Lessons learned from decommissioning of a liquid ammonia storage tank

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Summary
The liquid ammonia atmospheric storage tank in Pardis Petrochemical Complex had an accident on August 8, 2011 due to a sudden increase in pressure followed by the rupture in the roof to shell joints and spread of ammonia gas into the atmosphere of the Pars Energy special economic zone in the Assaluyeh Port, Bushehr, Iran. Next, decommissioning of this tank (TK-4501A) was ordered even though due to the unexpectedness of the incident, executive action or prior planning for decommissioning and internal inspection of the tank was not foreseen. Due to safety considerations stemming from the dangerous nature of the ammonia and the special design of this tank, the operation of complete drainage of the remaining ammonia in the bottom of the tank and the necessary ventilation for the entry of personnel into it for inspection took approximately 297 days from the time of the incident. Yet, this operation along with the hardships and difficulties in the planning and operation was a successful experience and created a new view in the operation of safe decommissioning of liquid ammonia atmospheric storage tanks. This paper discusses the decommissioning procedure to carefully and safely empty and purging of this tank and the problems, which have been occurred. The decommissioning took place in August 2011 until May 2012 and all together it covered 297 days Net Time: Emptying 5 days, Purging 60 days. 232 other days: Preparing new procedures and equipments. Because of the existence of another two tanks, there was not any problem in ammonia production and storage of the plant.

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Key words: Liquid ammonia storage tank, Decommissioning, Siphoning phenomenon, Nitrogen partial pressure effect
INTRODUCTION

Pardis Petrochemical Complex, with two units of Ammonia each with a capacity of 2050 tons per day (Licensed with M.W.Kellogge) and two units of urea each with a capacity of 3250 tons per day (Licensed with Stamicarbon) is situated on a site with an area of 64 hectares, 270 kilometers southeast of the Bushehr port in the Pars Energy Special Economic Zone in the Assaluyeh port, Iran. This plant contains three liquid ammonia storage tanks each with a capacity of 20000 tons with an overall capacity of 60000 tons. The Ammonia Tanks are double integrity cup in tank type with perlite insulation in annular space. These storage tanks transfer their stored ammonia through a 14” line with a length of 2000 meters to the sea export terminal, Pars Port in Persian Gulf.

On Monday morning the 8th of August 2011, between the hours of 5:34 and 5:36 AM, the internal pressure of one of the ammonia storage tanks in this plant (TK-4501A) suddenly rise, leading to the rupture at two points in the dome roof to shell joints and the spread of ammonia gas to the regional atmosphere. This increase in pressure also caused the folding and sinking in some other parts of the shell at the connections to the dome roof.

Fortunately, because of unique characteristics in the design of this type of storage tanks, its effects were limited to the spread of ammonia vapor in the amounts of approximately 10-50 ppm in the region’s atmosphere in a radius of approximately one kilometer in the direction of the prevailing wind and resulted in no significant human loss or injuries.

The reason of the incident was the entering of ammonia product at unsuitable temperature and also high flow rate, which made ammonia vapor more than the design quantity in the tank. Within 24 hours of the incident, using an innovative design by making several clamps and installing them on the locations of rupture stopped the spread of ammonia gas from the damaged tank.

At the time of the incident, TK4501A contained 8640 tons of liquid ammonia (43.2% was the level of the ammonia in the tank) with 99.8% purity. After the incident, reducing the amount of ammonia remaining in the tank began by transferring it to two urea units in the complex and within 5 days, the ammonia remaining in the tank reached a level of 5.7%. At this point the ammonia pumps did not have the capability of further drainage of the tank due to gassing.

By performing the necessary calculations, it was observed that at this stage there was still approximately 1140 tons of liquid ammonia remaining inside the tank at -33°C. The drainage of this remaining amount of ammonia was necessary in order to inspect the interior of the tank and to examine and estimate the type and extent of damages incurred and to begin the maintenance. The examination of all existing documents related to ammonia storage tanks in Pardis plant indicated that no special decommissioning method in this area was presented for the ammonia units in the plant by the Japanese manufacturing company (Kanetsu K.K.) or the Japanese engineering consulting company (Toyo).

Considering the previous experience in decommissioning of ammonia tanks for periodic inspection in three different ammonia plants at national level (Iran), the methods of drainage of ammonia tanks have been studied. These units, in order of priority in the decommissioning and inspection of ammonia tanks are: Razi (Mahshahr Port), Khorasan and Shiraz Ammonia and Urea Petrochemical companies. In order to have access to the quick and safe method of complete drainage of tanks, two projects of liquid ammonia storage tanks decommissioning were also examined in Morocco and Bahrain. The type of insulation in existing tanks in the Pardis Petrochemical Complex is different from all the ammonia tanks in the mentioned petrochemical complexes. This fact had caused them to be able to use simpler methods in the drainage of remaining ammonia in the tanks and expedite the operation. In all of these tanks, the thermal insulation of the tank has been placed on its external shell.

Therefore, it makes it possible for the complete drainage of remaining ammonia from these tanks with the removal of part of the thermal insulation on the tank, increased the heat exchange rate of the environment outside the tank with the interior of the tank which caused increased the evaporation of liquid ammonia. Considering the design of the thermal insulation of the tank in Pardis Petrochemical Complex and the presence of ammonia vapors inside its insulation caused the creation of thermal penetration to the tank was not be possible.
The information and experience gained in the operation of complete drainage of TK-4501A can be utilized in operations of this sort tanks and prevent the unnecessary repetition and trial and error of various methods of drainage of liquid ammonia tanks. The practical use of the set of methods and experiences gained in the operation of drainage of the damaged tank (TK-4501A) in the Pardis Petrochemical Complex can also be utilized as the method of execution of passive defence systems for the complete drainage of this type of tanks in emergency times.

**TK-4501A RUPTURE CASE STUDY**

The rupture of TK-4501A ammonia storage tank of Pardis Petrochemical Company on the 8th of August, 2011 was mainly due to human error and the transfer of liquid ammonia at unsuitable temperature, -12°C (Design temperature is -33°C), and also a very high flow (112 cubic meters per hour), and amplifying factors such as unsuitable thermodynamic conditions of the transfer line and the produced ammonia storage tanks, the emergency refrigeration compressors in the storage tanks locations being out of service, and the lack of reception of vapors by refrigeration compressors of the ammonia units 1 and 2 of the complex due to operation and mechanical problems eventually, led to over pressure in TK-4501A and rupture in the connection points of the roof to shell followed by the spread of ammonia gas to the plant atmosphere.

Although the design of this tank prevented a major disaster and human catastrophe, the serious pursuing problems in the control of vapor leaks in the shell and roof in the damaged areas were controlled within the first 24 hours of the incident by installing 3 clamps manufactured within the Pardis petrochemical complex.

![Ammonia vapor jet visible at the rupture point in the northern section. The Picture was taken 2 hours after the incident, 8th of August, 2011, 7:30 AM](image)

The tensions caused due to the increased internal pressure of the tank was followed by the elongation and deformation in some of the nuts and bolts connecting the external shell to the concrete bottom, and caused the detachment of one of the bolts.

The spread of ammonia gas in the area resulted in the announcement of an emergency situation in the Pars Energy Special Economic Zone, and the evacuation of the non operation personnel and employees in some of the neighboring petrochemical complexes in the early hours of the incident.
Fig. 2: The picture of TK-4501A after the incident – The change in the color of the tank resulting from the spray of water in order to prevent the formation of ammonia vapor cloud. (Right Image) The damage of shell to roof joints on both upper sides of the TK-4501A (Left Image)

Fig. 3: The form of the damage in the northern section of TK-4501A

Fig. 4: The form of damage in the southern section of TK-4501A
Lessons learned from decommissioning of a liquid ammonia storage tank

**SPECIFICATIONS OF TK-4501A**

- Inner tank inside dia. = φ 44,000
- Outer tank inside dia. = φ 45,400

![Diagram of tank specifications](image)

Fig. 5: geometric view of the tank and situation of Perlite and polyurethane blanket between the two layers.

2.1 Tank Type: Double Integrity (Cup in Tank) with Suspended Ceiling and Dome Roof
2.2 Capacity: 20,000 Metric Ton
2.3 Ingredient: Liquid Ammonia @ -33°C, 99.8% concentration, (0.2% Water)
2.4 Design Temperature and Pressure: -40°C, 50mbar
2.5 Manufacturer: Toyo Kanetsu K.K, Japan
2.6 Internal Diameter: 44 m
2.7 Maximum Height: 30.2 m
2.8 Insulation: Loose Perlite in Annular Space of the tank

THE PARDIS PETROCHEMICAL COMPLEX LIQUID AMMONIA TANK DECOMMISSIONING PROJECT (IRAN-ASSALUYEH) (2011-2012)

The storage of ammonia in the form of liquid or gas due to its burning and suffocating properties of live beings contains safety points of high importance and necessity. Therefore, in the decommissioning operation of the liquid ammonia storage tanks consideration of safety issues related to this matter is of high importance and creates numerous restrictions in choosing the manner of drainage.

Latent heat in the evaporation of liquid ammonia at -33°C is equivalent to 1369 kJ/kg. In the implementation of decommissioning method this point is very effective and is demonstrative of the high thermal energy required for the remaining evaporation of liquid ammonia at the bottom of these tanks.

**Decommissioning Approach and Methodology**

Before the tank can be inspected, it has to be emptied and all liquid and gaseous ammonia would have to be removed from the tank. The pump suction line was however located somewhat above the bottom of the tank (100 mm) which means that a certain amount of liquid ammonia remains in the tank, amounting to, by estimation, approx. 140 t. It is important to state that there were no manholes available and there was not a possibility for draining below tank bottom level.
Preparing the Procedure (Options for Decommissioning)

After maximum reduction of the ammonia level in the tank by ammonia feed pumps to urea plants (P-4502A/B), five options were considered for removal of the liquefied ammonia below the pump suction.

1. A combination of pumping liquid ammonia out of the tank with a temporary pump through a siphon drain line and evaporating the remaining liquid with hot ammonia vapor.
2. Using only hot ammonia vapor.
3. Natural evaporation.
4. Adding water to the tank and pumping aqueous ammonia out of the tank.
5. Evaporating the remaining liquid by heating.

The perlite insulation placed in the annular space between inner and outer walls. Natural evaporation was discarded as too time consuming. The insulation could not be removed. Water addition was also discarded due to associated waste disposal problem.

EXAMINATION OF DIFFERENT METHODS OF DECOMMISSIONING PROCEDURE

The liquid ammonia storage tanks decommissioning in different parts of the world for periodic internal inspection of these tanks is described. To do this normally, planning for the drainage of the selected tank is done several months before placing it out of service. Due to the low temperature of ammonia stored inside these tanks (-33°C) and the special design and type of usage of different layers of insulation at their bottom, the drain lines are not installed at the bottom of this type of tanks. Only a 4"or 6" line which has entered from the body and near the bottom and has then deviated downward has been installed as a siphon drainage line, blinded outside the tank and is not connected to any particular path.

Normally, no particular instruction for complete drainage of these tanks is included in the related documents. Thus the complete drainage of the tank from the remaining ammonia in the bottom of the tank is in a sense left up to its user. Yet in most of these operations during the drainage, various unforeseen problems arise which cause the lengthening of the time of drainage and ventilation of the tank in comparison with the time planned for the entry of personnel.

In TK-4501A, a 4" line has been considered as a siphon drain which has entered from the tank body and after bending downward continues to within 50 mm of the bottom of the tank. The distance of the suction nozzle of the pump transferring ammonia to the urea units to the bottom of the tank is equal to 100 mm
and the distance between the nozzle of the suction line of the pumps transferring ammonia toward the export ship and the bottom of the tank is equal to 530 mm.

![Fig. 7: The position of the 4" siphon drain line inside and outside the tank](image)

The damaged liquid ammonia tank (TK-4501A) has two metal wall where the 70 cm layer between them has been filled with cold thermal insulation, Perlite. A suspended roof has been placed on the perimeter of the interior layer, but has not been welded to its upper section, and is at a little distance away from the interior layer. Nylon tapes have been used in this section too. A Perlite layer has also been poured on the suspended roof.

The draining operation of the TK-4501A tank began in the early hours of the day of the incident, August 8, 2011 with the transfer of the ammonia present in the tank toward the urea producing units. At this time the level of remaining urea in the tank was about 43% and equivalent to 8,600 tons. These operations were continued for 5 days around the clock, using a pump P-4502B until the NPSH of the pump did not let the operation continue. At this stage there was approximately 5.7% ammonia left inside the tank which was equivalent to 1140 tons. The distance of the center of the siphon drain line where the level transmitter is also installed to the bottom of the tank, is approximately 500 mm.

The preparation of the decommissioning procedure began with the study of draining methods used in ammonia tanks in Morocco and Bahrain. The different methods below were examined and eventually the utilization of temporary pump in the path of the 4" siphon drain and the transfer of remaining ammonia to the neighboring tank was to be done.

**Unloading perlite insulation to increase the heat exchange rate**

Thermal insulation of TK-4501A by a layer of blanket insulation of polyurethane material, and also mass insulation of Perlite with 70 cm thick, which has been placed between two inner and outer metal wall. The method of insulating the tanks at the joints of the internal layer to the suspended roof using Perlite and plastic sheets is in such a way that it creates a suitable thermal impermeability.

Considering the cases mentioned above, the possibility of opening the manhole for entry to the space between the two layers and removal of part of the Perlite and blanket insulation did not exist. In case of performing such activity, in addition to the personnel being exposed to ammonia vapors, the possibility of entry of air into the tank and an explosive mixture of air and ammonia vapors existed which was eliminated using this method.

**Water injection to the tank**

Injection of water into the tank caused the exothermic reaction of ammonia with water and evaporated ammonia at a suitable rate.

The remaining aqua ammonia also could be mixed with the pure ammonia of other tanks and be fed to the urea unit with a concentration of approximately 96-97%. This action caused the increase in load on the vaporizing section of the urea units and reduced the production capacity of these units. Due to the
production priorities in these units, the probability of development of certain unknown effects, this method was removed from the list.

**Injection of warm nitrogen gas**

Injection of warm nitrogen inside the tank for the purpose of transfer of heat to it and increase in the rate of evaporation of the remaining ammonia was not considered feasible. Due to the high volume of remaining ammonia and the high degree of latent heat of evaporation of it this method is very time consuming and lengthy.

**Injection of warm ammonia vapor**

The injection of warm ammonia vapor with a temperature of about 140°C from the exit line of one of the emergency refrigeration compressors was also examined, which due to the high volume of liquid ammonia remaining inside the tank, lengthening of the drainage time, additional repair and operational problems with the two emergency refrigeration compressors and the difficulty with control conditions this operation was also eliminated from the list of priorities at first.

**Installation of temporary pump in 4” siphon drain line**

With the feasibility study and the calculations performed, the installation and utilization of a temporary pump in the path of the 4” siphon drain, drainage of remaining ammonia and transfer it to the neighboring tank was realized as the quickest and safest method of tank drainage. The successful performance of this task was conditioned upon the fact that the phenomenon of siphoning could be created inside the tank in order to be able to drain the remaining ammonia. Thus in the best scenario considering the 50 mm distance between the tip of the nozzle of drain line and the bottom of the tank, approximately 70 tons of ammonia would be left inside the tank.

**TEMPORARY MODIFICATIONS FOR DECOMMISSIONING**

The level of the ammonia in the tank had been reduced to around 5.4% using the normal pumps (Ammonia feed pump to urea plants), leaving approximately 1140 MT of liquefied ammonia. To reduce the level further, a temporary pump would be connected to the 4” drain line of the tank.

For the final stage of emptying, by creating a suitable pressure differential between the tank and pump suction, 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.

**Installation of Temporary Pump in Siphon Drain Line**

Pursuant necessary examinations, the method of tank decommissioning using a temporary pump was issued on August 30, 2011 and through a technical meeting dated September 9, 2011 was announced to the operating units. The decommissioning operation of TK-4501A following the installation of lines and temporary pump (P-3003B), for the transfer of ammonia remaining at the bottom of the damaged tank to
TK-4501B began at 10:50 on Friday October 28, 2011. Due to low static pressure of ammonia and also quick evaporation of ammonia in the suction line the start-up of the pump faced difficulties.

Finally, following several stages of testing and piping modifications the temporary pump was put into service for 48 hours starting on Tuesday November 8, 2011. Low pressure at the entry of the pump caused the pump discharge valve restricted due to prevent gassing. These operations were overall not satisfactory and eventually the pump was placed out of service.

**Injection of nitrogen into the tank (Nitrogen partial pressure effect)**

With the temporary pump being put out of service, injection of nitrogen for the purpose of purging the ammonia vapors at equilibrium with liquid ammonia and following that, the increase in the rate of evaporation of liquid ammonia was placed into the program. Injection of nitrogen began on November 17, 2011. The path of the vapor lines of tanks TK-4501B/C to the flare was closed and only the path of TK-4501A vapors was left open.

Following that, increase in the rate of evaporation, considering the temperature fluctuations in the tank and also the rise in the flame of the flare of the tanks was visible and effective in the primary stages. The minute reduction in pressure of the ammonia vapor inside the tank led to the increase in the rate of evaporation of liquid ammonia in the tank which was noticeable from the size of the flame of the flare. With the increase in the rate of evaporation the temperature of the remaining ammonia was reduced to -38°C where in order to prevent it from reaching the designated temperature of -40°C, the nitrogen to tank valve was shut off on November 26, 2011. Following the increase in temperature, the nitrogen valve was reopened and its injection into the tank continued until December 9, 2011.
Considering the temperature restrictions of the operation of injecting nitrogen into the tank, the drainage operation using a temporary pump based on considering the thermodynamic results of the injection of nitrogen was placed in the order of actions.

**Siphoning Based on Nitrogen partial pressure effect**

To provide sufficient static pressure in the temporary suction pump fit up to the siphon drain line, the TK-4501A tank was leveled up to approximately 20%. Nitrogen injection started and the tank temperature was reached to -39 C. From February 6, 2012, the temporary pump (P-3003B) was put into service and the operations of tank drainage began. Following starting the pump, its suction pressure was about 0.5 barg and its discharge pressure was equivalent to 5 barg. Its discharge flow based on the tank level reduction curve is estimated, approximately 25 t/hr.

At 5:55 AM, On February 13, 2012, the level of the tank TK-4501A reached 0% on the transmitter, and the pump was still in service. At 15:00 PM the suction pressure of the pump dropped and reached approximately zero and then became negative. By reducing the outlet pressure of the pump to approximately 1 barg, the P-3003B dropped out of service.
With calculations done, considering the time of the level of the tank reaching zero and the temporary pump falling out of service, approximately 70 tons of ammonia were estimated to be remaining in TK-4501A. The pumping rate was monitored hourly and it averaged about 25MT/h. The pressure in TK-4501A was around 55 mbarg.

**WARM AMMONIA VAPOR INJECTION**

Once it became impossible to pump the remaining liquid, TK-4501A was ready for heating up with hot gas. Hot ammonia gas from the compressor (2-RU-4501) discharge was introduced to the tank 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.

Following reduction of the Level of the tank to 0% through a temporary pump using a transmitter on February 13, 2012, the operation of piping for the purpose of injecting warm ammonia vapor from the outlet of the emergency refrigeration compressor (2-RU-4501) began which ended by early march. Following the remedy of the problems with the electromotor of the compressor and the oil pump had occurred.

During piping and placing the emergency refrigeration compressor in service for injection of warm ammonia vapor, the temperature of different sections of the tank had an upward trend which was indicative of the evaporation of the remaining ammonia in the tank.

![Fig. 12: Piping from the outlet 2-RU-4501 for injection of warm ammonia vapor into the tank](image)

On March 28, 2012, when the compressor was ready to put on service, the temperatures of different sections of TK-4501A were inspected through the related panel, which were all positive and the temperature of its lower section was +14°C.

**PURGING WITH NITROGEN AND AIR**

Following the temperatures of all 16 transmitters of the internal temperatures of the tank becoming uniform at 24°C and for assurance of a lack of presence of liquid ammonia, injection of nitrogen into TK-4501A began at 16:00 on Saturday April 15, 2012, where no noticeable change in temperature was obtained.

This fact was indicative of a lack of presence of liquid ammonia in the tank. Thus, injection of nitrogen for the purpose of purging the tank was continued and a nitrogen hose from the main nitrogen header of phase 2 of the complex was also installed.

**Nitrogen Purge**

Purging was started by admitting nitrogen at the tank floor level at a rate of flow of 500 Nm3/h. The tank pressure was maintained at 70 mbarg. The vapors from the top of the tank were analysed for ammonia content and divert to the flare.

The nitrogen should have to be carefully inserted since the layers of ammonia and nitrogen clouds can mix up with each other when this is done "too wild"; this because of their different densities.
Purging with nitrogen (N₂) is based on the principle of creating a difference of density in the layers of NH₃ (molecular weight 17) and nitrogen (molecular weight 28).

To find a suitable location for sampling an inspection was made on April 17, 2012 from above the tank where following opening one of the valves related to one of the tank level transmitters and getting gas analysis by the safety department gas detector, the amount of ammonia was assessed to be low.

Fig. 13: Measurement of the concentration of ammonia at the time of purging with nitrogen using titration devices and gas analysers

For accurate analysis of the ammonia gas concentration in the tank, the laboratory personnel using the related titration device attempted sampling from the instrument connection at the top of it. The vapors were analysed for ammonia content at several points and after 10 days of purging, the concentration at the top of the tank was 1.58% ammonia. A temporary vent pipe was installed in designed 12" valve and spool line to facilitate local venting. After confirming the purge gas analysis, nitrogen was closed and the tank was depressurized.

**Air Purging Before Tank Entering**

Before tank inspection, ventilation by air must to be down. This could be performed by means of a high performance fan of 50,000 Nm³/h blowing through a manhole.

The nitrogen content has to be measured and when the O₂ concentration is in the range of 20 to 21%, ventilation can be stopped and maintenance and inspection personnel can then safely enter the tank.

The required time for air ventilation based on comparable situations was estimated at 5 days. In total the estimated time period for emptying, nitrogen purging and air ventilation would cover probably 30 days.

After depressurizing 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" manhole removed and the manhole diaphragm plate was cut.

The air driven reaction fan was fitted in the nozzle. The top central as well as periphery manholes were opened and sweetening was started.
Due to the tank pressure being low for the purpose of sampling an air conditioner compressor was used for suction and sampling of the vapors in it on the 2nd, 8th, 14th, and 16th of May, 2012, where the concentration of ammonia was declared by the laboratory in the complex to be 3.5%, 2.39%, 0.3%, and 0.21% by volume. The temperatures of the different parts of TK-4501A according to the related panel was approximately +30°C.

The NH3-concentration <20 ppm (MAC value), the environment is safe for entering the tank. The shell manhole, in the lower section was opened and inspected on May 6, 2012. The cap of the interior manhole was warm and there was no special frost formed on its wall which was indicative of a lack of presence of liquid ammonia in the tank and the correct performance of internal thermal transmitters.

The clamps of the rupture locations in the tank were fastened on Tuesday, May 9, 2012, by the maintenance unit.

The control of the high pressure valve of the tank toward the flare (PIC-4504A) was also opened completely. The valve for the path of the 12” vent above the tank TK-4501A was opened as a test at 17:00 on Tuesday, May 16, 2012. When the appropriate operator announced that no special ammonia odor is sensed. The performance of the operations of blinding the entry and exit lines of the tank was begun on May 17, 2012. Following the opening of manhole and the welding of the lower section of the tank at 14:45 on May 28, 2012 the first person entered the tank for inspection.

**PRACTICAL CALCULATIONS FOR DECOMMISSIONING BASED ON PARDIS EXPERIENCES**

Increase the pressure of the tank by increasing the set point of the compressor. The pressure relief valves at the tank were set at 98 mbarg. A pressure increase of 70 mbarg, which was fully acceptable, the pump could remove an extra 1140 t. of liquid ammonia at reduced flow and the required time for that should be approx. 70 hours.

A quantity of 70 ton ammonia should then remain in the tank. The left over then would have to be evaporated. For aforementioned method options, calculations were made and the required “decommissioning” time was estimated based on pardis tank experience and without any time lost resulting in:

- Using modification pump (Siphoning phenomenon and nitrogen partial pressure effect used): 3 days (pumping 25 ton/hr)
- 2. Evaporating residual ammonia by hot ammonia vapor: 17 days (70 ton, 200 kg/h)
- Nitrogen purging (1000m³/hr): 5 days
- Air Purging (Using plant air and fan): 5 days
Total estimated time required for same operation: 30 days

**ENCOUNTERED PROBLEMS DURING DECOMMISSIONING**

There was very difficult to estimate the remaining ammonia level in the tank. The level indicators did not work correctly and the ammonia level got lower than the level transmitter leg in final steps of the decommissioning operation.

A lot of time was spent to install a reliable measuring device by means of a floater, a thick shelf and finally steel buses.

- The ammonia tank pumps (Ammonia to urea plant and to export port: P-4501A/B and P-4502A/B) did not have the expected duty (possibly gassing).
- Removing parts of the insulation was impossible. Because of the design the perlite insulation was in the annular space of the inner and outer wall of the tank and unloading of it caused ammonia vapor spread to the local area and air penetration to the tank. The ammonia and air mixture between 15-28 vol% is explosive.

**LESSONS LEARNT**

For both parties at the phase of emptying the tank as part of the overall decommissioning, before preparing a desk procedure the engineer should execute enough site visits to make notice of local circumstances and discuss the planned approach. It is advisable to make a very practicable procedure with step by step actions and explanatory drawings instead of a desk report with theoretical assumptions and schemes. The engineers should verify and list all the necessary measuring devices, auxiliary tools and equipments and ensure the local availability.

The operations of the drainage of the liquid ammonia storage tank of Pardis Petrochemical Complex, following the incident of August 8, 2011 as a special and emergency situation was placed in order for execution under such circumstances that there was no procedure in place for this operation. The stages of preparing tank decommissioning procedure led to obtaining valuable information in this matter which will be explained below.

**Preparation of decommissioning procedure with high operational potential**

In preparing the procedure of draining liquid ammonia storage tank, we must give high importance to the point that the preparation of procedure is not feasible from behind the desk. Certain differences in the design of these types of tanks, the situation of the tank and the situation of different lines around it are main factors making the drainage method for the tank of interest, unique. Thus, presence in the situation of the tank, line up the piping and feasibility study on any type of decommissioning plan with the facilities on hand must be taken into consideration by the tank decommissioning team thoroughly. This fact causes the primary procedure to be examined from all aspects and the odds of its successful operation to be high. More attention is paid to this matter being stuck with the phenomenon of trial and error in the methods of drainage of tanks will be prevented.

**Preparation of equipment list**

In preparing the decommissioning procedure we must pay particular attention to the prediction of required items and equipments, ascertaining their existence onsite or determining the need for purchasing them with regard to different stages in procedure. Keeping this fact in mind leads to making sure before the start of operation and placing the tank out of service, the equipments on site to be collected and considering each stage to be utilized as needed.

In this operation sufficient attention has not been paid to this matter, much time had been dedicated to making available one or more equipment and cessation of operation. Repetitious stoppage of operation made loss of self confidence and self esteem in successful performance of the operation.

**Calibration of tank level Indicators**

Due to the importance of safety in liquid ammonia storage tanks, proper functioning of the level indicators in the tank during the tank service time is of great importance. At the time of decommissioning of these...
types of tanks also, the function of level transmitters have a major role in the determination of the accurate amount of ammonia remaining at the bottom of the tank. Thus in the decommissioning operation, precise calibration of the indicators must have taken place and their proper functioning must be ascertained. At the time of placing order for the design and manufacture of these types of tanks the installation of several types of level indicators of different types including level indicator of radar type must be made mandatory by the clients for the designers and manufacturer of tanks.

Preparation enough amount of nitrogen and air required for tank purging

Following the drainage of the remaining ammonia in the bottom of the tank, the operation of injection of nitrogen for purging remaining ammonia vapors must be performed. Following this stage, there is need for injection of air into the tank to prepare its interior atmosphere for the entry of the crew into it. In the event the amount of nitrogen and air were insufficient the necessary piping must be done to supply these utilities for tank purging. If possible portable liquid nitrogen tankers with evaporator may be used for supplying the required amount of nitrogen. Considering the purging operation using nitrogen and air being inherently lengthy, the insufficiency of their flow affects the lengthening of the duration of purging program.

Nitrogen Partial Pressure Effect

The experience of injection of nitrogen gas into the tank containing liquid ammonia in Pardis Petrochemical Complex indicated that, following the injection of this gas into the tank due to its high molecular weight changed ammonia vapors equilibrium with liquid ammonia. This fact causes the phase equilibrium of ammonia vapors and liquid ammonia to be disturbed and the tendency of liquid ammonia toward evaporation for reinstating the equilibrium to be increased.

Liquid ammonia in order to evaporate absorbs its required heat from the liquid ammonia remaining at the bottom of the tank and causes the reduction its temperature. With the injection of nitrogen gas the temperature of ammonia remaining at the bottom of the tank is reduced down to -38 °C. This method prevents liquid ammonia evaporation in pump suction line.

The method of nitrogen injection for purging purpose

The injection of nitrogen into the liquid ammonia storage tank with a capacity of approximately 30,000 cubic meters (20,000 cubic meters capacity of storage for liquid ammonia in addition to approximately 10,000 cubic meters of volume in the dome roof section) for the purpose of replacement with ammonia vapors involves special technical points which is mandatory for achieving quick and safe ventilation.

In the event there is no purging ring available inside the tank quick injection of nitrogen with high flow from one point to the tank results in lack of sufficient time for the steady spread of nitrogen and creation of a layer of nitrogen gas under the space for ammonia vapors. The presence of this fact causes the channeling of the flow of nitrogen gas inside the tank and the lengthening of the process of purging by nitrogen. The best method for injection of nitrogen into the tank is injection with low flow rate at first, so that there is sufficient time for the formation of a nitrogen front below the ammonia vapors. We can then increase the flow of nitrogen in order to create the nitrogen front and in a piston-like fashion, attempt the removal of ammonia vapors. The implementation of this method also prevents the interaction of the layers of ammonia vapors with nitrogen which had different densities and can cause the creation of disturbances in flow inside the tank. The utilization of this same method, at the time of injection of air into the tank for purging nitrogen is also very useful and effective.

Design Modifications and install the necessary equipments for draining the tank

The present design of most of the liquid ammonia storage tanks, such that the spare equipments required safe drainage of ammonia remaining inside the tanks and internal inspection of these tanks have not been installed. In addition, access to sufficient amount of required utilities including nitrogen and plant air for quick ventilation of drained tanks must be forecasted and installed in the position of these types of tanks. Considering the high latent heat of evaporation of liquid ammonia which is equivalent to 1369 kJ/kg have
been made that the most efficient method of drainage of liquid ammonia storage tanks is to drain the ammonia in the tank in liquid form by any safe method possible. Otherwise, a large amount of energy using other fluids such as ammonia vapors and warm nitrogen must be transferred to the liquid ammonia and be used for evaporating it where the utilization of these methods will take up much time. Therefore, the designers of these types of tanks must take responsible measures toward the consideration of the required facilities required for the safe drainage of ammonia tanks.

**SUGGESTIONS FOR DESIGN REVIEW**

Considering the decommissioning experience of the ammonia storage tank of Pardis Petrochemical Company, the following suggestions for changes in design and installation of equipments necessary for the operation of safe and quick decommissioning of these types of tanks is suggested.

- Use of floating pumps in the tank, with the ability to sink to the bottom of the tank and act as bottom suction pumps. This system is currently being used in the gas condensate storage tanks.
- Installation of drain in the bottom center of these types of tanks and the creation of appropriate slope at their bottom toward the nozzle of the drain line. In case siphon drain is used appropriate slope be created at the bottom of the tank from the center of the bottom toward the interior wall which siphon drain is installed.
- Installation of an ammonia pump with appropriate NPSH in drain line for drainage of the liquid ammonia remaining at the bottom of the tank.
- Installation of appropriate heating system (Heater) at the bottom of these types of tanks so that through its decommissioning the rate of evaporation of liquid ammonia have been increased.
- Installation of purging ring inside the tanks in order to that ventilation operation takes place steady state and at a suitable rate.

**CONCLUSION**

Performing the operation of drainage of damaged liquid ammonia atmospheric storage tank (TK-4501A) at Pardis Petrochemical Complex provided valuable experiences in this field. Considering the high latent heat of evaporation of liquid ammonia, the safest and most efficient method of decommissioning of these types of tanks was the usage of a temporary pump in the siphon drain line of these types of tanks and the creation of a siphoning phenomenon in order to maximum level reduction of ammonia take place.

Prior to putting the temporary pump in service through the injection of nitrogen gas to the tank due to reasons mentioned in the article, we can reduce the temperature of the remaining liquid ammonia to design temperature of these tanks which is approximately -40 °C in order to prevent the evaporation of the liquid ammonia in the suction pump line, increase the duration of the pump being in service and maximized the amount of ammonia drained from the tank.

Following this step, with the injection of warm ammonia vapor, the rate of evaporation of the remaining liquid ammonia may be increased. The present design of the liquid ammonia storage tanks due to not taking into consideration the facilities necessary for their quick and safe drainage, including periodic inspection or any possible incident is incomplete.

The time needed for the drainage of a liquid ammonia tank under normal conditions and for periodic inspection due to the implementation of different drainage techniques, because of the type of design and the situation of the tanks and trial and error in this field is time consuming and costly. At the times of incidents or the possibility of any danger threatening the safety of the tank, we practically are not able to quickly perform any special actions toward the drainage of the tank. Therefore the design and installation of necessary equipments in this field must become mandatory for the designers by the clients placing orders for these types of tanks.
Annular Space of the Tank after Unloading of Perlite Powder Insulation