Tips on insulating tanks

Operating experience with low temperature ammonia storage tanks yields valuable information on techniques and materials.

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ANHYDROUS LIQUID AMMONIA can be stored either in a high-pressure steel sphere or in a container designed to keep the ammonia at —28°F and 1 atm. Low temperature storage is cheaper and enjoys the added safety feature of slower gas release in the event of a tank failure.

Low temperature storage has included the following techniques:

1. Single-wall tanks insulated with foam-glass blocks, organic foam, or reflective-type multiple foil systems.
2. Double-wall tanks containing perlite in the annular space between the walls.
3. Underground storage in natural or man-made caverns.

The basis for selection of a system must include: the volume of ammonia to be stored, the requirements for purity of product, safety factors, probable maintenance costs, and the cost per unit volume of storage.

The economics of underground storage are favorable only if a large quantity (500,000 bbl.) of ammonia is to be stored and the local geologic structure is appropriate. Unlike underground LPG storage where product contamination by water seepage or reaction with wall rock is seldom a problem, underground ammonia storage considerations must include both these factors. It is probable that future

Table 1. Typical properties of materials considered for low temperature insulation.

Material	Density, lb./cu. ft.	Compressive strength, lb./sq. in.	Conductivity (75°F mean), Btu/hr.-sq. ft.-°F/in.	Burning* classification, ASTM	Water vapor** transmission, perm-in.
Urethane foam (5 brands)	1.66–1.90	29–43	0.15–0.18	S.E.	1.18–2.11
Polystyrene foam (3 brands)	0.98–2.16	7–51	0.24–0.29	B–S.E.	0.9–5.4
Polyethylene foam (1 brand)	2.3	5.7	0.42	B	1.07
Foam-glass	9	125	0.4	Nonburning	—

* *B = burning; S.E. = self extinguishing.*

** *A Perm is the amount of water that will penetrate a material under a given set of conditions and is expressed as gr./hr.-sq. ft.-in. Hg/in.*

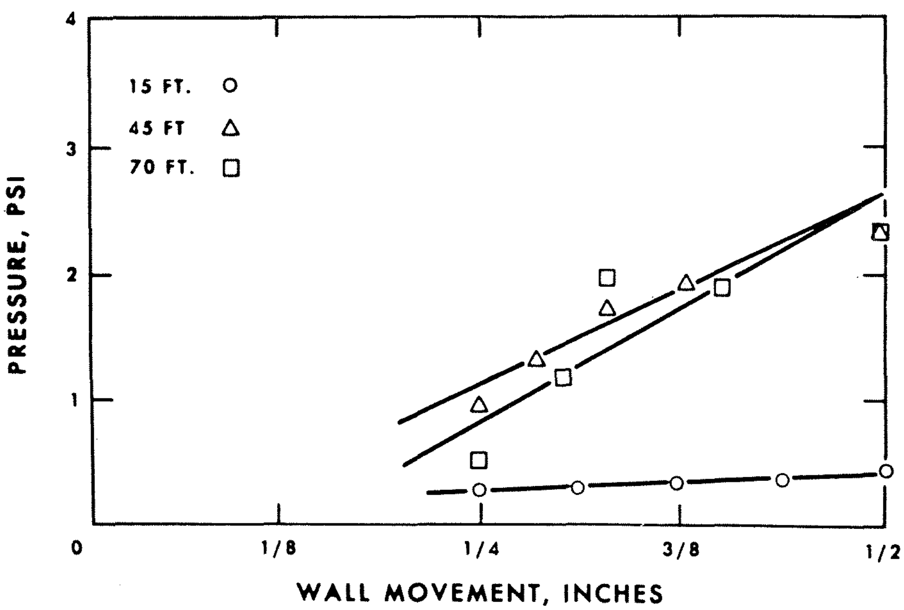

Figure 1. Equilibrium wall pressures as a function of height and movement (perlite fill with 2 in. of 3/4 lb./cu. ft. glass-fiber felt against moving wall).

underground storage of ammonia will be very limited because the cost of insulated tank storage is constantly decreasing.

Double-wall tanks

The choice between single-wall and double-wall tanks is a matter of initial cost, maintenance cost, and refrigeration requirements. Double-wall tanks are more expensive to build, but their maintenance costs are usually lower, and their refrigeration holding capacity can be reduced because their heat losses are generally less.

Before the decision was made to build single-wall tanks for the American Oil Co. plant at Texas City, experiments were made to determine how settling of the loose perlite fill affects the pressure build-up in the annular space between the two shells. The pressure varies as the walls move relative to one another. Three types of movement occur:

1. The inner shell contracts as it is cooled in service; this may amount to as much as 0.5 in. over an interval of several years.
2. The outer shell expands and contracts in response to atmospheric temperature changes; the daily movements are minor but the total yearly magnitude can approach the cycling of the inner shell.
3. The perlite fill settles gradually to maximum compaction under the combined influences of gravity and occasional ground vibration; as a result the fill exerts a pressure against the tank walls.

The pressure build-up was measured in a box built to simulate a portion of the annular space between the tank shells. The fill was commercial perlite, an expanded volcanic ash weighing 2.7 lb./cu. ft. Plywood ends represented the tank walls, and one wall was fixed while

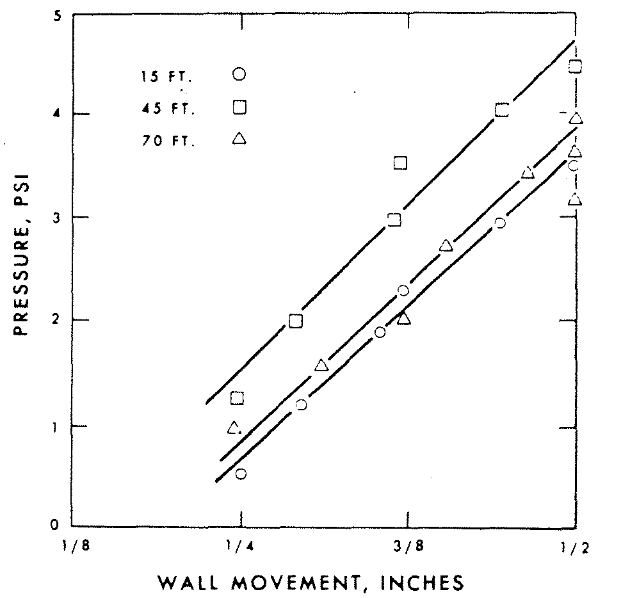

Figure 2. Equilibrium pressures as a function of height and movement (perlite fill without glass-fiber felt).

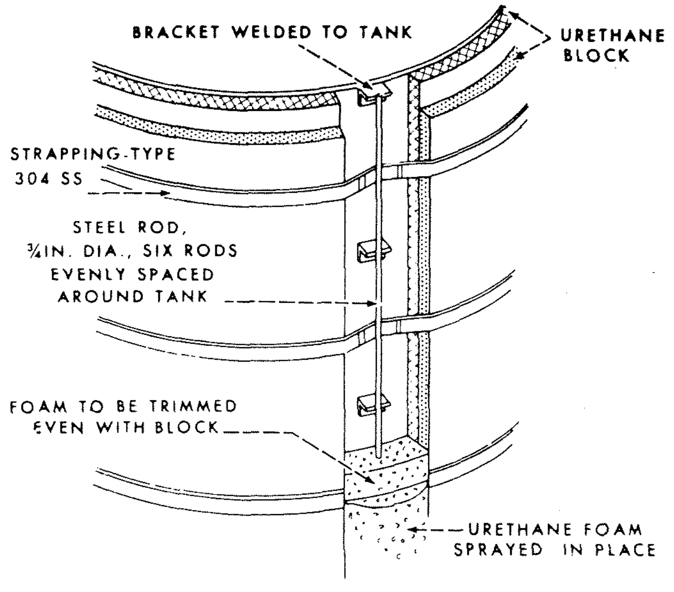

Figure 3. Insulation details for walls of the ammonia tanks at the Texas City refinery.

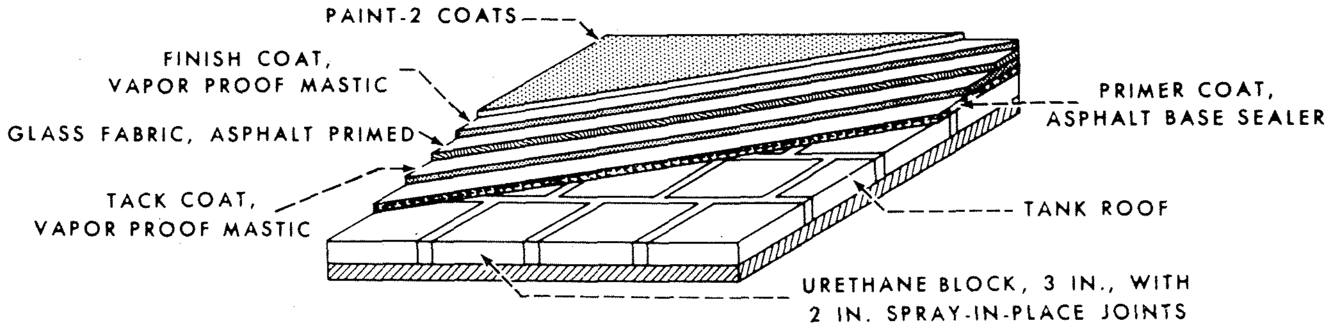

Figure 4. Details of roof construction for ammonia tanks.

the other was controlled by two drive screws. The cross-section of the insulating fill was observed through transparent plastic sides. The test volume was 12-in. thick (typical of actual tanks), 6-in. circumferential wall length, and 18-in. deep. A 25-lb. weight carrier and additional weights were used to simulate various wall heights. A piezo-electric transducer, built into the movable end, recorded the wall pressure on an automatic recorder. Figures 1 and 2 show the pressure increases as a function of wall movement for tanks of several heights.

The tests led to the following conclusions:

1. The pressures developed in perlite-filled double-wall tanks are determined by the magnitude and frequency of shell movement and by the degree of settlement-inducing vibrations to which the tanks are subjected.
2. Wall height affects pressure only in tanks of small diameter or in tanks exposed to only moderate temperature fluctuations.
3. Glass-fiber felt pads prevent substantial wall pressures only in low tanks, say, 15-ft. tall.
4. Wall pressures of at least 7 to 8 lb./sq. in. may be expected in 70-ft. tall perlite-insulated tanks.
5. In tanks over 45-ft. tall, in which wall movement is more than about 0.25 in., glass-fiber felt pads probably reduce maximum wall pressures by about 2 lb./sq. in.

Ammonia storage

Because of the improved economic picture in low temperature tank storage, underground storage was not considered for the Texas City refinery. The estimates for tanks to hold 250,000 bbl. of anhydrous ammonia were as follows:

1. Double-wall, perlite insulation, $766,000
2. Single-wall, reflective foil insulation, $728,000
3. Single-wall, urethane foam insulation, $656,000

A number of materials, *e.g.*, foam-glass styrene foam, and urethane foam, were considered for the insulation. Urethane foam was selected because it has a low *K*-factor (thermal conductivity), low vapor permeability, good physical properties, and low cost. Table 1 lists the properties of the materials that were considered.

The details of construction have been given by Weyermuller (*1*). They are summarized in Figure 3, which shows the details of the wall insulation, and in Figure 4, which shows details of the roof construction for the Texas City tanks.

Ammonia vapor is not vented to the atmosphere except under very unusual conditions. The normal vapor generated by heat leakage into the tank is led back to the central ammonia-compressor system by a suction line. A combination pressure-vacuum relief valve is on each tank. The tanks are designed to run at 1 lb./sq. in. gauge, but they actually operate at about 0.5 lb./sq. in. gauge. Air could enter the tank if a vacuum should develop from a change in barometric pressure. To prevent this, an external heat exchanger, triggered by a vacuum gauge, adds heat to the tank contents when a vacuum begins to form.

Foam block installation

While the first tank was being insulated, a number of blocks of urethane foam on the tank became wet during a rainstorm. The blocks, unprotected by weatherproofing or a vapor barrier, swelled and pulled away from the tank in many areas. In one instance the swelling force was sufficient to break a steel band. The foam block manufacturer indicated that the volume expansion was due primarily to water vapor absorption from the rain, and also that banding should be on 12-in. centers. The defective areas were cut out and replaced with new 24 by 96 by 1.5-in. block insulation or with sprayed foam. For the repaired areas on the first tank and much of the area on the second tank, the blocks were placed with the long dimension horizontal; the strapping was on no more than 12-in. centers and no farther than 1 in. from any horizontal joint. According to the manufacturer, expansion of the block because of moisture pick-up may reach 2%, thus, the 0.87-in. increase found in the 48-in. width of the initial block appears normal for the high temperature, high humidity conditions. No subsequent swelling problems have been encountered since the finish of construction, and the tanks are reported to be operating according to the design specifications.

Severe service

In May, 1960, two vertical contractors, 7 ft. in diameter by 10 ft. high, at the Whiting refinery were insulated with urethane foam block after the original vegetable cork insulation had deteriorated. These units cycle between −40°F and +80°F every 20 min., yet the urethane block has proven very satisfactory in this severe service.

Poor experience in foam block insulation has been encountered by others who have designed insulated tanks using light-weight cone roofs with the roof block held by mastic adhesive. Aluminum jacketing was used in place of a vapor barrier. The roof flexed with minor internal pressure fluctuations and external wind pressures, and the roof blocks buckled severely. The block joints became filled with ice, and more ice formed between the shell and the loose blocks. Because of these difficulties, the Texas City tanks were built with a much stiffer dome roof, and sprayed foam was used in the joints to help anchor the blocks to the roof. An excellent vapor-barrier system keeps water vapor from forming ice next to the shell[1].

Future design of insulation

Recent improvements in application techniques for sprayed urethane foam indicate that our future designs will probably use this system in place of block insulation. A typical installation will involve several inches of urethane foam sprayed over a red-lead primed tank. The foam thickness will depend on the operating requirements. An asphalt-base vapor-barrier will be used if operating conditions or the climate indicate its desirability. The outer covering will be several coats of high-quality paint.

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