Ammonia Storage Design Practice

Results of a comprehensive survey of industry experience in the United States and Canada on four specific features in the design and operation of atmospheric ammonia storage tanks.

C.C. Hale
Adtek, Inc.
Kansas City, Mo.

Major highlights of a recently completed industry survey of atmospheric ammonia storage terminals have revealed the following major conclusions regarding four specific design and operating features of this type of equipment.

1. Refrigerated storage tank insulation systems are a major item of maintenance, due to water penetration of the moisture seal, resulting in ice damage. Moreover, double-wall tanks and reflective insulation systems are more expensive, but they continue to give good protection and have few failures. When tank bottom heating is used, there are also maintenance problems but not nearly as serious as tank wall insulation failures.

2. Protection of foundation from frost damage. This is usually achieved by insulation and heating coils. About 75% of the tanks surveyed have such heating systems. The most frequent failure was that in the electrical resistance coil heating system. Hot air or gylcol solution circulating systems appeared satisfactory.

3. Dikes to retain liquid in the event of a spill are used in about 60% of the tanks surveyed, although in most cases they are not required by the federal codes. Problems are apparently only those associated with routine maintenance. In no case has there been an actual spill.

4. Flares to dispose of ammonia vapors are also used in about 60% of the tanks surveyed. The only problems are apparently associated with the lighting of the pilot and the actual burning of ammonia in the flare.

The survey covered 150 tanks in the United States and Canada, with an accumulative total capacity of 3 million tons of liquid ammonia. Returns from 50 companies, in 30 states and three provinces, have been analyzed. The average tank size was 20,000 tons. The 30,000-tonner, however, is the most commonly built tank at present. Five of the 50 companies operate almost half the total number of atmospheric ammonia storage tanks covered.

The background to the study

The manufacture and distribution of anhydrous ammonia in the United States and Canada is already one of the largest volume synthetic chemical industries. The handling methods for these large volumes has naturally changed over the years. Conventional practices of using tank trucks and tank cars were first supplemented by the use of river barge. Now two inter-state pipelines transport large volumes from the Louisiana Gulf coast and from Texas to the central and midwest U.S.A.

The major portion of this pipeline and barge ammonia shipped into these regions is now used for fertilizer and is applied directly to the ground. Shipping and storage patterns developed around the demands of the fertilizer market. Current practice in the midwest farming areas has been to apply at least 75% of the total ammonia used as fertilizer each year in a four-to-six week period. The starting time and the length of the fertilizer season are somewhat dependent on the weather, so this is not always the same period each year.

Obviously, this type of demand for product posed a few problems for an industry that had developed large-scale, single-train ammonia manufacturing plants in which continuous production has been a major factor in obtaining the maximum economy. The logical answer to this problem has been the development of economical large-scale storage facilities to bridge the gap between continuous production and seasonal demand for the product.

Marketing of ammonia on a volume basis can be described in five steps:

1. Large-scale manufacturing plants operating on a continuous basis and located near the source of natural gas feed stock.

2. Transport of these large volumes of liquid ammonia from the point of manufacture batchwise by pipeline, refrigerated barge, or tank car to the area where it will be used.

3. Accumulation and storage of the liquid ammonia in large capacity tanks at essentially atmospheric pressure in storage terminals. These terminals are usually located next to the river or close to a pipeline.

4. High capacity load-out facilities from the atmospheric storage tank through a re-heating system for rapid shipment of the liquid ammonia by pressure tank–car or tank-truck to the local fertilizer distributors within a short radius around the terminal.

5. Finally, application of the liquid ammonia to the ground by the individual farmer or by contract applicators.

This article is concerned only with the third step in the sequence: storage of the liquid ammonia in atmospheric storage tanks and, in particular, a few of the practices that have developed over the years in these terminals.

A review of the published literature on the subject of ammonia storage revealed very little that had been published except in the reports from this series of ammonia conferences. According to these conference articles and my own survey, the first atmospheric ammonia storage tanks were built in Canada in 1941. These were 35 ft. in diameter and 30 ft. high, with flat bottoms and cone roofs. Prior to this, the same company had employed low-pressure refrigerated spheres, 38 ft. in diameter to store liquid ammonia at a pressure of 12 lb./sq. in. gravity. Each tank held 500 metric tons of ammonia.

The first atmospheric ammonia storage tank in the United States, completed in 1956 with a capacity of 7500 short tons, was 110 ft. in diameter and 40 ft. high. It had a cone roof designed to operate at 6 inches of water pressure. Since 1956 the number and the size of the tanks being built has steadily increased. In this survey, during this last year, over 150 of these tanks were found in the United States and Canada alone. If all of the tank owners had been located and had replied to the survey, this number probably would have exceeded 200.

Table 1 lists the size and number of the tanks reported in this survey as built since 1941. The size of the tanks has seemed to have leveled off, with 25,000 to 30,000 ton the most common size built in the last five years. Two 40,000-ton tanks were the largest actually reported in this survey. A typical 30,000-ton atmospheric ammonia storage tank, as reported, would be between 165 and 170 ft. in diameter and between 63 and 65 ft. high. The top dome on these tanks will add another 15 to 20 ft. to the overall height.

The rapid growth of Atmospheric Ammonia Storage capacity is illustrated graphically in Figure 1. Although the bulk of liquid ammonia is now stored in atmospheric storage tanks, other forms of storage are still used and have been compared in the Table 2 which includes the three most commonly selected operating pressures. The three types of commonly used storage systems are illustrated in Figure 2.

From Table 2 it can be seen that only one of the 40,000-ton storage tanks is the equal in capacity to 200 of the large pressure storage tanks. The total amount of steel required for the pressure tanks would be about five times that required for one atmospheric tank of the same capacity and the cost would also be in the same ratio.

Large underground storage caverns have also been used for the storage of liquid ammonia (as well as for natural gas). Their use has been limited to a certain extent by the structure of the ground, and they have not been used extensively in the farming areas for the storage of ammonia.

By way of definition, the term "atmospheric storage" usually refers to tanks designed for internal pressures up to 1.0 lbs./sq.in. gauge. At this level, the ammonia vapor pressure will correspond to a temperature of close to 28°F. below zero. Obviously, refrigeration is required to maintain the ammonia at this temperature. The actual operating pressure is usually controlled automatically close to the mid point between zero atmospheric and the maximum tank design pressure. The refrigeration compressors recover the vapor boiling off from the tank and return it to the tank as a liquid.

This survey was limited to four specific areas. The main purpose was to try to cover items which the potential new tank owner might want to consider before finalizing his design. These are the areas:

1. Refrigerated tank insulation systems.
2. Refrigerated tank foundation systems to prevent frost damage.

Table 1. Atmospheric ammonia storage capacity

No. of tanks of each size* vs. year built in the U.S. & Canada

YEAR BUILT	TANK SIZE IN SHORT TONS: 7500 or less	10,000	15,000	20,000	25,000	30,000+
1941	4					
1956	1					
1957	1					
1958	2					
1959						
1960	3	3				
1961	6		8			
1962		1	4			
1963	1	1	5	1		1
1964	2	3	5	4		2
1965	4		4	13	1	5
1966	1	2	3	7		8
1967				2	4	5
1968			2		3	10
1969					1	4
1970						
1971						1
1972	1		1			5
1973					1	3
Totals	26	10	32	27	10	44

*Sizes grouped for simplification.

Note: Total amounts to approx. 3,000,000 tons for all tanks listed.

Table 2. Tank design comparison—ammonia storage

Type	Rating lb./sq.in. gauge	Temp. °F.	Refrigerat. compressor stages	Tank diam. & ht., ft.	Capacity ton
Horizontal cylindrical	250	ambient	none	12 x 130	200*
Spherical	60	34	single	68 diam.	3,000
Vertical cylindrical	1	−28	double	185 x 71	40,000

*100,000 gal.

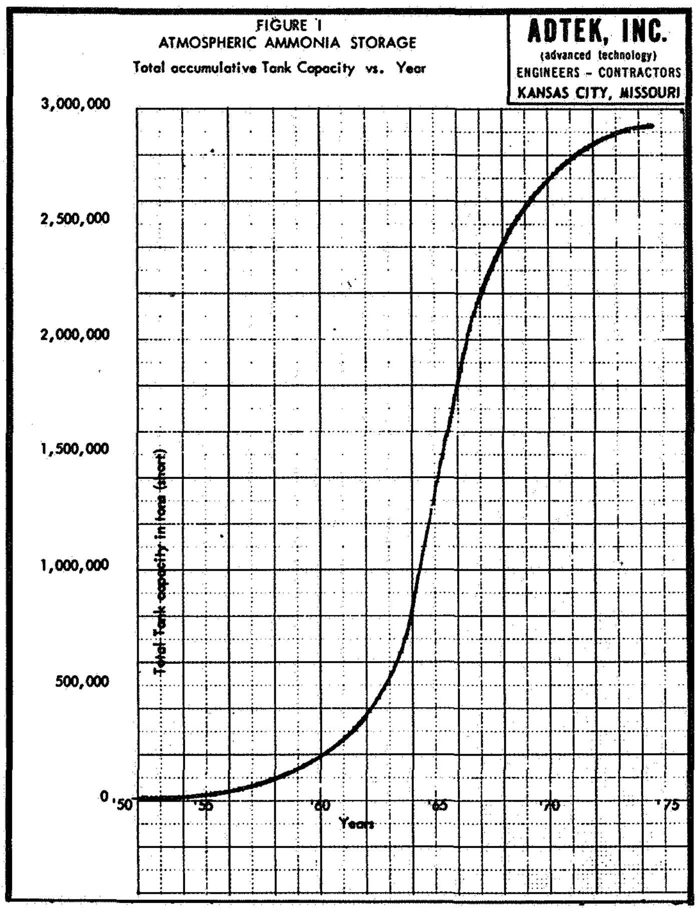


Figure 1. Total accumulative tank capacity vs. year.

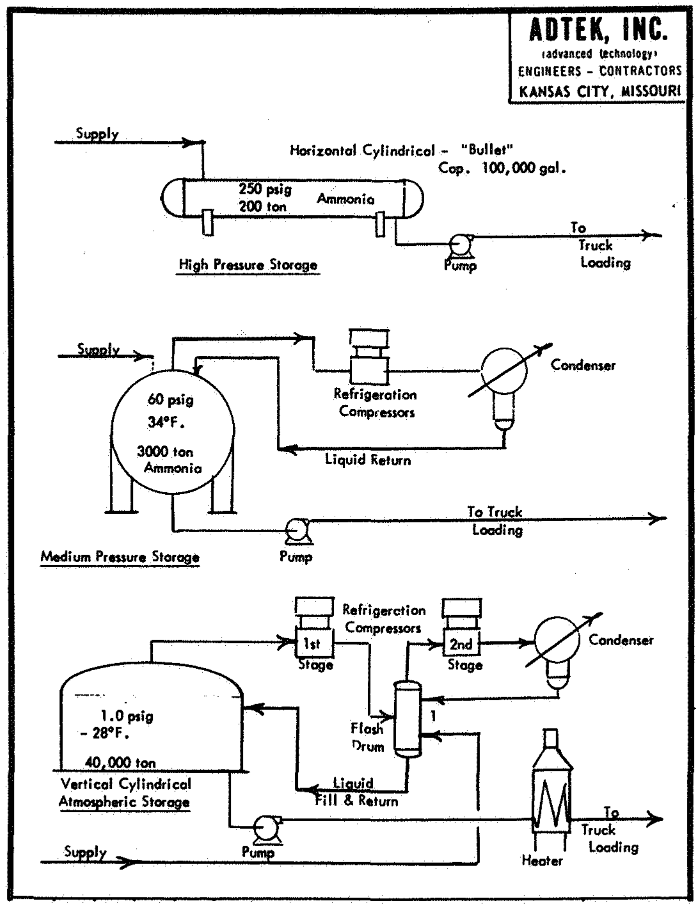


Figure 2. Tank design comparison.

3. Dikes to retain the liquid ammonia in the event of a spill.

4. Flares for the disposal of ammonia vapors.

For each item two basic questions were asked: first—describe the installation you now have; and, second—what problems have you had with this installation? A brief discussion of each item covered by the questionnaire was enclosed to give each operator a general idea of the type of information we were trying to accumulate on each subject. Letters transmitting the questionnaires were mailed out to over 100 companies. About 50 replies were received covering the 150 tanks included in this survey. Copies of the questionnaire are available for review. Copies of the summarizing report paper were offered to the operators in the letter of transmittal, and we agreed not to quote specific companies on any of the answers.

Question 1: Refrigerated tank insulation systems

Insulation systems for refrigerated ammonia tanks do not differ basically from tanks storing other refrigerated products. Ammonia storage at −28°F. is similar, for example, in many respects to propane which is stored as a liquid at −45°F. to −50°F. Based on the returns from this survey, the insulation systems reported fell into six different classifications. Table 3 lists these systems and summarizes the frequency of failure on each type.

It was not possible to determine the exact reason for failure of the various insulation systems based on the information received in this survey. The only classifications which are shown in Table 3 are "major failures" where most of the insulation was replaced, and "minor failures" which also included minor maintenance of bands, rivets. In other words, where repairs were made which did not involve replacement of the insulation itself, it is shown as a "minor failure", such as merely patching of the seal layers.

Three of the six types of insulation systems reported had only minor problems. The double-wall tank systems have been used for many years with considerable success in this service. The annular space between these two walls is filled with expanded perlite. A few reports indicated frost spots had occurred but no major problems in this type were reported. One company reported, however, that the perlite had settled and additional insulation was added. This problem was avoided on most of the tanks reported by the installation of a resilient fiberglass blanket against one of

Table 3. Insulation systems

Tank Construction	% of total No. of Tanks	% Failures* Minor	% Failures* Major
Double wall tank with expanded perlite and a blanket insulation	38	7	None
Foam glass block with a moisture and weather outer seal coat	24	45	20
Polyurethane foam with an outer seal coating	17	12	23
Reflective aluminum in multilayers with air spaces for insulation	9	21	None
Styrofoam with a moisture and weather coat	9	43	14
Fiberglass blanket with outer seal coat	3	--	--

*Within each classification.

the walls before the perlite is blown in to avoid settlement as the tanks expand and contract.

The only failures reported on the reflective multilayer aluminum insulation systems involved seal leaks between the adjoining sheets. This results in ice accumulating between the layers and damage to the sheets. Repairs to this type of installation can be made, however, without complete replacement because the ice can be melted and the water will drain out the bottom through pipes provided for this purpose.

Repairs to foam glass, Styrofoam, or urethane insulation systems can be rather expensive and time consuming. A detailed report of one such incident was presented at this conference in 1967 by Allen Hoffman of Farmland Industries. Detailed installation methods were presented in 1965 by Mr. Crowly of American Oil and Mr. Laing and Mr. Henderson of Dow Chemical.

The high frequency of failure over the years with standard block insulation systems indicated by this survey as listed in Table 3 is primarily the result of water penetration of the outer seal layers. New seal coatings are now available, thus these results are not necessarily representative of what can be expected in the future. The moisture penetration of the seal coatings was in most cases caused by wind damage and by expansion and contraction of the outer layers as the temperature changes. The total number of failures amounted to 14 tanks out of 80 tanks with block type insulation. The incidence rate was about two per year for tanks built between 1965 and 1968. None of the tanks built after this reported major failures in this survey.

The cost of a tank installation with the double wall or reflective aluminum insulation systems will usually be at least 5% to 20% more than tanks with block or foam insulation systems.

Question 2: Refrigerated tank foundation systems to prevent frost damage

Atmospheric pressure ammonia storage tanks resting directly on the ground must usually be protected from "frost heaving" if water can penetrate below the tank. An excellent description of this problem and how to prevent it was presented to this conference in 1967 by Morrison and Marshall of Chicago Bridge and Iron Co.

In areas where water is available in the ground the problem of frost heave can be avoided by shielding the ground from the freezing temperatures of the ammonia within the tank. This is accomplished by building the tank on top of a layer of insulation and with heat coils installed between the insulation and the ground. Heat is then added as required to compensate for heat loss from the ground into the tank, and the ground can be maintained above freezing temperatures. A series of thermocouples in the heated area will monitor the temperature to control the heat.

Based on this survey, only 75% of the tanks had heating systems for this purpose. About 15% of the tanks were built on a slab supported by piling. These tanks have an air space between the bottom of the slab and the ground. Thus free air circulation protects the ground from the freezing temperatures within the tank. An additional 10% of the tanks were built on solid rock or other impervious soil and had no heating system. None of the tanks without heat shields reported any problems.

Of the 75% of the tanks having heating systems, 70% used electric cables and resistance heating. The cables are in conduit so they can be removed if necessary.

Three major failures were reported, and minor repairs were required, in 30% of the installations using electric cable for heating. One major failure included replacement of the tank bottom and the other two required 100% coil replacement. The remaining tanks reporting the use of heat for frost protection used pipes to circulate either hot air or glycol solution. Both methods were apparently satisfactory. So few were reported using these two methods that the results are not too significant. Table 4 summarizes the overall results of this survey on frost protection systems for tank foundations.

Table 4. Tank foundation frost protection

Tank Construction	% Total	% Failures Total	% Failures Major
Bottom slab supported on piling.			
Free air circulation	15	None	–
Bottom slab on insulation with heat shield			
Electric (resistance)	70	30	3
Glycol solution circ.	3	One leak	
Hot air	2	None	
Bottom slab on insulation on rock or impervious soil (no heat)	10	None	

Question 3: Dikes to retain liquid in the event of a spill

Although most state and federal regulations do not require dikes around anhydrous ammonia storage tanks, many local areas now add this to the list of safety features required before a building permit will be issued. The American National Storage Manual for Anhydrous Ammonia lists two options in their recommended safety requirements: either a dike to contain the entire contents, or drainage to a safe area.

About 60% of the total number of tanks listed in this survey were protected by dikes, and in all but a few installations the dike was considered of adequate size to contain the entire contents of the tank. In several cases, more than one tank was in the same diked area. Only two owners reported the latter case with drainage to a holding pond area. One owner reported his tank was inside a steel tank which served as a dike because it was larger in diameter than the inner tank but not as tall. All the rest of the dikes were earth.

Problems with the dikes are apparently limited to normal maintenance only because none of the tanks surveyed had indicated a need for the dike to retain the liquid ammonia. A few reported flood water from nearby rivers had come up on the outside of the dike.

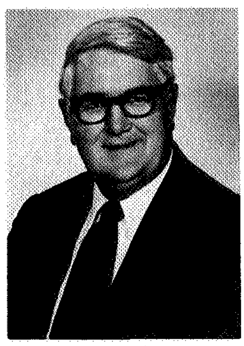
Previous meetings of this conference have heard discussions of the use of these dikes and the need to restrict the overall surface area of the liquid by the use of tall dikes. Details of this work were reported by Ball in a paper, "Review of Atmospheric Ammonia Storage Research Study." Operators did note problems in maintaining tall or steep dikes. If the slope of the dike is steep, erosion occurs and the control of the grass is a problem. These steep dikes also limited the access to the base of the tank for maintenance of the pumps or tank insulation.

Question 4: Flares for the disposal of ammonia vapors

In normal operation of an atmospheric ammonia storage facility, very little ammonia vapor is vented. The refrigeration compressors recompress vapors as they are generated within the tank, and after condensation the ammonia is returned as a liquid to the tank. All the terminals reported have at least two compressors for this purpose. During electrical power outages, however, these compressors are not available unless a source of standby power is included in the design.

Another alternate, however, has been found for the disposal of these vapors by burning in a flare to nitrogen and water vapor. About 60% of the tanks surveyed were connected to a flare. In installations having more than one tank, only one flare was used. Practically all of the tanks having flares discharged the ammonia vapor to the flare automatically based on pressure in the tank. The flares were located in various places, such as flanged to the top of the tank, on top of a stair tower adjacent to the tank, or—in a number of cases—outside the diked area. The sizes of the flares ranged from 3 to 11 in. in diameter with heights from 20 to 110 ft. The most common size was 4 in. in diameter, for one tank.

The only problems listed in this survey concerned the lighting of the pilot and burning of the ammonia in the flare. The flare pilots are usually hard to light and blow out frequently with high winds and rain. One company did report a deposit in the flare line, but this material was not identified. About half of the tank owners having flares kept the pilots operating all the time to avoid the problem of relighting during a storm or a power failure. #



HALE, C. Clay