should be replaced in the next turnaround, possibly redesigning the support shape to minimize the number of welds on the liner and to have full access to weld inspection and maintenance activities.
2) The defective longitudinal and circumferential welds of the liner should be refurbished, in order to minimize the further development of an undercut on the side of the welds.
3) The relining of the upper section of the reactor was taken into consideration but, on the base of the results of the thickness measurement, case history of other plants

and licensor recommendations, such an action was not considered to be of immediate concern.

6. REPLACEMENT OF THE TRAY SUPPORTS

For the replacement of the tray supports, two options were taken into account:

Option 1: install tray supports of new design, welded directly to the existing liner.

Option 2: install tray supports of new design welded on a backing strip which, in turn, would be welded to the existing liner.

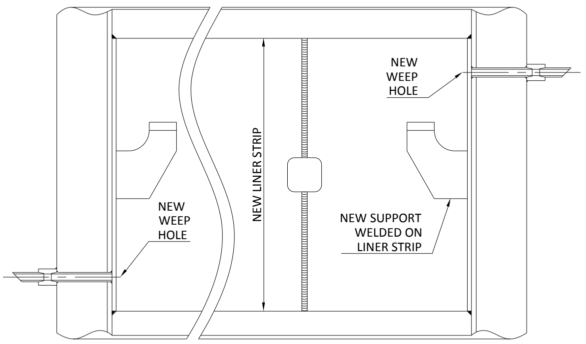


Figure 3: option 2, single support gusset with backing strip

The future accessibility for inspection and maintenance, and the absence of blind spots were investigated by making a mock up demo piece for both options and by actually carrying out on this mock-ups all possible maintenance activities, such as grinding, welding and testing of the welds.

The basic design for both options was the outcome of discussion between the licensor inspectors, the owner inspector / maintenance team, and other operators. The design was further improved after conducting the mock up demo test.

In addition to the above, and as a result of discussion with other urea specialists, it was also agreed to modify the inlet and outlet nozzles of the reactor by adding a cover strip over the welds and providing them with a leak detection system, since these welds were not monitored by weep holes and the possibility of a weld defect was present, due to vibration of the nozzles, specially the NH3 inlet.

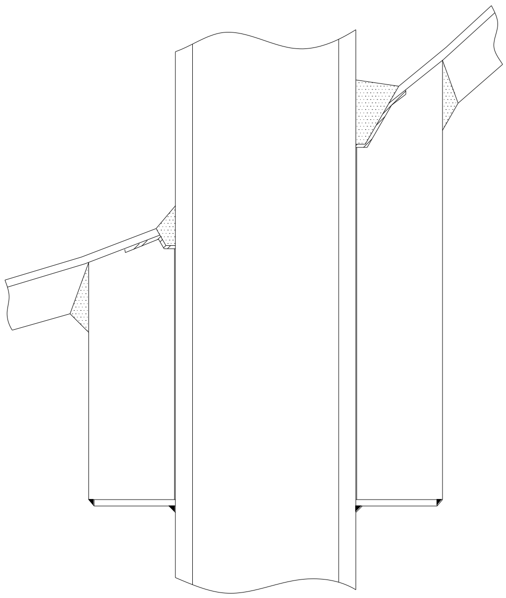


Figure 4: original nozzle joint layout

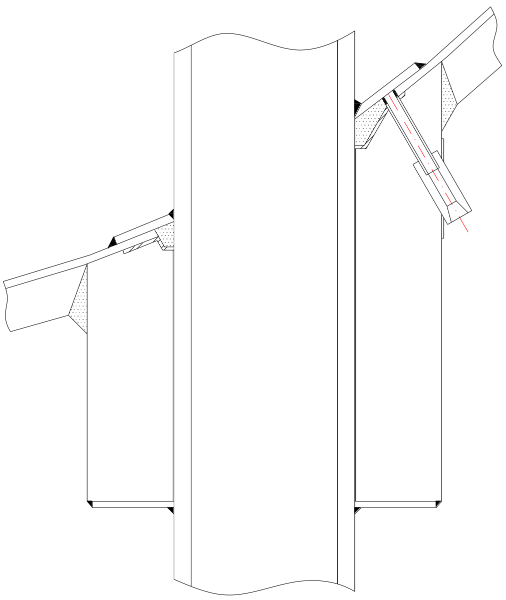


Figure 5: modified nozzle joint layout

Due to the amount and the specialized nature of the work, it was agreed to involve contractors familiar with urea reactors to carry out the above activities. Such involvement provided valuable on the quality control and safety approach to all activities inside the reactor.

The original schedule was planned for execution in November 2001, but unfortunately due to the 2nd Gulf war impact on the area, the overall program had to be postponed to March 2003.

7. TURNAROUND 2003: INSTALLATION OF THE NEW TRAY SUPPORTS

For turnaround 2003 the repair and modification activities were planned to include:

- Repair of the defects that would be found in the liner circumferential and longitudinal welds upon inspection. Eventually though, due to time limitations, not all defects observed were repaired. An immediate action was taken only on those areas judged as not capable of standing another 24 months of operation, whereas the repair of any other observation was deferred to next turnaround.
- Replacing the outlet pipe supports
- Installing cover strips on NH3, CO2 and Urea outlet nozzles.
- Replacement of the tray supports. Since the final choice between option 1 and 2 would be based on the results of the reactor's inspection, a complete set of tray supports manufactured per option 1 and a second, complete set manufactured per option 2 was procured.
- Wherever option 2 would be chosen for the new supports, modification of the tray periphery to account for the local reduced reactor diameter.
- Installation of an adjustable ring under the trays to make it possible to regulate the gap with the liner to the specified measure.

To perform the inspection and repair activities in 1997, 1998, 1999 and 2000, the method of access to the reactor had been the opening of staggered tray segments and the putting in place of aluminum ladders in a zig-zag layout all along the reactor's height.

For 2003 turnaround, though, an extensive scope of work had been scheduled, and such extensive scope of work had to be performed on many different elevations inside the reactor and involved the positioning of large pieces of material.

For this reason, the planning of the activities included the study of a new method of access, with the scope of making the transport and placements of the materials as easy and safe as possible and consenting a fast and safe evacuation of the personnel from the reactor in case of need.

The new access method involved the installation of a 1.5 ton hoist on the top of the reactor and the design and manufacturing of two manbaskets:

- One of rectangular shape, meant to be assembled inside the reactor and to be used only for the inspection, capable of transporting three persons.
- A second one of cylindrical shape, to be used for the repair operations, which could lodge one person only but was small enough to pass through the manhole.

Figure 6 cylindrical manbasket

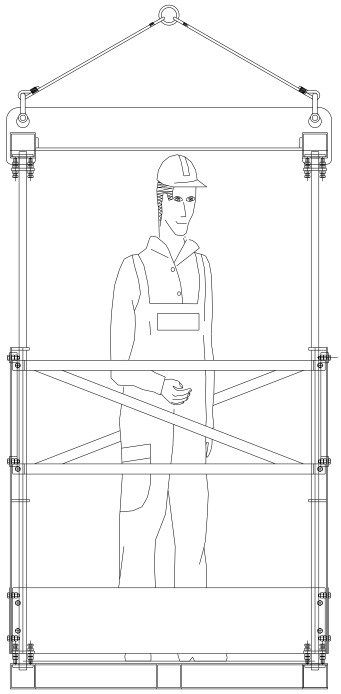


Figure 7 Rectangular manbasket

The inspection was carried out by GPIC, licensor inspectors and contractor project manager. Initial recommendation for support replacement after the preliminary inspection was to carry out option 2 for trays #1 to #7 and option 1 for the other trays but, due to interference between the welds of the new option 1 supports and the existing vertical liner welds for trays # 8 through #12, the final decision to apply option 2 to tray #1 through 12 and option 1 only for the last two trays.

It is worth noting that:

- As anticipated severe corrosion/deterioration was observed in the welds and in the parent metal of the tray supports and of the overflow pipe support brackets. Removal of tray supports and pipe brackets gave evidence that the welds connecting them to the liner were not full penetration. The areas where the supports and bracket welds lay were checked visually and by liquid penetrant (PT) examination. Weld buildup was carried out at trays #13 & #14, where the old support location would be exposed to the process fluid since the new liner strip had not been added.

  All new support and liner strip welds were subject to visual, liquid penetrant (PT) and ferrite examination and found satisfactory.

- The trays were observed to be corroded, in particular on the peripheral band. The bands were renewed with 25-22-2 material. The first four trays displayed the worst corrosion attack. Nevertheless, thickness measurement showed generally satisfactory condition.

- The lining parent metal was observed to be generally rough, especially on the area between the top dome and the 8th tray. Below this elevation the surface gradually smoothed down; within this area the roughness was at its worst between tray #4 and #6.

  Between trays #4 and tray #5 channel-like formation was observed on the liner parent metal. Maximum thickness loss was recorded to be 0.5mm and ferrite content at the channel to be 0.67%. The channel formation could be attributed to poor plate quality.

- Corrosion and undercuts were observed on the liner circumferential and longitudinal welds and HAZ. The maximum undercut measured was approximately 1.5mm. This was more evident above tray #6. The defects were repaired by welding using 25-22-2 filler material in a total of eight circumferential and four longitudinal welds. Visual inspection, liquid penetrant (PT) examination and ferrite check were carried out on all repair welds and found satisfactory. Localized corrosion was observed on a few locations of the previously repaired welds at the weld stop / start points.

- The top dome liner appeared to be in generally satisfactory conditions. The parent metal surface was slightly rough, the portion above the outlet pipe elbow was covered by a blue passivation layer, and some superficial defects were observed in the welds and HAZ, both longitudinal and circumferential.

- The bottom dome liner condition was satisfactory.

The outcome of this turnaround has shown that efficiency and safety of all operations carried out inside the reactor can be significantly improved by:

1) A well planned entry method. The overhead hoist and manbasket system had proved to be quite successful in reducing the work downtime due to movement of workers and material along the reactor, at the same time guaranteeing a safe and fast entry and, most important, evacuation way from the equipment.
2) An efficient communication system between the inside and outside of the reactor, in this case a cable interphone.
3) A powerful and reliable chiller/blower unit connected to the bottom nozzles of the reactor to guarantee a reasonable temperature inside and the flow of air necessary to remove the welding fumes, grinding dust, and PT vapors.
4) An optimal co-operation between the contractor and the owner inspector. This aspect was further improved by the positive contribution of the inspection engineers of other urea plants that GPIC utilized to support its personnel.

Also, the leak testing carried out after all welding was completed, put into light the necessity to consider very carefully the interconnection between the original and the new weep holes to avoid any bypass.

8. OPPORTUNITY INSPECTIONS, FEBRUARY & JULY 2004

After 2003 turnaround the next inspection was meant to come after 24 months. An operation upset in the ammonia plant in 2004, though, presented two opportunities to open and inspect the modifications carried out and to repair and assess the areas that had not been attended due to time constraint in 2003. The inspection was carried out in the traditional method of opening the tray manways and using a zigzag ladder arrangement.

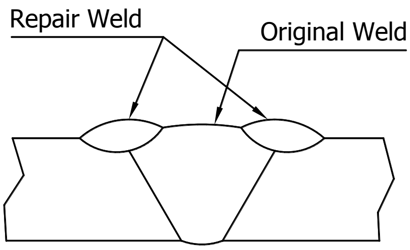
This opportunity shutdowns helped to highlight four significant observations that set the scene for 2005 turnaround preparation, in detail:

1) The general condition of the modified tray supports arrangement on tray No. 1 through tray No. 12 was excellent. No sign of corrosion / erosion was observed either on the parent material or in the welds. The weld overlay that had been made over the location of the removed supports at tray No. 13 and 14, though, showed signs of corrosion attack. This observation brought to the decision to extend the "Option 2" (liner strip + support) arrangement to tray No. 13 and tray No. 14 upon next turnaround.
2) On the areas that had not been repaired in turnaround 2003, excessive corrosion and undercuts were observed on the circumferential and longitudinal welds and HAZ. The observation was noted all over the original liner welds. The maximum undercut depth measured was approx. 3.5mm. The most affected areas were from the top dome and up to the 9th tray. The defects were classified based on severity of attack to allow prioritization for repair. Given the available time, again only the most affected areas were repaired. All defects were ground out up to 3-4mm of depth and repaired by welding using 25-22-2 filler wire. Liquid penetrant (PT) and ferrite check were carried out after welding. It was recommended to refurbish the full liner welds on the next turnaround.
3) Corrosion attack was observed on the uncovered portion of the repaired welds. These areas were continuously deteriorating and this trend could lead to possible attacks on the weld repairs. It was recommended to grind all uncovered weld portions and to make a weld buildup over them using 25-22-2- filler material.
4) The overflow pipe weld and parent metal were badly corroded. A number of holes were observed on the welds. It was recommended to renew the outlet pipe with 25CR-22NI-2MO material.

9. TURNAROUND 2005: REPAIR OF LINER WELDS AND REPLACEMENT OF OVERFLOW PIPE

Based on the findings and on the recommendations deriving from the previous inspections and repairs, the following action plan was scheduled for Turnaround 2005:

1) The supports of tray #14 and tray #13 would be replaced with the back strip arrangement.
2) The straight portion of the overflow pipe would be replaced. The replacement pipe, though, would be still 316L urea grade, as 25.22.2CrNiMo pipe delivery time would exceed the turnaround date.
3) The liner welds between the bottom dome and tray No. 14 would be repaired on the side, as shown in figure 8:



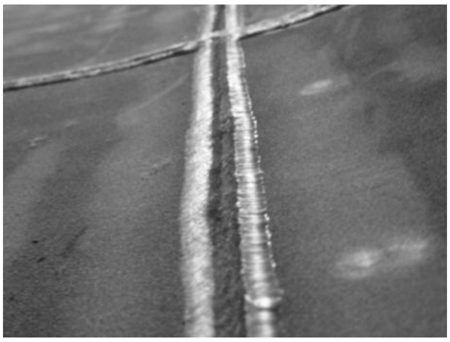


Figure 8: weld repair below tray No. 14

4) The liner welds above tray No. 14 would be repaired in the center of the weld bead, between the repairs made during Turnaround 2003, as shown in Figure 9:

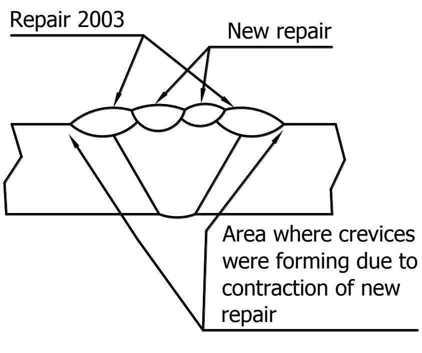


Figure 9: weld repair above tray No. 14

5) The weld repair would be attained through the following sequence of operations:
   - Grinding of repair area to a maximum depth of 1.5mm
   - Make repair weld by TIG using 25.22.2 rod
   - Perform PT examination on new weld

The activities proceeded as planned from the bottom end up to tray No. 10. At this elevation the PT examination of the weld shown a defect forming between the repair weld bead made in Turnaround 2003 and the parent metal (see figure 9). Probable cause was established to be the contraction of the new repair weld acting on the HAZ of the old one. After discussion with the contractor it was agreed to extend the repair to the whole width of the weld, including the repair welds made during Turnaround 2003.

When the repair activities reached the 1st circumferential weld above tray No. 8, the welders reported porosity and impurities from the ground area in the center of the weld bead, below the original weld. Close inspection revealed blackish dots which, checked for ferrite content, gave a high result (up to 1.0%). It was concluded that the original welds were of such a poor quality that they could affect the new weld material.

For this reason it was agreed to stop the extensive scope and carry out only spot repairs according to the sequence:

- Inspection to mark areas that required repair.
- Grinding up to 2mm of depth.
- Inspect the area for any abnormality
- Welding of ground welds.
- Liquid penetrant, ferrite examination and acceptance by inspection.

Furthermore, according to the original plan the whole of the passivation scale was to be removed from the top dome by grinding. This activity, though, was suspended due to the scale being too hard and the grinding activity removing some of the liner material.

Due to the amount of grinding and welding to be carried out on the dome, it was agreed to start the repair on one weld and then re inspect before finalizing the repair for the rest of the welds. During the inspection of the 1st repaired weld, cracks developed in what appeared to be the parent metal. Close inspection revealed that the cracks had developed in the scale due to un-complete cleaning before welding, the cracks were easily removed with shallow grinding not more than 0.5mm deep. It was therefore agreed to grind the area 100mm on both side of the welds and up to a remaining wall thickness of 8 mm on the liner parent metal to ensure complete removal of scale. The new procedure was adopted after experimenting on one weld which was found defect free after welding. Cracks were due to the high hardness in the scale.

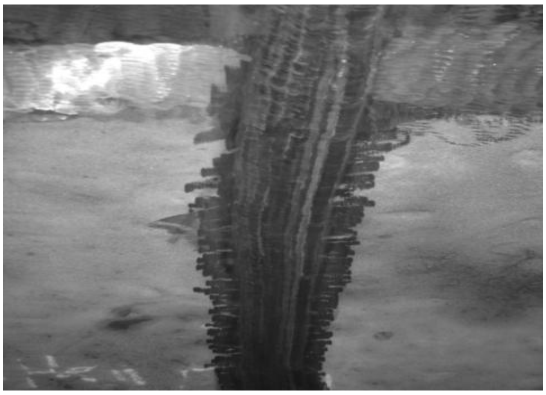


Figure 10: repair on top dome

The new overflow pipe was installed in five sections. The pipe installation was carried out alongside the liner repair activities. Pipe material was checked by alloy analyzer and it was found meeting the licensor specification.

After completion of all welding inside the reactor, air and ammonia leak tests were carried and no leak was detected. Then, the HP loop was boxed up and hydraulically pressurized at 150 bars. After pressurizing, the reactor was opened and PT examination was repeated to ensure no cracks developed due to weld stresses. All tests gave satisfactory results.

10. TURNAROUND 2007: RELINING OF MANHOLE, TOP DOME AND A PORTION OF THE CYILINDRICAL AREA

The common trait of all the inspections and repair activities carried out since the installation of the reactor was the evidence of an insufficient quality of the liner welds, which would potentially compromise the reliability of the equipment. Experience made in 2003 and 2005 turnarounds shown that a repair procedure that would improve the weld quality to the standard required for a reliable urea reactor was not technically achievable. For this reason, starting from T/A 2007, a reactor relining plan was put in place.

The relining would be carried out in more than one phase, due to the limited duration of a typical turnaround versus the time required to reline the whole reactor. The first phase interested:

1 - The manhole nozzle neck + gasket seating ring
2 - The top dome
3 - The top cylindrical portion, down to tray No. 1.

The relining plan consists in applying a new liner made of 25.22.2CrNiMo plates over the existing 316L UG liner. The plates of the new liner are 6mm in thickness, and they are rolled and cut into strips short enough to be inserted through the 510mm manhole. The strips are fit and welded into the reactor, each course being divided into three 120° sections. All longitudinal and circumferential welds connecting the new liner strips are interrupted by a weld gap, which is plugged by a cover strip. This arrangement allows a possible leak developing anywhere in the new welds to reach the closest weep hole passing through the weld gaps. Special attention had to be paid during the design phase to the weep holes arrangement, to minimize the need of new weep hole and to consent a rapid recognition of the defective spot in case of a leak.

The following sketch shows the relining layout for the top part of the reactor:

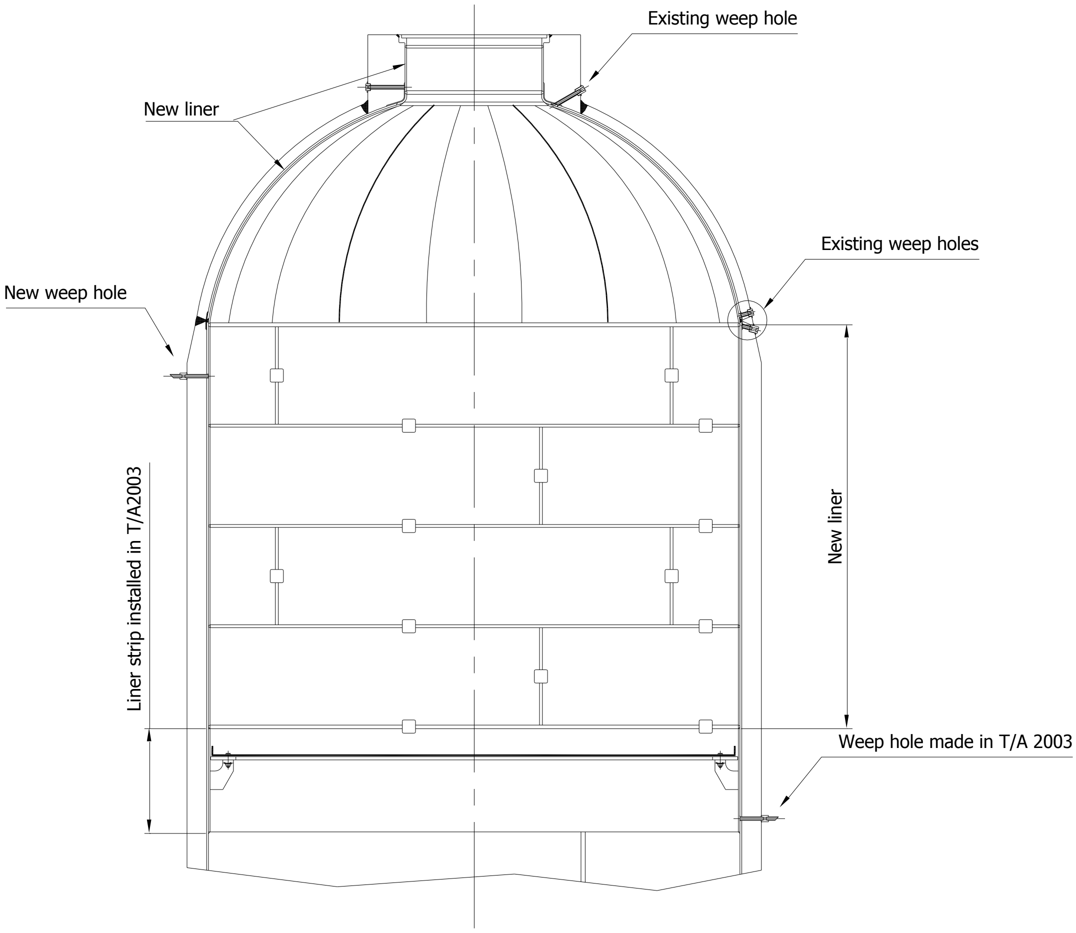


Figure 11: relining scheme

To avoid a reduction of the i.d. of the manhole nozzle, instead of applying a new liner over the existing one in this area the old lining was removed and replaced. This operation involved the removal of the gasket seating ring, which was machined away completely. A new piece consisting of a gasket seating ring + nozzle neck was then inserted and welded. After welding the new gasket seating ring was machined in situ to finished dimensions and tolerances.

The original top dome was made of no. 6 petals, each one controlled by No. 2 weep holes. In consideration of the bad condition of the top dome liner and to avoid making new weep holes, the layout of the new liner was made to reflect the existing one. The petals, though, were too big to pass through the manhole, so each one of them was cut into three pieces. The pieces were inserted into the reactor and welded together on the convex side. The original weep holes were extended through the thickness of the existing liner by drilling, and the partially welded petals were then fit on the existing dome by means of an appositely designed hydraulic tool. When all the petals were in place, welding was completed.

In addition to the relining, the following operations were performed during the turnaround:

1 - Complete inspection of the reactor, identification of some welds that required further repair and repair of the identified welds by the procedure applied in the previous turnarounds.
2 - Replacement of tray No. 4, 5, 8, 9, 10, 11, 12, 13 and 14 with new trays.

All the material used for the relining and the manufacturing of the new trays was procured from qualified vendors and tested in accordance to the specification of the Process Licensor. In the same way the welding procedure, in addition to be qualified per the requirements of ASME IX under the supervision of a third party, was also submitted to the tests required by the Process Licensor specification under the Process Licensor supervision. This guidelines were strictly followed to guarantee that the new liner conforms to the high quality standard necessary for a reliable urea reactor.

11. CONCLUSION

This paper present GPIC experience in minimizing the impact of the Urea Reactor corrosion problem through open channel communication with the process licensor, contractor and other urea plant operators. The nine inspection & repairs opportunities provided wealth of information to consider during the life of such item.

The design features and the process inherent corrosion phenomena present a challenge for any reliability program. The reliability of such equipment can be significantly improved if it was properly addressed at the design and construction stage taken in consideration the field experience of other operators and specialized maintenance contractors.

To summarize , the most important lesson learned from the reactor history up to the date of this paper is that knowledge / information sharing approach and dynamic / proactive planning are two side of the same coin that contribute to the success of reliability program design for urea reactor, HP equipment or any special feature/design equipment.

References

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