SAFETY AND LOW PRESSURE AMMONIA STORAGE

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Low pressure ammonia storage has increasing acceptance for two reasons. First, it requires much less capital per unit volume. Second, it is equally as safe and in some ways safer than conventional sphere storage.

The extent of low pressure storage acceptance is shown by the following figures of facilities built by Chicago Bridge and Iron Co., one of the foremost builders in the business:

Built by C.B.I. since 1959: Low temperature tanks in Service—97,050 tons; Low temperature tanks under construction—173,000 tons; Sphere Storage built and under construction—1959 to present—13,900 tons.

The Tuscola model

The illustrative model used to evaluate the safety of low pressure ammonia storage tanks is the tank at U. S. Industrial Chemicals, Tuscola, Illinois.

This tank, 87 feet 8 inches in diameter and 56 feet high, is designed to operate at 15 to 20 inches of water pressure and contain 6,500 tons of anhydrous ammonia. Operating temperature is -26° F. Insulation is provided by Perlite contained within a second concentric tank.

The compressors, ammonia condensers, and the instrument control panel are located remotely from the tank at the ammonia synthesis compressor house. The ammonia synthesis compressor operator controls the operation of the tank and compressors as a part of his other duties. This gives a maximum amount of operating skill with a minimum amount of training cost.

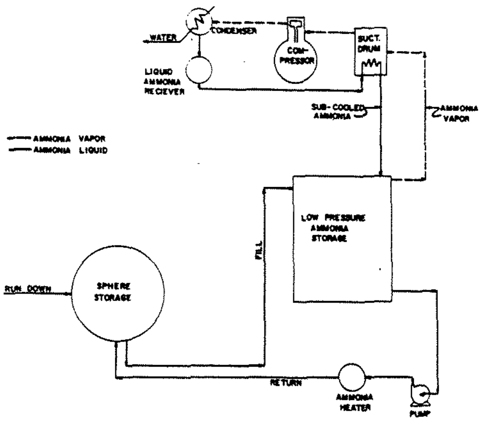

Figure 1. Simplified flow sheet of low pressure ammonia storage system.

Total refrigeration at each location will depend on the tank filling rate required. At Tuscola a total of 150 refrigeration horsepower was purchased to allow filling 75 tons per day. This is provided by two sets of Frick compressors. As only one set of compressors is required to hold inventory, there is 100% spare capacity. Standard compressor safety devices such as low lube oil pressure shut downs are provided. No auxiliary generator is provided for the compressors. The ammonia loss due to heat leak when not loading is too small to justify auxiliary compressors either from a safety or economic view point.

Insulation with a double tank

The most unique feature of the Tuscola tank is insulation by utilizing perlite, contained within an outer tank.

Considerable discussion exists on the best insulation for use on low pressure ammonia storage. Foam glass, polystyrene, and spaced layers of aluminum have all been used successfully.

At Tuscola an outer tank of 1/4 inch carbon steel is used. It is built to allow a 30 inch annular space between the outer and inner tank. This void is filled with perlite, and kept under 4 inches pressure with dry nitrogen. The outer tank method was chosen on the basis of the vendors recommendation. These recommendations appeared valid to use and are shown below:

1. The initial materials cost of foam glass insulation is much cheaper than a double tank. However, insulating labor costs are so high that, depending on local conditions, a double tank can cost very little more than foam glass.

2. The use of a double tank with a dry nitrogen pressure allowed keeping ice out of the insulation and to build the inner tank with no corrosion allowance. Nitrogen is best because it eliminates an explosion hazard, but dry air would prevent corrosion.

3. Maintenance cost on bare foam glass at Tuscola has always been high. However maintenance on double walled vessels filled with perlite has always been practically non-existent. Foam glass with aluminum sheeting has required considerable maintenance on the aluminum in our acid atmosphere. At least one tank has styrofoam popped off by a sudden atmospheric pressure change.

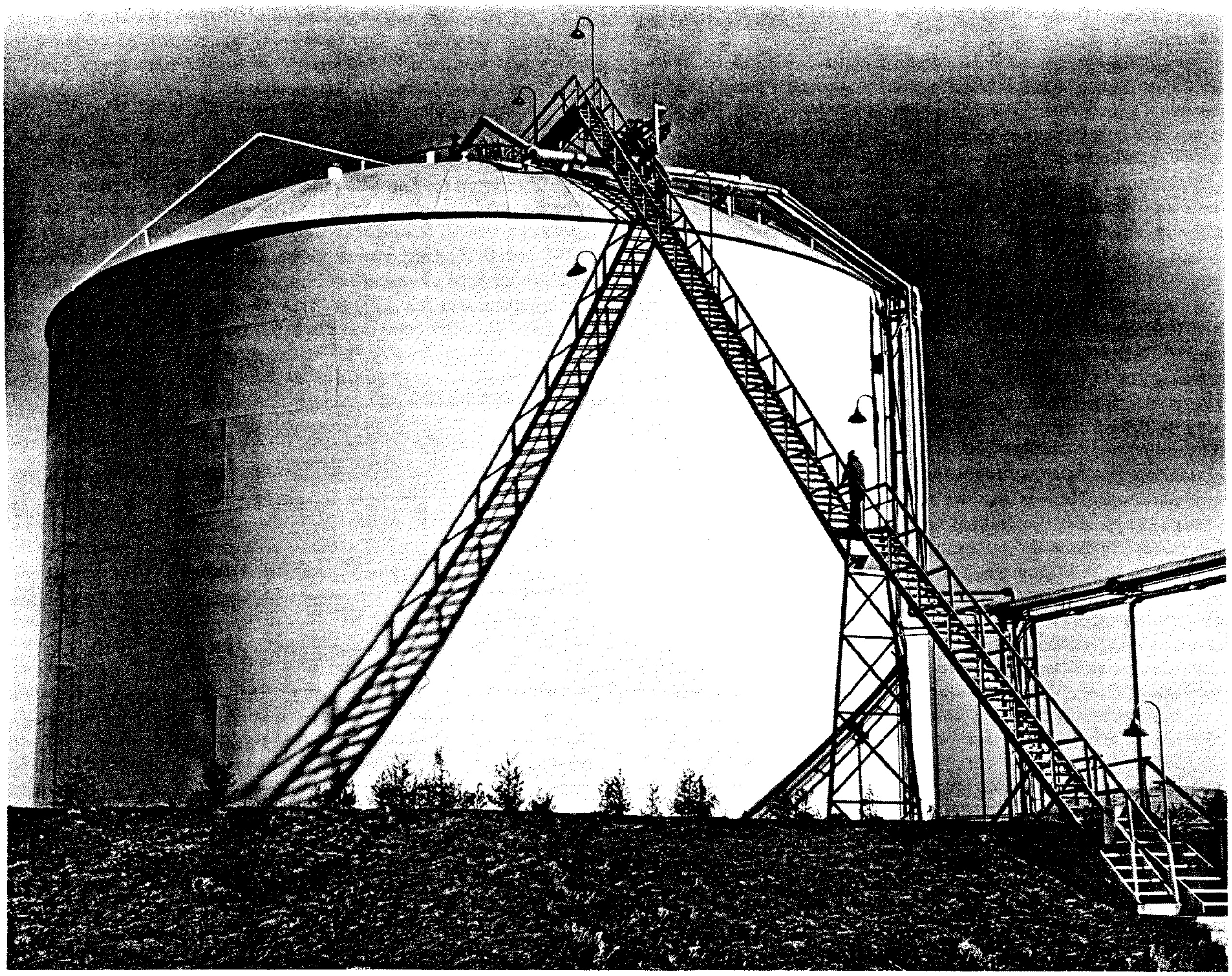

Figure 2. This tank stores 6,500 tons of ammonia at 1 lb./sq. in. gauge and minus 28°F.

Initial cool down

Initial cool down of the tank presents several problems which are not encountered frequently by the average operator. These problems include the presence of a combustible mixture and the possibility of uneven cooling. The author recommends that someone with considerable field experience such as C. B. & I. or Girdler be brought in on the original cool down.

In spite of these difficulties St. Paul Ammonia switches its tank from liquid butane service to liquid ammonia and back each year.

Tank safety devices

The safety devices on the low pressure ammonia storage tank can be divided into six categories as follows: Foundation heaters; Tank construction; Pressure control system; Dike; Ammonia return system; Other devices.

Foundation heaters

The cold from the liquid in the ammonia tank will draw heat from the earth foundation and cause freezing if foundation heaters are not installed. Freezing earth under the tank will cause the foundation to heave and crack. This could easily break the welds in the tank.

The Tuscola operation utilizes a 40 KW electrical resistance heater on thermostatic control. A few installations use air foundation heaters and damper system. At least one installation heats their foundation with a mixture of Water and Ethylene Glycol.

Electrical foundation heating provides the most maintenance free, compact, easily operated system available. Since it draws power only when necessary it is also the cheapest to operate. Five thermocouples are provided in the foundation and the thermostatic controller is maintained at 40°F. on the coldest thermocouple.

Tank construction

The inner tank, which holds the ammonia, is constructed according to API Code 620. The materials of construction are specified for −50° F. This will allow us to swing the tank to propane service if the demand exists in the future. In any case plain carbon steel is not recommended since it is brittle at these temperatures. The material used at Tuscola is alloy steel (A201 Grade B firebox). All other lines, pumps, etc. which could receive below zero liquids are designed for −50° F.

The tank was hydrostatically tested before placing it in service, but as we forecast continuous service without any appreciably temperature stress or corrosion, we do not intend to hydro test on a yearly basis. Tank foundation must be designed for hydro testing.

The tank also has a liquid overflow line to prevent excessive hydraulic stress. A small sump is provided at the low point in the tank bottom and an oil drain off point is provided.

The fill line has a special safety feature to prevent liquid rolling in the tank. The fill line enters the tank and dumps into an open pan. Flashing occurs here and the remaining liquid which is cooler than the tank liquid, is drained from the bottom of the pan to the bottom of the tank. If the feed were allowed to flash in the bottom of the tank, large bubbles would form and rolling would result.

Water sprays on the outer tank which would activate in the event of fire were considered. This idea was abandoned because of the narrow range of combustibility of ammonia (16 to 25% in air). Also the addition of large amounts of water intensifies the hazard by adding heat to the ammonia and causing additional vaporization. If very large amounts of water were added, the ammonia could overflow the tank dike which can hold 150% of tank capacity. The tank is located about two feet above ground to further remove it from the high ground water table in the area.

The outer tank has a 4 inch Shand Jurs combination relief valve and vacuum breaker. Pressure relief occurs at 4 inches of water pressure and 2 ounces vacuum. The outer tank also has a 20 inch diameter weighted manhead which relieves at 6 inches pressure in case of a major rupture of the inner tank.

Pressure control system

The problem of determining what should be the tank operating pressure received a great deal of attention. This discussion centered primarily around differences in atmospheric pressure. Several tanks are now operating successfully at 3 inches of water pressure with the relief valves set at 6 inches of water. We were still concerned that this was too close to atmospheric pressure to insure adequate safety. The maximum atmospheric pressure changes at Tuscola were obtained from the weather bureau and are shown below:

	Maximum Atmospheric Pressure Change	
Time Interval	Inches of Mercury	Inches of Water
10 min.	0.1	1.3
1 hr.	0.2	2.6
6 hr.	0.5	6.5
24 hr.	1.5	13.
All time	2.3	30.

It appears from the above data that a tank which operates in the pressure range below 10 inches of water gauge is actually a differential tank. A sudden atmospheric pressure rise could cause the tank to be under a slight vacuum so that the vacuum breaker would open and admit air to the tank. This could make a combustible mixture inside the tank. A sudden drop in atmospheric pressure could cause the tank to become over pressured and vent ammonia. To avoid these hazards and allow greater operating flexibility with resulting lower compressor power costs, we chose an operating pressure of 20 inches of water (3/4 psig) with the relief valve set at 40 inches (1 1/2 psig).

The operation of the pressure control system is done from a remote panel in the ammonia synthesis plant compressor house. All gauges on the low pressure system are calibrated in inches of water. Three separate control systems are used. Pneumatic and electrical systems back up each other for normal control and first line safe failure. Ultimate failure protection is provided mechanically by combination relief valve and vacuum breaker. Two such valves are provided to permit maintenance on one.

Pneumatic sensing devices are provided by differential pressure cells located at the tank and transmitting pneumatically to the control panel. Electrical sensing devices are provided by mercury switches located at the tank and transmitting electrically to the control panel. A special vacuum prevention device is provided by taking vapor from the spheres to the tank in case of low pressure. If spheres are not available, some other device should be considered to prevent vacuum, in addition to a mechanical vacuum breaker.

Overpressure

The operation of devices to prevent overpressure of the tank is described below, all pressures are in inches of water:

At 22 inches Pneumatic Volume Controller loads compressor.

At 27 inches Electrical High Pressure Alarm Sounds.

At 30 inches Solenoid closes the "Ammonia to Low Pressure Storage" loading valve.

At 35 inches Pneumatically controlled vent valve opens.

At 40 inches mechanical relief valve opens.

Vacuum

The operation of devices to prevent occurrence of vacuum in the tank is described below:

At 12 inches Pneumatic volume controller unloads compressor.

At 10 inches Electrical low pressure alarm sounds.

At 7 inches Electrical relay shuts all compressors down.

At 5 inches Pneumatic valve opens, allowing sphere vapor to enter the low pressure tank.

At −2 inches Mechanical vacuum breaker opens.

Safety dike

A dike has been provided around the Tuscola tank which serves two purposes. First, the dike limits the amount of warm ground which would come in contact with an ammonia spill. This in turn greatly reduces the amount of flash. Second, the dike protects against liquid ammonia coming into contact with personnel or ignition sources. The Tuscola dike provides capacity for 150% of the design tank contents.

Low temperature storage reduces flash of liquid on spilling almost to zero, since it is at almost atmospheric pressure. Vapor formation is then by slow heat transfer from air and ground. Diking (minimizing air and ground contact) minimizes heat transfer.

Ammonia return system

At Tuscola ammonia is returned from the low pressure storage tank to sphere storage before being shipped out. In order to prevent damage to the carbon steel spheres, and tank cars, a heater is installed in the return line. This heater warms the return ammonia to 30° F. Local and remote shut offs are provided for the pump which returns ammonia to the spheres. All lines and the transfer pump which are subjected to below zero liquid are specified good to -50° F.

Other devices

No flare has been provided because of the narrow combustility range of ammonia (16 to 25% in air). Flares would be more of a hazard than a safety factor in the event of a large spill.

Insulation purge

A dry nitrogen purge in the insulation space between the two tanks prevents the formation of ice which could rupture the tank as well as decreasing the insulating value of the perlite. Dry nitrogen also eliminates the possibility of a combustible mixture in the insulation. Dry nitrogen is available to us from our Air Still at a negligible cost.

DISCUSSION:

JONES—One thing that bothers me a little bit about this large tank—there is no code for design and construction of any mandatory nature which applies. It is a question of the good conscience of responsible contractors. The probability is that those presently in the field are in this category, but it is a competitive business. The pressure will be to reduce costs, to succeed in making bids and the like, and the user of such a tank might reasonably say "at what point should the line be drawn." This sphere perhaps has some element of reliability built into it, inasmuch as it is a pressure vessel, and there are certain design rules and quality features which are, in the majority of the places, enforced by state law. I would very much like to see some minimum standard of design and construction required for very large tanks of this sort. The dike, I am sure, does provide very good protection. I am wondering about the bottom construction of the tank. Is this a lap welded bottom or is it of butt-welded construction; and I am wondering whether there is any restriction on the location of these tanks? Can you build one in a big city, a densely populated area, without any protest from house dwellers nearby, or are they just in blissful ignorance?

JENKINS—You asked about a code? There is no code. We have the code which Chicago Bridge and Iron has been building by, and it should be more than adequate. However, people could begin to short-cut. The fact is that a low pressure tank generally does have some considerable economic advantage. We should therefore try to design a tank which will do the job safely and not try to be extremely cost conscious.

The tank is butt-welded. Another point that you raised is location. We are fairly well out in the country. Phillips has probably the two largest tanks and a very interesting installation right in the middle of a metropolitan area.

JONES—What about the need to keep the dikes clear of snow and water?

JENKINS—We have a drain on the tank which, of course, works fine in the summer. It is a drain which automatically closes because it has a "U" tube in it. In the event of an ammonia spill, this would freeze up and stop the ammonia from going out of the dike. However, in the winter time, we have made no special provision for removal of water other than the fact that we have the dike drain. The dike is 150 percent of the capacity of the tank but, of course, you would get a heating reaction and a good deal of vaporization if snow or ice were present.

HAYS—Perhaps I can answer some of the questions on some of the precautions we took during construction of the tank. For example, all of the vertical seams were x-rayed and the bottom plate welds were all vacuum tested. We took quite a few radiographic shots ourselves on the horizontal seams and a few on the vertical seams as a check. All material, of course, was tested the piping checked and all fittings and valves with A-350 Spec. were checked. In testing the dome, we couldn't fill the tank completely. We filled it up to the overflow line and tested the shell, then dropped the water down to about a six-foot level, and put about a one and one-half pound air pressure in there and soaped the dome to make sure we didn't have any leaks. As a further precaution, we even tested the outer shell. We put a one and one-half pound pressure on the outer shell and soaped all the seams as an extra precaution. In addition, we were particular about the type welding rod used.

WEIGERS—I have two unrelated questions. One of them concerns the initial cool-down. I am not too concerned about the problem of preventing cracking in the metal as I am about the problem of getting rid of the ammonia vapors which are bound to evolve. I rather assume that your vapor handling equipment can't take the volumes of dilute ammonia vapor that you would have on your initial start-up. What sort of equipment would be necessary to handle the ammonia vapors while they are diluted with air? The second question I have is the one involving the dike. Assuming that you have a spill and you fill this dike with 6,000 tons of anhydrous ammonia. You have contained it but then what?

JENKINS—If we contain the ammonia in a dike, we have avoided a catastrophe. We could at least evacuate the people and get them out of the area. Then supposedly we would have time to put the ammonia in any tank that we had available.

On the question of ammonia vapor during start-up: We are fortunate in having an air still. We purged the entire tank with nitrogen so that we didn't have to worry about purging oxygen from the tank to prevent a combustible mixture. We actually just purged with ammonia until we smelled a little bit of ammonia. At that time we put the compressors on the line, put the fixed gas eliminator in service and waited. It took a couple of days to get the nitrogen but we didn't have any vapor loose in the area at all.

WELLS—I was a little concerned about how you would dispose of this lake of ammonia if you got it in the dike. Do you have any plans that you would put into effect to put this into your other storage?

JENKINS—We have a complete disaster plan written up to the point we get everybody out of the area and evacuated. Beyond that point, we don't have a finalized plan. The disposal of the dike full of ammonia will basically depend on what direction the wind is from and how we can work with the various lines. It is a matter primarily of the conditions as they exist at the time and we wouldn't know what tanks would be empty and what tanks would be full. We haven't determined exactly what would be our final course.

JACKS—M. W. Kellogg—I would like to make mention of one point that I noticed in reading the paper. The double wall tank has an inner wall which has no or zero corrosion level. Now, I would just point out that when you constructed this tank, you had to static test with water. It takes a while to fill this tank and empty it and test it. If you aren't careful, you can have corrosion of that inner wall from water that is in the tank before you start to use it. I wonder if you had thought of this or if you took any special precautions during your hydrostatic testing.

JENKINS—We started to fill as soon after testing as possible and, of course, ammonia has got a tremendous affinity for water. Once you get any ammonia in that tank you don't have any water in there.

JACKS—I am talking about between the time that you start to fill it and the time that you start to fill it with ammonia.

JENKINS—Well, this is a short period of a week or two. I don't think we will get a tremendous amount of corrosion in that time.

MURPHY—Esso Research—I was wondering why you picked the figure of 150 percent for your fire bank capacity. Have you given any thought to excessively high fire banks delaying any fire fighting activity? There have been a few cases in the petroleum industry where firemen have been seriously hampered in fighting a fire if fire banks have been eight to twelve feet high.

JENKINS—The primary reason for 150 percent is that if, in fighting the fire, we have to put water in the tank we wouldn't overflow the top of the pit.

MURPHY—Have you tried using foam on this ammonia to extinguish the fire or just plain ammonia? We did a little work on ethylene and it will freeze your foam right up on some sections and it will bubble through with a high vapor pressure.

DUNCAN—There are some comments I would like to make on atmospheric storage. Most of your controls for pressure relief or high pressure control and for low pressure control will be either electric or pneumatic. Both of these systems can fail, and we have had failures on both types of systems. So, when you are talking about high pressure and you are going to build one of these tanks, be sure to put a "hatch" on this tank that works only from differential pressure because mechanical relief valves or pneumatic-operated flare valves will fail. Now about the vacuum control. We have automatic blowers. These blowers are operated by electric solenoid pressure switches and these can fail. We have a pressure switch that is completely isolated from our pressure control switches that will shut these compressors down on low pressure. We have a 45-pound vapor system that opens up pneumatically to put 45-pound vapor in the storage tank on low pressure. We have also a natural gas system (175-pound) hooked up so that we can put natural gas into this storage tank. We also have a vacuum breaker on top of the tank. The problem is that you never want, if you can possibly help it, to get air into that tank so we can use ammonia and natural gas before we let air come in. I might say, in the five years operation of the tank, with atmospheric conditions down as low as 9°F., we have never had a vacuum on this atmospheric storage tank. We operate this tank in a pressure range of one to three inches of water.

JENKINS—Your points are very well taken. I particularly think that we ought to stress again the fact that we have used both pneumatic and electrical controls wherever we could so that if one fails completely, we are still safe. We don't anticipate both systems failing at once. If they do, we would have trouble. The electrical system is on an auxiliary generator so that the auxiliary generator, in case of failure of the main power supply, picks up within a few seconds; thus we don't feel that both of these systems can fail at the same time. I want to stress very strongly that your pressure control system must be absolutely "fool" proof. A mechanical relief system provides final pressure relief. However, you don't want oxygen in this tank no matter what you do, and a simple vacuum breaker is not adequate. This idea of natural gas butt up in case of low pressure is one that I hadn't heard of. It is a very good idea.

MURPHY—On your vents that open up at forty inches are they sized to relieve a fire exposure in the pit area? And, if they are, do you consider that your outside shell may be damaged from heat so that some of your insulation might escape?

LAWRENCE—The thing that was considered was that if you can protect the outside to 150 degrees on the skin, you wouldn't even feel it on the inside. The fire would have to actually destroy the skin so that you would actually try to wet the outside skin to prevent fire from damaging it.

DUNCAN—You have to remember that most of you probably have seen the spillage of anhydrous ammonia under pressure and when it hits the ground it vaporizes very rapidly. Now the ammonia in this tank is going to be minus twenty-eight degrees and, as soon as it cools and ices about a foot layer of the ground in the dike, all it is going to do is sit there and slowly vaporize. I would imagine that in a dike the size that we have at Southern Nitrogen, that there wouldn't be over fifty to one hundred tons a day of the ammonia in the dike that is going to vaporize. You might have to evacuate the plant and just the surronding area, but that is just about all. Under no condition should you put foam, water or anything in that dike to make it vaporize faster. In fact, if the ammonia in the dike caught fire, I think I would just stand off and watch it burn. I still wouldn't put water in the dike. I don't think I would put foam in the dike.

JENKINS—We are in general agreement. We won't put any more water than we have to in the dike. We will fight a fire though. We believe that we should fight a fire, but with a minimum of water.