Successful inspection of two large Ammonia Storage Tanks

GPIC complex has two atmospheric ammonia storage tanks, each of 20,000 MT capacity. The tanks have been in operation since 1985. European Fertilizers Manufacturing Association guidelines for ‘Ammonia Tanks Inspection’ were adopted to set the frequency for inspection of the tanks.

One ammonia tank was decommissioned in 2004 for internal inspection as well as replacement of insulation blocks. The decommissioning, inspection and recommissioning project duration was 5 months. Based on this experience, the 2\textsuperscript{nd} tank was successfully decommissioned and inspected in the year 2006 in just 4 months.

This paper describes the methodology followed for the inspection project of the tanks along with details of decommissioning and recommissioning.

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1.0 Introduction

Gulf Petrochemical Industries Co. (GPIC) was formed on 5\textsuperscript{th} December 1979 as an equal partnership between the governments of Bahrain, Saudi Arabia and Kuwait with the primary objective of utilising Bahrain’s natural gas for the production of petrochemicals.

GPIC’s first project was its grassroots petrochemical complex at Sitra Island on the north-east coast of Bahrain. A site of 60 hectare was successfully reclaimed from the sea to construct the ammonia and methanol plants (with an original capacity of 1000 MT per day of each product), along with the related Utilities and Offsite facilities. In 1989, the ammonia and methanol plants were debottlenecked to a production level of 1,200 MT per day each. In 1998, GPIC diversified into the manufacture of fertilizer with the commissioning of a 1,700 MT per day single stream Granular Urea plant with associated Offsite facilities.

2.0 Description of the NH\textsubscript{3} tanks

The GPIC complex has two ammonia storage tanks (T-7101A and B) each of 20,000 MT capacity for storage of liquid ammonia at near atmospheric pressure. Basic engineering for the ammonia tanks was done by UHDE GmbH and
construction by Motherwell Bridge Engineering Ltd. The tanks were commissioned by Snamprogetti in 1985.

The storage tanks are cylindrical with domed roofs and designed as double wall double integrity tanks (cup in tank). Each tank is installed on a concrete raft foundation protected by an electrical heating system which prevents freezing of the load bearing insulation blocks and the subsoil below (Refer to Fig.1). The tanks are externally insulated with polyurethane foam (PUF). The aluminium cladding joints on the roof and sidewalls of the tanks are vapour sealed. The technical data of the ammonia tanks are given in Table-1.

![Figure-1: Tank Foundation Base Insulation Arrangement](image)

The ammonia storage facility has three screw type compressors for maintaining the tank pressure. Three high capacity ammonia pumps are available for export to ships. A separate vapour return line has been provided to handle vapours from the liquid loading line as well as from ships. A common flare system is provided for both the tanks.

### 3.0 Operation and Maintenance History

The ammonia storage tanks have been in operation since the year 1985. The performance of the storage tanks and the refrigeration system has been satisfactory due to the stable operation of the tanks between 40 and 50 mbarg pressure. The base heaters of the tanks have been operational throughout and an effective preventive maintenance schedule has been in force.

In 1995, both the tanks showed signs of deterioration of the roof and shell vapour seals. The insulation was found saturated with water at some locations on T-7101B. Complete renewal of the vapour sealing was carried out for both the tanks T-7101A and B. Again in 2002, the vapour sealing system for both the tanks showed deterioration and was renewed.
Type | Double wall double integrity cup in tank with dome roof
Design code | API 620 Appendix ‘R’
Storage capacity | 20,000 MT
Design temperature | -33°C
Design pressure | 100 mbarg
Tank diameter | 41.6 m (outer shell); 40.0 m (inner shell)
Cylindrical height | 25.4 m (outer shell); 24.8 m (inner shell)
Wall thickness (inner/outer shell) | 23 mm (bottom tier); 8 mm (top tier)
Roof thickness | 5 mm
Foundation | Concrete raft foundation.
Shell / Roof insulation | 100 mm PU-Foam with 0.8 mm aluminium cladding
Bottom insulation | 50 mm sand screed layer + 2 layers of foamed glass 100 mm and 200 mm insulation blocks
Base heating elements | 46 elements divided into two zones (2 thermocouples in each zone for measurement)
Base heater temperature indication | One for each zone

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Actual</th>
<th>Allowable Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Content (%)</td>
<td>85 – 90</td>
<td>&lt; 12</td>
</tr>
<tr>
<td>Compressive strength N/mm²</td>
<td>1.5 – 2</td>
<td>4 – 6</td>
</tr>
<tr>
<td>Density Kg/m³</td>
<td>500 – 550</td>
<td>400 – 500</td>
</tr>
<tr>
<td>Chlorides %</td>
<td>0.03</td>
<td>0.06</td>
</tr>
</tbody>
</table>

The stairway platform supports on the top for both the tanks were found to be corroded and these were renewed. To ascertain the condition of the tank foundations, the concrete based insulation blocks below tank T-7101B were inspected in September 2002. This inspection revealed severe icing and varying degrees of deterioration on the outer concrete insulation blocks (refer to Fig. 2).

A similar icing phenomenon was observed in tank T-7101A. To determine the failure mechanism of the concrete insulation blocks in the foundations of tanks T-7101A and B, specialists from UHDE and Motherwell Bridge were invited to site for inspection. The icing and deterioration phenomenon were reviewed. Core samples were collected from a depth of approximately 400 mm from the insulation blocks of T-7101B for analysis and compared to design specifications. The laboratory results of the core sample are shown in Table-2.

**Table-1 : Technical Data of ammonia Tanks**

**Table-2 : Core Sample Analysis**
The analysis revealed significant damage to the outer ring of insulation blocks. This was attributed to moisture ingress through ‘breathing’ of air into the blocks. The compressive strength was also lower than specification. This ‘breathing’ effect could be due to the damage to the vapour seal on the tank shell despite complete replacement in 1995. All the core samples showed severe icing at the outer edge of each sample.

As a temporary measure to prevent further ingress of moisture, a skirt made of aluminium cladding sheets was fixed to the bottom of the shell insulation covering the concrete foundation to prevent moisture ingress into the foundation and to divert condensation and rain away from the foundation blocks.

4.0 The Reasons for the Tank Inspection

Based on analysis of the insulation block core samples and site inspection findings and recommendations, replacement of the damaged bottom insulation blocks was planned.

Applying European Fertilizer Manufacturer’s Association (EFMA) “Guidelines on Ammonia Tanks Inspections” to GPIC’s ammonia tanks, the inspection frequency falls between 10 and 20 years. The tanks had not been inspected since commissioning.

GPIC management approved plans to decommission and inspect one tank in 2004. It was deemed necessary to carry out the internal inspection of the tank T-7101B along with replacement of the insulation blocks. The following broad strategy was adopted:

- Review and finalise proposals for the replacement of insulation blocks.
- Firm up inspection scope based on EFMA guidelines.
- Finalise decommissioning and recommissioning procedures for review by UHDE.
- Start decommissioning of T-7101B in April 2004 and replace insulation blocks under UHDE supervision, inspect and recommission the tank.
- Ensure stability and monitor performance of T-7101B for 2 years; then proceed with inspection of T-7101A in 2006.

On the advice of UHDE, it was decided to replace the damaged insulation blocks by installing wooden wedges made up of a specified type of hard wood.

5.0 Decommissioning Approach and Methodology

5.1 Options for decommissioning:

The complete list of activities was sequenced in line with the decommissioning and recommissioning operations. Following maximum reduction of the ammonia level in the tank, three options were considered for removal of the liquefied ammonia below the pump suction.

1) Natural evaporation.
2) Allowing the liquid to evaporate by admitting only hot ammonia vapour.
3) Adding water to the tank and pumping out the aqueous ammonia.

Natural evaporation was discarded as too time consuming. Water addition was also discarded due to associated waste disposal problem. The option of hot ammonia vapour addition was selected as it is environmentally friendly and the overall duration was within the required time schedule.

5.2 Project Team Formation:

A dedicated project team was formed in year 2003. The procedures for decommissioning and recommissioning were prepared and reviewed by UHDE. P&I diagrams for both decommissioning and recommissioning
situations were developed and subjected to a detailed Hazop study.

5.3 Need for supporting the tank:
One critical aspect was the need for supporting the tank prior to warming up of the interior as the damaged bottom insulation blocks would lose their strength while thawing. Based on static load calculations, it was decided to remove the insulation blocks between the anchor point locations to support the tank prior to thawing. The tank has been provided with 65 anchor points on the outer shell. These are embedded in the concrete raft foundation. Only after supporting the tank between anchor points, warming of the interior could be started, along with the removal of insulation blocks in the remaining locations and replacing these with wooden wedges.

5.4 Risk Analysis / Environment Impact:
The hazards associated with the project were identified by the team and an appropriate risk analysis plan was prepared. Suitable mitigation measures were also included to reduce the overall risk to an acceptable level.

The team also studied the environmental impact of the project. One important point that emerged from this study was the impact of mercury in the liquid ammonia. The presence of mercury had first been observed at GPIC during 1996 at the drain point of the heat exchanger in the ammonia refrigeration loop. The natural gas feed stock to the GPIC complex normally contains 50 microgram/Nm³ of mercury. A guard reactor was installed in 1996 to remove mercury in the feed natural gas. This prompted the team to consider the possible presence of mercury which could have collected there during plant operations before the installation of the mercury guard reactor.

Based on the experience of other plants and following UHDE’s guidelines, suitable procedures were developed for dealing with mercury, both to eliminate potential explosivity as well as dealing with disposal. To enable analysis for mercury in the vapor phase during purging operations, a portable analyser (Mercury Tracer 3000) was procured.

6.0 Temporary Modifications for Decommissioning

6.1 Emptying the tank:
In accordance with the decommissioning procedure, the level in the tank would be reduced to around 1000 mm using the normal export pumps, leaving approximately 900 MT of liquefied ammonia. To reduce the level further, a temporary pump would be connected to the 6” (150 mm) drain line of the tank. This would enable reduction of the level to 450 mm corresponding to the drain line elevation (Refer to Schematic-1). For the final stage of emptying, a knock-out drum would be provided between the tank and the pump. The knock-out drum would be connected to the refrigeration compressor circuit. By creating a suitable pressure differential between the knock-out drum and the tank, siphoning action would enable liquid to flow from the tank, thus facilitating the removal of the remaining quantity of liquid ammonia. The final liquid level would be approximately 50 mm which represents the protrusion of the drain line above the tank bottom plate.

![Schematic-1: Tank Drain Nozzle Elevation](image-url)
The knock out drum, transfer pump along with related piping and instrumentation arrangements are shown in Figure-3.

Figure-3 : Knock-out Drum and Pump Arrangement

6.2 Provision of 6” (150mm) vent inter-connection to flare:

As part of decommissioning sequence, the tank had to be purged with nitrogen to expel all ammonia vapour. During the initial phase of purging, the ammonia vapours would be recovered by the refrigeration compressors. As the ammonia content in the vapour decreased, the vapour would be diverted to flare. To achieve this, the ammonia vapour from tank T-7101A would be isolated, as both tanks are interconnected, followed by stopping the refrigeration compressors. Moreover the estimated duration for purging would be 10 days and in that period the refrigeration system had to be available for pressure control of tank T-7101A. To accommodate both purging of T-7101B and pressure control of T-7101A, the vapour return line from the export wharf would be disconnected from T-7101B and a suitable 6” (150mm) connection would be made to the flare system. This connection would facilitate trouble-free purging of T-7101B without any interruption. The refrigeration system would remain available for T-7101A throughout.

7.0 Decommissioning of Tank T-7101B

Based on the availability of the wooden wedges and ammonia export shipping program, the inspection was scheduled for the first quarter of 2004. All the required temporary piping systems with the above modifications for decommissioning were fabricated and installed. The decommissioning activities started on 10/04/2004.

7.1 Level reduction:

The main loading pump was started transferring from T-7101B to T-7101A and the level in T-7101B level was reduced to 1000 mm which was considered as a safe level for this high capacity pump. Further level reduction to 600mm was achieved using the temporary vane pump, which was connected to the 6” (150mm) drain of T-7101B. The vane pump discharged to the 6” (150mm) drain line of the tank T-7101A. The pump capacity was ~30 MT/hr. The knock-out drum which was installed between the tank and the temporary pump was
taken in service. The temporary pump was connected to the knock-out drum for final emptying.

7.2 Wooden wedging: (under cold conditions)
Two specialists from UHDE were on site to supervise the wedging. As planned, removal of the insulation blocks between the anchor points started, followed by insertion of the wooden wedges. After removing the insulation blocks, the surface was prepared by cleaning with cotton rags and applying glycol to melt and remove any ice formed. The surface was coated with a layer of bitumen and the wooden wedges were installed immediately. Core samples of second row insulation blocks were collected at several locations. The samples were dry, indicating the soundness of the second row of blocks, which justified the decision to replace only the insulation blocks in the outer row (refer to Figures 5 and 6). UHDE had also recommended replacing only the outer row insulation blocks as the inner row blocks were in good condition.

After supporting the tank, UHDE agreed to reducing the level in the tank further and proceeding to the subsequent decommissioning steps. The replacement of insulation blocks with wooden wedges in the rest of the outer row continued and was completed in 30 days (refer to Figures 7 and 8).

7.3 Emptying the tank:
The knock-out drum which had been installed between the tank and the temporary pump was taken into service. The pump was connected to the knock-out drum. The pumping rate was monitored hourly and it averaged about 25MT/hour. The knock-out drum pressure was 10 mbarg which was the compressor suction header pressure. The pressure in T-7101B was around 55 mbarg. The differential pressure
conditions between the main tank and the knock-out drum remained throughout the level reduction. During the last stages of pumping, liquid ammonia samples were collected and analysed for mercury. No mercury was found present. The activities for mitigating the effects of mercury were, therefore, not considered, although these had been planned.

### 7.4 Purging the tank:

Once it became impossible to pump the remaining liquid, T-7101B was ready for heating up with hot gas. This step was required to evaporate any liquid ammonia in the tank near the walls in the inner and outer shells as well as in the pipes in the outer shell. The ammonia tanks were built with a provision to supply nitrogen to the outer shell and the inner shell through a common line. This line supplies distributors which are located at floor level. Hot ammonia gas from the compressor discharge was introduced to the nitrogen ring header for heating. The tank has 16 skin thermocouples on the inner and outer tank shells. These indications were provided with appropriate trending facility in a small control panel. The heating rate was slow as the temperature of the inlet gas was 20 °C. A small jacketed steam heater was connected in the system and temperature of the ammonia gas was increased to 70 °C.

Gradually all the skin temperatures exceeded 10°C and heating was considered as complete.

### Chart-1: Heating Profile

During heating of the tank, the pressure was maintained at 60 mbarg and vapours were routed to the refrigeration system. The heating took 240 hours (refer to Chart 1).

After completing the heating operation, purging was started by admitting nitrogen at tank floor level at a rate of flow of 600 Nm³/hr. The tank pressure was maintained at 60 mbarg. Nitrogen
was routed through the same jacketed steam heater and the temperature was 70 °C. The vapours from the top of the tank were analysed for ammonia content. Inert gas levels in the refrigeration system were monitored based on the discharge pressure and the purge valve opening. After 3 days, the purge valve opening was at maximum and the nitrogen analysis at the top of the tank was 9% (Refer to Chart-2).

Because of high inert levels, it was decided to divert the vapours to the flare. Steam to the nitrogen jacket heater was isolated when the tank base temperature reached 20 °C. This was necessary in order to prevent the tank temperature exceeding ambient temperature. However, the temperatures stabilised at 40 °C which is a typical ambient temperature likely to prevail in the Arabian Gulf during the summer months.

The vapours were analysed for ammonia content at several points and after 9 days of purging, the concentration at the top of the tank was 1.58% ammonia. One of the tank’s safety valves was removed and a temporary vent pipe was installed to facilitate local venting. After confirming the purge gas analysis, nitrogen was closed and the tank was depressurised. The mercury content in the vapour was found to be 20 micro gram/m³.

7.5 Air purging:

After depressurising the tank, blinds were installed at all tank flanges. The blinds were fabricated of stainless steel material and thickness was chosen to withstand the design line pressure. Stainless steel material was preferred as it was considered suitable to withstand against cold ammonia which is likely to be present should any tank side valves pass. The 24” (600mm) liquid line was removed and an air-driven reaction fan was fitted in the
nozzle. The top central as well as periphery manways were opened and sweetening was started. A manometer was installed at the tank bottom to closely monitor the tank’s internal pressure at low ranges because of the high capacity of the reaction fan. The tank safety valves and vacuum relief valves were removed and electric air movers were mounted on these nozzles.

The outer tank manway cover was removed and after 3 days of sweetening, the manway diaphragm plate was cut using the cold cutting technique (refer to Figure 9).

The ammonia content in the annular space was 12 ppm and mercury was 5 micro gram/m$^3$ maximum. The inner tank manway cover was opened using full Personal Protective Equipment (PPE). The same cold cutting technique was adopted for removing inner tank manway diaphragm plate.

7.6 Tank entry and cleaning:

The tank was ready for entry after 40 days. Initial entry was made using full PPE to ascertain the condition inside the tank. Ammonia concentration around the floor was 10 ppm and mercury was 8 micro gram/m$^3$, both of which are well below the allowable limits. The allowable exposure limit for mercury is 100 micro gram/m$^3$ (OSHA standard). Oxygen levels were normal at 20.8%.

The first inspection of the tank revealed a fine film of oil over the entire floor and small puddles in a number of places due to the unevenness of the floor plates. Oil had collected against the outer periphery plate for a depth of maximum 20 mm since the tank floor plates have a fall of 25 mm from the centre towards the circumference. A two-staged approach was adopted for removing oil. First, the bulk oil was removed using vacuum truck and dispatched to a dedicated disposal facility. A total of 5 m$^3$ of oil was collected from the tank (refer to Fig. 10).

After removing the oil, the surface still had a lot of oil residue, puddles as well as an oil coating over the wall plates at the bottom remained. It was decided to clean the floor plates including the tank wall surfaces up to the first course weld joint using a high pressure hydrojet. While hydrojet cleaning, the oily water was removed continuously using the vacuum truck (refer to Figure-11).
A total of 35 m$^3$ oil / water mixture was removed and stored in dedicated tanks. The hydrojet cleaning took 5 days. The required 50V lighting with centrally earthed transformers, were provided and power cables were inserted from the top through one of the safety valve nozzles for safety. The bottom manways were kept free of cables and hoses to ensure quick evacuation of personnel, if required. The utility hoses were routed through the 24” (600mm) liquid discharge line into the tank. After hydrojet cleaning, the floor surface and wall became oil free and dry and posed no slipping hazard.

The oily water mixture was analysed to contain 7 ppm of oil only and could therefore be discharged safely to the holding pit of the plant’s water treatment unit for further disposal. The entire cleaning activity took 12 days.

8.0 Tank Inspection

8.1 T-7101B – Inspection Scope:

In line with the EFMA guidelines, the scope of inspection had been finalised in the project formulation stage. The detailed scope is as follows (refer Schematic-2):

8.2 Preparations for inspection:

Mobile scaffolding was erected for the internal tank shell inspection of the first and second course weld joints. For the annular shell first course weld joints, a small wooden structure was suitably arranged in line with the curvature of the annular space. A fixed scaffolding tower was installed covering the required EFMA scope of 10% T joints up to the top of the inner tank (refer to Figure-12).

Rope access methods were planned for the internal roof surface and annular space between
the two tanks. The required scaffolding was brought into the tank through the peripheral roof manway. All the weld joints were power-brushed to requirement of the Inspection Section.

Extensive safety checks and preparations were made for entry to the tank.

- A Confined Space Rescue Plan was prepared and provided to the team.
- A Confined Space Entry Control Format was developed and administered by a dedicated Safety Operator. This included a board displaying the company badges of the personnel inside the tank.
- A suitable warning arrangement was installed inside the tank to alert personnel in case of emergency in the complex.
- Air Chillers were provided for the comfort of the personnel as hot summer weather conditions prevailed.
- One reaction fan was kept running at the top of the tank to provide ventilation.
- All personnel entering the tank were provided with torch lights as a protection against power failure.
- An Emergency Evacuation exercise was carried out to check the adequacy of preparations and capabilities of the overall system.
- An independent Safety Auditor was appointed to monitor all work permits and related preparations.

8.3 Inspection Findings:

1) Inner Tank – Shell:

All the cleat marks on the first and second shell courses were cleaned by buffing and slight grinding. Fluorescent Magnetic Particle investigation (FMPI) was carried out on all cleat marks. A total of 23 linear indications were observed mainly on the first course shell (refer to Figure-13).

All defects were removed by grinding. The depth of defects varied from 1.0 mm to 1.5 mm. FMPI was carried out on all locations after grinding and all were found to be satisfactory with no recordable indications (refer to Figure-14).
On-site metallurgical examinations were also carried out on 10 selected locations where linear indications were identified by FMPI. The services of a metallurgical specialist were engaged for this task. The metallurgical study revealed that all the indications examined, both externally and internally, were original defects caused by either fabrication (lack of fusion, overlap or hydrogen cracking) or minor laminations formed during the plate rolling process. The metallurgical specialist studied the selected locations by replica test methods and concluded that these were not stress corrosion cracking marks (refer to Figure-15).

![Figure-15: Metallurgical Testing](image)

2) Inner Tank – Bottom Plate:

FMPI was carried out on the bottom plate welds and these were found normal except for one linear indication of 10 mm long on the annular plate (refer to Figure-16). The defect was removed by grinding and FMPI revealed no recordable indications afterwards.

![Figure-16: Floor Plate Inspection](image)

Vacuum box leakage tests were carried out on all bottom plate welds. No leakage was detected (refer to Figure-17). Ultrasonic thickness measurements were carried out and the results were normal.

![Figure-17: Vacuum Box Leakage Test](image)

3) Outer Tank:

FMPI was carried out on all 65 external tank securing anchor straps, shell to annular plate welds and tank nozzles (refer to Figure-18).

![Figure-18: FMPI Work on Outer Tank](image)

Twelve (12) anchor straps were found to have linear indications, classified as original construction defects. All indications were ground to a depth of 1 mm and further FMPI revealed complete removal of these indications. FMPI was done for annular welds (between inner and outer shell) and no defects were found.
4) Roof:

Externally, an ultrasonic thickness survey was done for all the roof plates. Vacuum box tests were performed for all roof plate welds joints and FMPI testing was carried out for all nozzles and structural attachment to the roof.

Internally, eddy current examinations were carried out on all central nozzle welds and the circumferential weld at the roof to outer shell joint. The under-side of the roof was visually inspected and the condition of the epoxy coating was found to be satisfactory. The internal inspection of the roof was done utilising rope access techniques (refer to Figure-19).

![Figure-19 : Rope Access Technique](image)

9.0 Recommissioning of Tank T-7101B

After the successful completion of the inspection and other related modification work, the recommissioning program below was followed.

9.1 Leak test with air/integrity checks:

After boxing up the manways, the tank pressure was gradually increased to 70 mbarg by introducing air from a portable compressor. Leak checks of all flanges were performed and subsequently the pressure was slowly increased to 100 mbarg. The pressure was held for 30 minutes and all the nozzles, anchor straps, foundations, etc. were checked for integrity and found normal. After that the tank was depressurised to proceed with nitrogen purging.

9.2 Nitrogen Purging:

The purging with nitrogen started at a rate of 200 Nm$^3$/hr., vented at the top of the tank. A nitrogen shortage at the time enforced a lower rate of purging.

After 15 days, the Oxygen level in the tank was found to be 2%. Removal of all blinds was started after reducing the pressure to 5 mbarg and maintaining nitrogen flow at 100 Nm$^3$/hr. After removal of the blinds, the tank pressure was again increased to 70 mbarg and all flanges connected to the tank were again leak tested.

It was decided to reduce the Oxygen level to less than 0.2% since the presence of Oxygen, even in very minor concentrations in liquefied ammonia, can lead to a considerably increased risk of Stress Corrosion Cracking (SCC). To achieve these very low concentrations, a pressurising and depressurising technique was adopted. These step actions effectively strip out pockets of Oxygen which are likely to exist in the tank under continuous purging conditions because of stratification.

The Oxygen level in the tank was reduced to 0.15%, which was confirmed by four repeated samples. The duration of purging was 20 days, a longer period than expected because of the nitrogen shortage mentioned (refer to Chart-3).
9.3 Water addition to the tank:

Based on UHDE’s recommendation, water was added to avoid direct impingement of liquefied ammonia droplets on the bottom plate during the cooling down period. These may create localised stress and possible cracks. The pool of water on the bottom plate ensured a uniform cooling effect over the entire bottom plate. In accordance with the dimensional calculations a volume of 20 m³ of demineralised water was introduced to the tank for this purpose.

9.4 Ammonia-Nitrogen exchange:

It was planned to add ammonia vapour to the top of the tank and to withdraw the ammonia-nitrogen vapours from the bottom, followed by flaring. This exchange operation was completed in 5 days. Subsequently the tank vapour outlet was connected to the suction of the refrigeration compressors and arrangements were made to start cooling down operations.

9.5 Tank cooling down:

To facilitate cooling down, liquid ammonia was introduced from the top of the tank. It was envisaged to utilise the loading line as liquid buffer from where the liquid ammonia was introduced to the central distributor at the top of the tank, using the cool down line. The total expected cooling down time was 54 hours, based on a 1 °C/hr cooling rate, however for safety reasons the cooling period was doubled using a cooling rate of 0.5 °C/hr. Cooling was closely monitored using the bottom plate and shell skin temperatures. The tank bottom plate temperature reached -31 °C after 7 days (refer to Chart-4).
Subsequently, liquid ammonia at a rate of 2 MT/hr was introduced to the tank until level indication was obtained. Later the tank level was increased to 300 mm to enable the tank and insulation system temperature to reach an equilibrium profile.

The tank was recommissioned successfully on 14/09/2004 and is in operation in a satisfactory manner since that time.

10.0 Inspection of Tank T-7101A

Based on the experience of inspecting T-7101B, GPIC has successfully completed the inspection and recommissioning of the other ammonia storage tank, T-7101A, during the first quarter of 2006. The same methodology and procedures were adopted for T-7101A. The temporary piping and relevant decommissioning arrangements were adapted and relocated to suit T-7101A. The complete project, including supervision of the insulation block replacement, was executed by the GPIC team. Roof insulation was not replaced as it was in good condition. Salient features of the inspection of T-7101A, along with T-7101B, are tabulated below in Table-3.
<table>
<thead>
<tr>
<th>Description</th>
<th>T-7101B</th>
<th>T-7101A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Year of decommissioning</td>
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<td>2006</td>
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<tr>
<td>2) Decommissioning method</td>
<td>Dry method with hot vapour addition.</td>
<td>Dry method with hot vapour addition.</td>
</tr>
<tr>
<td>3) Jobs carried out</td>
<td>Outer row insulation blocks replacement.</td>
<td>Outer row insulation blocks replacement.</td>
</tr>
<tr>
<td></td>
<td>Roof insulation renewal.</td>
<td>6” &amp; 24” liquid O/L bellows change.</td>
</tr>
<tr>
<td></td>
<td>6” &amp; 24” liquid O/L bellows change.</td>
<td>Enraf level monitor modifications.</td>
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<tr>
<td>4) Salient Inspection findings:</td>
<td>26 Nos. linear indications with max. 1.5 mm. (at cleat areas).</td>
<td>4 Nos. linear indications with max. 10 mm. (at cleat areas).</td>
</tr>
<tr>
<td>(a) Inner tank shell</td>
<td>1 linear indication.</td>
<td>No linear indication.</td>
</tr>
<tr>
<td>(b) Bottom plate</td>
<td>Linear indications at 12 anchors.</td>
<td>Linear indications at 9 anchors.</td>
</tr>
<tr>
<td>(c) Outer tank</td>
<td>Normal.</td>
<td>Normal.</td>
</tr>
<tr>
<td>(d) Roof</td>
<td>Linear indications of shell cleat areas revealed defects due to Hydrogen crack/lack of fusion.</td>
<td>All linear indications were due to fabrication defects and no evidence of cracks due to fatigue or SCC.</td>
</tr>
<tr>
<td>(e) Metallurgical Study</td>
<td>Fabrication defects (removed by grinding).</td>
<td>-</td>
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<tr>
<td></td>
<td>No evidence of service related crack growth externally (due to fatigue) or internally (due to Stress Corrosion Cracking).</td>
<td>-</td>
</tr>
<tr>
<td>(f) Repairs carried out</td>
<td>None.</td>
<td>None.</td>
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<table>
<thead>
<tr>
<th>Project duration:</th>
<th>Days</th>
<th>Days</th>
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<tbody>
<tr>
<td>(a) Wooden wedging (initial 65 locations)</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>(b) Wooden wedging (remaining locations)</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>(c) Tank emptying</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>(d) Hot gas purging</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>(e) N₂ purging</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>(f) Tank cleaning</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>(g) Inspection</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>(h) Reommissioning</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td><strong>TOTAL NO. OF DAYS</strong></td>
<td><strong>147</strong></td>
<td><strong>114</strong></td>
</tr>
</tbody>
</table>

Table-3: Salient Features of both ammonia Storage Tanks inspected

11.0 Difficulties Faced

11.1 Ammonia released from sand screed:

Longitudinal cracks were observed in the protruding layer and these were repaired. Even after emptying and purging the tank, ammonia was released from the sand screed and it was difficult to work in the annular space (refer to Figure-20). The annular space inspection and sand screed repair work were delayed in both the tanks due to the presence of this ammonia. Work could only be completed after applying adequate safety measures.

A 50 mm deep cement-sand screed ring is provided between the inner tank cup bottom and the outer tank bottom. The width of the ring layer is 900 mm and it protrudes by 125 mm outside the inner shell into the annular space.
12.0 Improvements

12.1 Provision of a skirt and insulation for the tank foundation:

To prevent ingress of water into the bottom insulation blocks through the foundation plinth a skirting cover was provided for the full circumference (refer to Figure-21). However, the provision of a skirting cover cannot eliminate condensation on the foundation. Water vapour inside the void space between skirt and tank wall can condense on the foundation as a result of the low temperatures there.
The void space between the skirt and the tank was filled with polyurethane foam to provide a vapour barrier to avoid condensation (refer to Figure-22).

13.0 Conclusion

(a) The successful inspection of the ammonia storage tanks at GPIC ensured the following:

- Improved safety and reliability of the ammonia storage tanks T-7101A and B.
- Assurance of tank integrity.
- Improved integrity of the tank foundations as a result of the replacement of damaged insulation blocks with wooden wedges.

(b) After 2 years of operation, the wooden wedge blocks in the foundation of T-7101B were checked and observed to be in excellent condition with no icing. This situation more than justified the decision to replace the insulation blocks with wooden wedges. (refer to Figure-23).

(c) Both the inspection projects were accomplished safely without any incident.

(d) The detailed schedule, operating procedures and comprehensive checklists ensured the progress of the inspection work in accordance with the plan. The effective interdepartmental communications and regular reviews contributed much to the overall success of these critical projects.