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Operation, Inspection and Maintenance of Ammonia Storage Tanks in Fertilizer Industry

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Abstract

Ammonia storage tank is an integral part of any ammonia producing and consuming facilities. The tank design has undergone significant improvement from pressurized bullets and Horton spheres for storing ammonia at ambient temperature in small quantities to atmospheric storage tanks for storing ammonia in liquid form at -33 ºC in large quantities. The installed capacity of Horton spheres in the country varies from 1000 to 3000 metric tonnes (MT) and atmospheric ammonia storage tanks from 3000 to 20000 MT. Ammonia is a hazardous chemical. Therefore, safety and integrity of these tanks are extremely important for the operating plants and the surrounding community. Horton spheres are covered under SMPV Rules and follow periodic inspections every five years as per the statutory requirement. There is no statutory inspection requirement for atmospheric storage tanks. The atmospheric storage tanks are susceptible to stress corrosion cracking. Periodic inspection through various NDT techniques has been employed to ensure integrity of these tanks during operation. A detailed inspection requires decommissioning and re-commissioning of the tank and hence longer service outage. In order to update the practices followed by various plants in inspection and maintenance of ammonia storage tanks, FAI collected the information from various fertilizer plants. The study covers 68 ammonia storage tanks belonging to 30 fertilizer plants. The paper includes inspection, commissioning and decommissioning practices followed by these plants. Observations during inspection and remedial measures are also covered.

Key Words : Ammonia storage tank, vessel, Horton sphere, atmospheric tank, commissioning, decommissioning, risk based inspection

1. Introduction

Ammonia is the key intermediate required for incorporating nitrogen in nitrogenous and complex fertilizers. All urea plants are integrated with ammonia plants. These plants have storage tanks at the plant site. Some complex fertilizer plants also operate ammonia plants but most of the requirement is met through imports. Ammonia storage tanks in these plants are installed at the plant site as well as some plants have installed the tanks at port jetties for imported ammonia. There are two locations where the ammonia storage tanks are being maintained by an external agency and information of one of the location was available and covered in the study.

Ammonia storage tanks can be categorized as pressurized and atmospheric type. The pressurized or Horton sphere tanks maintain pressure from 3.5 to 8 kg cm^{-2} and these are regulated as per the Static and Mobile Pressure Vessels (Unfired) Rules, 2016 issued by Department of Industrial Policy and Promotion, Ministry of Commerce and Industry, 2016. These tanks are suitable for small storage capacity of up to 5000 MT. In case of atmospheric ammonia storage tanks, the pressure is maintained close to atmospheric pressure but temperature is maintained at -33 °C. These tanks have capacity from 5000 to 20000 MT in the country. These tanks are relatively safer due to low pressure of storage.

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Keeping in view the risks involved in storage of ammonia, there are strict protocols for design, operation and maintenance of these tanks. FAI had kept its focus on safety of ammonia storage tanks. A paper on the safety and integrity of ammonia storage tanks was presented in FAI Annual Seminar 2012 (Pattabhatula, et al., 2012). A special issue of Indian Journal of Fertilisers on operation, inspection and maintenance of ammonia storage tanks was also published in June 2013 (FAI, 2013). Further, a need was felt to catalogue the inventory, inspection and maintenance practices being adopted by fertilizer plants. The present study covers 68 ammonia storage tanks belonging to 30 fertilizer plants. This represents ammonia storage capacity of 0.516 million MT. Two atmospheric storage tanks are under commissioning and are not covered in the study. **Table 1** provides the summary of the ammonia storage tanks.

2. Types of Ammonia Storage Tanks

2.1. Horton Sphere Tanks

There are 12 Horton sphere tanks in service at seven locations. All the Horton spheres are at plant sites. The characteristics of Horton sphere tanks with respect to capacity is given in **Table 2** and vintages are shown in **Figure 1,** respectively. Most of the Horton sphere tanks are of 1500 MT. Nine of the Horton sphere tanks are more than 40 years old. The

Table 1. Summary of ammonia storage tanks

Particulars	Nos.
Plants	30
Storage tanks	68
Horton spheres	12
Atmospheric storage tanks	56
Plant sites	
Horton spheres	12
Atmospheric storage tanks	49
Port sites (Atmospheric tanks)	7

youngest Horton sphere is 26 while the oldest is 52 years old.

Table 2. Capacity-wise categorization of Horton sphere tanks

Capacity (MT)	Nos.
1000	2
1500	7
3000	3
Total	**12**

2.2. *Atmospheric Storage Tanks*

The atmospheric ammonia storage tanks can be designed with either single or double wall. The double walled storage tanks may have double integrity or cup in tank or cup in cup structure. The tanks may further have a bund or dyke. These tanks have refrigeration system, vapour blower and flare stacks. Safety design features may include arrangements for water spray at tank top, water curtains around compressor house, ammonia transfer pumps, battery limit insulation valves to control leakage of ammonia, instrumentation system for monitoring pressure, level & temperature, operating alarms & interlock systems for critical parameters and reliable power supply.

There can be a number of combinations of atmospheric ammonia storage design and structure. For ease of reporting, these have been classified as single wall with dyke, double wall with dyke and double wall without dyke **(Table 3).**

Table 3. Categorization of ammonia storage tanks

Type of ammonia storage tanks	Number of tanks
Atmospheric - double wall tank with dyke	17
Atmospheric - double wall tank without dyke	36
Atmospheric - single wall tank with dyke	3
Total	**56**

Capacity of atmospheric ammonia storage tanks are given in **Table 4**. Out of the 56 atmospheric ammonia storage tanks, 26 are of 10000 MT capacity followed by 20 tanks of 5000 MT capacity. The largest capacity of a tank is 20000 MT. Vintage-wise details are shown in **Figure 2**. It may be seen that most of the atmospheric storage tanks have vintage between 20 to 40 years. Four tanks are between 40 to 50 years and oldest being 45 years. One atmospheric storage tank of 10000 MT and another of 20000 MT are under construction.

Table 4. Capacity of atmospheric ammonia storage tanks

Capacity (MT)	Nos.
3000	3
5000	20
7500	1
10000	26
15000	2
18000	1
20000	3
Total	**56**

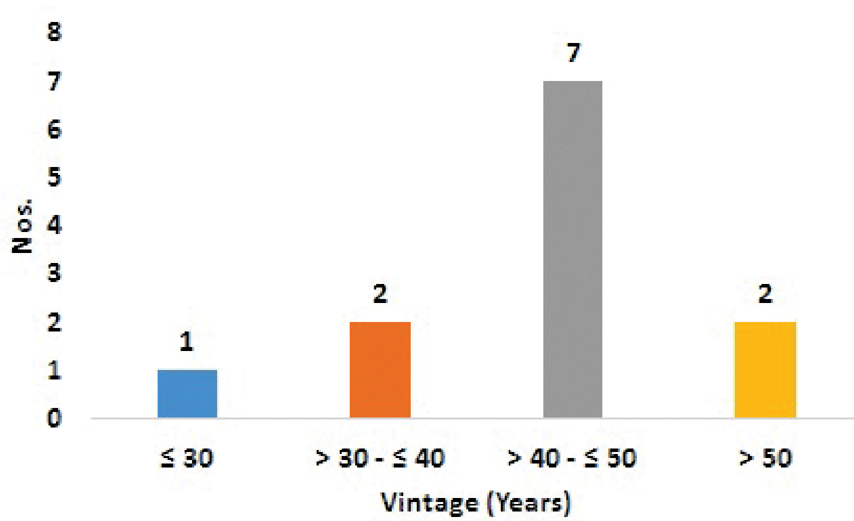

Figure 1. Vintage-wise categorization of Horton sphere tanks

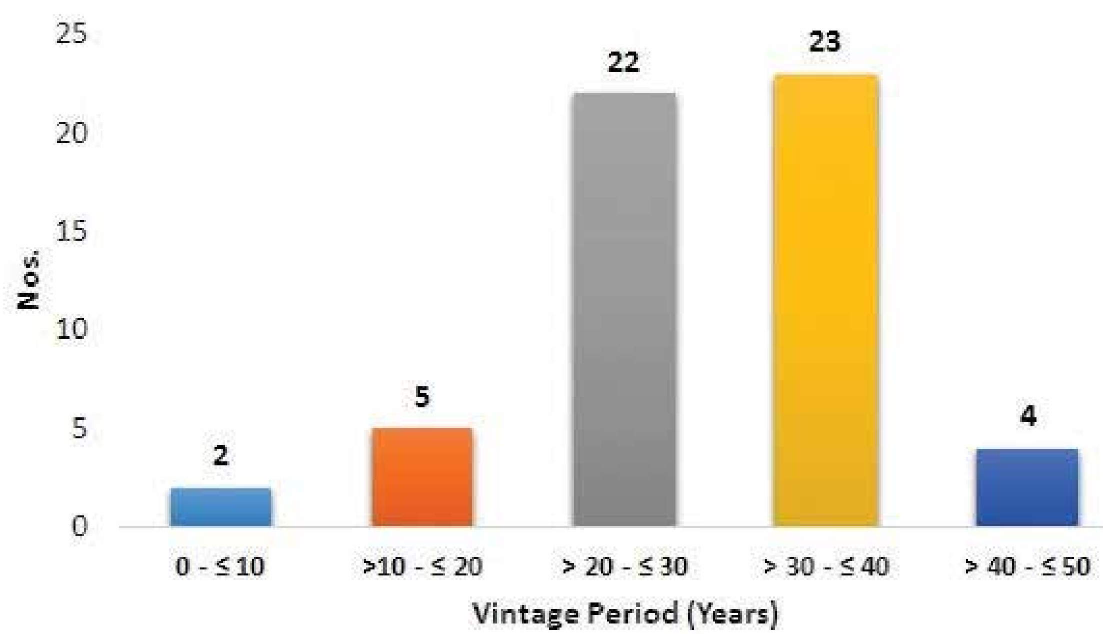

Figure 2. Vintage-wise categorization of atmospheric storage tanks

3. Inspection and Maintenance of Ammonia Storage Tanks

3.1. Horton Spheres

As per SMPV rules, ammonia Horton sphere tanks are subjected to first periodic inspection after two years of its installation and the inspection shall consist of detailed Non-Destructive Testing (NDT) of the vessel. The second periodic inspection has to be carried out after three years of first inspection and shall involve NDT and hydraulic testing of the sphere. Subsequently, periodic inspections including NDT and hydraulic testing need to be carried out every five years. Under periodic testing of pressure vessels in service, it has been specified that in case of vessels which are so designed, constructed or supported that they cannot be safely filled with water or liquids for hydraulic testing or which are used in services where traces of water cannot be tolerated, the Chief Controller may permit pneumatic testing along with NDTs instead of hydraulic testing, as per procedure laid down in vessel fabrication code; after satisfying himself about the adequacy of the safety precautions undertaken.

All the Horton spheres in the country are more than 30 years old and carrying out inspection every 5 years. Annual inspection is also carried out by plants. The types of inspection activities carried out by different plants are listed below:

3.1.1. Inspection every 5 years:

i. Residual life assessment (RLA).

ii. Structural stability test of tank foundation during RLA.

3.1.2. Annual Inspection:

i. Visual inspection of tank. Removal of insulation pockets from bottom 2 metre portion and visual inspection of insulation condition as well as vessel

ii. Thermography

iii. Testing of safety relief valves as per rule 18 of SMPV Rules 2016

iv. Inspection of support legs and its foundation

v. Thickness testing of connecting pipelines

vi. Painting of tank column legs and cross bracing structures

vii. Thickness testing of cross bracing structures

viii. Ultrasonic thickness measurement

ix. Ultrasonic flaw detection welds

x. Dye penetrant test

xi. Hardness test

xii. Hydro pneumatic test

xiii. Wet fluorescent MPT

xiv. Corrosion mapping

xv. Radiography

3.1.3. Risk Based Inspection (RBI): None of the plant has reported carrying out RBI inspection for Horton spheres.

3.1.4. Observations: No major defects were observed by the plants. Minor fissures were detected in a Horton sphere in the areas of temporary attachments welded during sphere fabrication. The cracks were grounded and removed and welding was required. However, a plant mentioned that superficial surface pitting marks are observed sometimes inside the surfaces which are treated as per Petroleum & Explosive Safety Organization (PESO) guidelines by PESO approved party.

3.2. Atmospheric Storage Tanks

Plants are carrying out inspection of atmospheric tanks periodically. Plants have been carrying out inspection annually, monthly, fortnightly and even daily basis. Of course, types of inspection with short periodicity differ from annual inspection. Complete internal inspection requires decommissioning and re-commissioning of the tank. There is always a risk of thermal stress and ingress of moisture during decommissioning and re-commissioning. This in turn may increases the probability of Stress Corrosion Cracking (SCC) initiation. RBI has been carried out by a few plants to identify the critical areas, optimize the inspection schedule, and adopt most appropriate method of inspection. RBI was carried out by 7 plants covering 10 numbers of atmospheric storage tanks.

3.2.1. Types of Non-Destructive Testing

Various inspection techniques being followed during the routine inspection as well as during decommissioning and re-commissioning are listed below:

- Visual/physical examination
- Ultrasonic thickness measurement
- Wet fluorescent Magnetic Particle Inspection (WFMPI)
- Dye penetrant testing of welds
- Ultrasonic flaw detection
- Hardness measurement
- Metallography examination
- Vacuum box testing
- Radiography of T-joints
- Bottom plate inspection by low frequency electromagnetic examination
- Foundation examination
- Hydrostatic & hydro-pneumatic test
- NDT tests from civil engineering point of view are:
    - Concrete core compressive strength test
    - Ultrasonic pulse velocity test
    - Rebound hammer test
    - Harden concrete carbonation depth test
    - Half-cell potential test

3.2.2. Details of Routine/ Periodic Inspection

Routine and periodic inspections are being carried out on daily, monthly, quarterly and annual basis.

- **Once in 2/3/4 years**: Thermo-graphic survey, safety & relief valve testing and settlement check.
- **Annual Inspection**
    - Visual inspection of tank
    - Thermography of tank to access tank insulation and find out any cold spot
    - Inspection/calibration of pressure relief valves and vacuum relief valves
    - Structural stability test of tank foundation
    - Thickness testing of connecting pipelines, painting of tank roof
    - Safety audit of the facility, through Authorized Third Party
- **Half Yearly:** Calibration of flow type level transmitter, calibration of gas detectors mounted on tank top, in service thermography inspection, roof plate thickness check and plants inspection.
- **Quarterly:** External visual inspection for corrosion in foundations, insulation, connected valves, roof paint, connected platform & pump suction bellows, thermography of tank bottom and whole tank.
- **Monthly:** Moisture and O_2 level monitoring in vapor and liquid ammonia. Safety Audit of the facility through internal team.
- **Fortnightly:** Filling up checklist every 15 days by operational department.
- **Daily:** Data monitoring of process & loading arm parameters. Check list to ascertain equipment and safety requirements.

Besides above checks, other periodic inspections include checking/calibration of instruments including level indicators, earthing systems, ammonia sensors, flare system/pilot burning and control valves.

3.2.3. Observations during Routine Examination and Maintenance Activities

- External corrosion and algae formation at isolated locations.

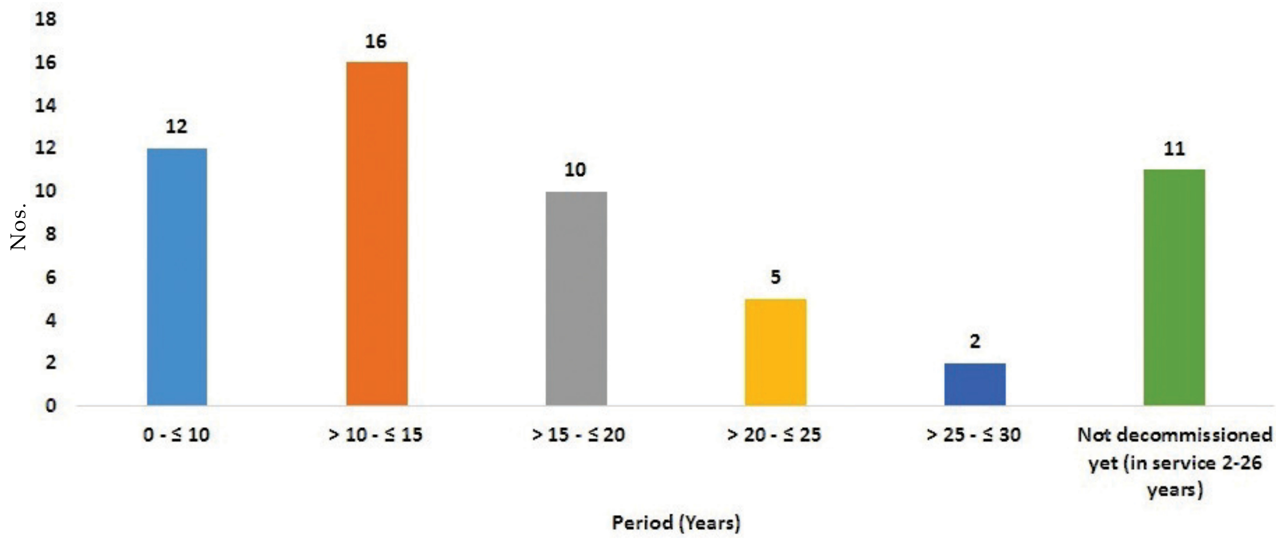

Figure 3. Years of service before first decommissioning

- Some minor spalling observed was attended.
- Tank bottom insulation of periphery Siporex block was replaced.
- Inner wall two anchors weld joints were found cracked which were repaired by welding.
- All primary isolation valves were replaced with stainless grade and gland design was also changed to bellow seal type to ensure more safety.
- Tank top hand railing was replaced with stainless grade to avoid frequent corrosion issues.

3.2.4. Decommissioning of Storage Tanks

There is no statutory requirement for inspection of atmospheric ammonia storage tanks. Guidelines were published (Fertilizer Europe, 2014) for inspection of atmospheric ammonia storage tanks. The document provides guidance for in-source inspection of atmospheric ammonia storage tanks located in Europe. The document focuses on periodic inspection and regular monitoring of atmospheric ammonia storage tanks. Plants in India have been carrying out decommissioning of the storage tanks based on condition monitoring results. In one instance, a plant had to carry out inspection of the tank located at port due to Hon'ble Supreme Court's Order. The tank was commissioned in 1976 and first decommissioned in 1985. In 1994, the Hon'ble Supreme Court appointed M/s EIL to carry out structural integrity and location suitability of the ammonia storage tank at port. This was followed by de-commissioning in 2003 for quantitative risk assessment and detailed technical study. The study recommended continued operation of the tank in its present condition and was also endorsed by the Hon'ble Supreme Court. **Figure 3** depicts the years of service before first decommissioning of atmospheric storage tanks after its installation. It may be seen that most of the tanks were decommissioned during 10 to 20 years' period.

Eleven plants have not yet decommissioned the atmospheric tanks. The longest atmospheric tank in service is for more than 26 years. The plant is now planning to inspect the tank and construct a 5000 MT tank for the purpose. Other plants which have not been decommissioned include six plants with service period between 18-23 years, 2 plants are in service for 11 years and one each for 7 and 2 years. A plant decommissioned its two tanks of 5000 MT each for detailed inspection after 7 years of service. There is no specific reason mentioned for such an early inspection. However, plant observed some minor spalling during routine inspection. The same plant carried out the second decommissioning of one of the tanks after 19 years (2020) and no major observations were made. The other tank is still in service after 20 years of the first decommissioning and second inspection is not yet planned. The other tanks which were decommissioned within 10 years of commissioning are: 2 tanks after 8 years, 4 tanks after 9 years and rest 4 after 10 years in service.

Second decommissioning has not been carried out in 29 tanks. There are 13 tanks that were decommissioned only after 10 years **(Table 5).** Six tanks were decommissioned between 10-15 years and another six between 15-20 years and one tank was decommissioned after 21 years. Only one tank has been decommissioned 3rd time for inspection.

Table 5. Years of service before second decommissioning

Period	Nos.
0 - ≤10	3
> 10 - ≤ 15	6
> 15 - ≤ 20	6
> 20 - ≤ 25	1
Not decommissioned after 1st decommissioning	29
Total	**45**

3.2.5. Observations after 1st Decommissioning

i. Corrosion/ pitting observed on the roof of the tank. Patch work was done on the same.

ii. Roof plate noticed with thickness loss and then replaced entire roof plate after 15 years of commissioning.

iii. Small porosity observed during DPT in one location at circumferential seam removed after grinding.

iv. The sand pad over and underneath the foam glass were found soaked in water.

v. Anchor strips of inner cup are to be rectified to permit thermal/expansion.

vi. Ring Girder palates of the inner cups were found distorted over a major section of the periphery.

vii. The annular layer of the PCC failed at one location of the tank.

viii. Bottom plates of the inner cup were deformed over a wide area.

ix. Slight bulging of annular space bottom plate at random.

x. The first supporting clamp of flash cooler outlet liquid line to storage was found detached.

xi. Crack indications in inner tank bottom and shell plates were observed.

xii. Ice formation on the periphery of the outer tank bottom which resulted in forced inspection.

xiii. Some defects were observed on inner tank shell T-joint. Corrosion observed at nozzle. Inner tank shell has been newly fabricated in 2020-2021. This tank was first decommissioned after 26 years.

xiv. Siporex blocks were replaced with perlite + concrete mix below outer tank annular plates.

3.2.6. Observations after 2nd Decommissioning

i. At one location, two tanks of double wall double integrity cup in cup without dyke were commissioned in 1986-87. Both the tanks were first decommissioned for inspection after 12 years. Second decommissioning for inspection was carried out after 19 years in one case and 20 years in the other. In both the tanks, corrosion/pitting were observed on top roof tank. Patch work was done on the same.

ii. An atmospheric double wall tank of 5000 MT commissioned in 1992 was decommissioned first time in 2005. Crack indications were observed in inner tank bottom and shell plates. These were rectified. The tank was decommissioned second time for inspection in 2019. Similar observations of crack indications in inner bottom tank and shell plates were noticed. The roof of the tank was replaced which was damaged due to corrosion. At the same location, another tank of 15000 MT commissioned in 1998 was decommissioned twice. The first decommissioning was in 2011 in which no defects were observed. During second decommissioning in 2018 *i.e.* after 7 years of first decommissioning, roof was found to be damaged by corrosion and was replaced.

iii. A tank commissioned in 1991 was first decommissioned in 2002 after 11 years and was found in satisfactory condition. The second decommi-ssioning was carried out again after 11 years in 2012-13. Tank was found in satisfactory condition. However, as per the recommendation of the agency, approximately 10-m length of ammonia line from refrigeration plant and ammonia circulation return line were replaced with SS 304 due to thickness reduction.

iv. A 5000 MT double wall double integrity tank with polyurethrene foam insulation on external wall was installed in 1993. It was first inspected after 11 years in 2004. Various NDT carried out inside the tank and no repairable defect was observed. The tank was decommissioned again after an interval of 11 years in 2015. Inspection was carried out after liquid ammonia was observed in annular space. Minor shifting of inner tank was noticed resulting in damage of expansion bellow and dislocation of ammonia filling pipeline. The pipeline and expansion bellow were replaced and tank operation is satisfactory.

v. An 18000 MT double wall tank was first decommissioned after 13 years of service. No major observations were found. Second decommissioning was carried out after 20 years of first decommissioning. Pittings were observed on the shell plate and near weld joints, flanges and insert plates. Curb angles of tank were found damaged. All recommended repairs were attended and RBI of tank was carried out before commissioning again.

vi. A 10000 MT double wall double integrity tank with dyke was decommissioned after 15 years. There were 231 cracks detected in WFMPI test. All cracks were attended by grinding and welding except four cracks which did not require welding. Roof area surrounding walk way's inner support plates were replaced with SS material (48 supports = 96 plates replaced). Support joint was covered with fibre cloth and painted with anticorrosive paint (STANGARD 1311 CORROKOTE). Due to thickness reduction in dome roof plate, a SS-304 plate (310 ~ 330 mm width & 5~6 mm thickness) patch work was carried out on dome throughout the circumference.

3.2.7. *Observations after 3rd Decommissioning*

i. Only one tank was decommissioned third time. The 10000 MT capacity tank was commissioned in 1980 having single wall design. The first decommissioning was done after 9 years in 1989 and 2nd decommissioning was carried out after further 10 years in 1990. On both the occasions, no abnormalities were reported. During third decommissioning in September 2009, 743 cracks were detected by Wet Fluorescent Magnetic Particle test. Out of which, 696 cracks were repaired by welding and 47 cracks were removed by grinding. Plant has now planned to replace single wall tank with new double wall tank. Contracting work is under progress. It is expected to be completed by year 2023.

4. Conclusion

Fertilizer plants are operating both pressurized and atmospheric ammonia storage tanks. These pressurized tanks are inspected periodically as per the statutory requirement. There is no regulation for inspection of atmospheric storage tanks. However, plants have been inspecting its integrity periodically to maintain high level of safety. The important observations during inspection of ammonia storage tanks by various plants have been compiled. These will help the plant managements to learn from other plants' observations/actions and take appropriate steps to ensure safety and integrity of these critical storage vessels.

References

Department of Industrial Policy and Promotion, Ministry of Commerce and Industry. 2016. Static and Mobile Pressure Vessels (Unfired) Rules, 2016 dated 1st December 2016. pp.143

Fertilizer Europe. 2014. Guidance for Inspection of Atmospheric, Refrigerated Ammonia Storage Tanks, pp.52

FAI. 2013. Operations, Maintenance & Inspection of Ammonia Storage Tanks, Technology Special. **Indian Journal of Fertilisers 9 (6)** pp. 104

Pattabhatula, Venkat; Nayak, Raghu and Timbers, Don. 2012. Safety & integrity of ammonia storage tanks. **Pre- prints of FAI Annual Seminar, 2012**. SIII-5, pp. 1-14. ■