

Repairing Ammonia Tank Insulation

A case history of a successful repair following a major failure of the sidewall insulation; about 85% of the material was replaced with a new type material.

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Large-scale repairs after a major failure of insulation on a low-pressure ammonia storage tank have proved completely successful, based on a thorough inspection two years later. The replacement insulation system, involving a urethane structure, shows no sign of impending problems and is expected to continue to perform satisfactorily.

The 20,000-ton capacity tank, 138 ft. 4 in. in diameter, with 63 ft. 3 in. sidewalls, and a dome roof with a 112-ft. radius dome was built in 1966 at Simplot Chemical Co., Ltd., Brandon, Manitoba, Canada. Original insulation and coating took place in late fall of 1966 and winter of 1967. On June 18, 1971, approximately 85% of the sidewall foamglass insulation collapsed. This event, however, was only the final result of a series of troubles suffered by the insulation which compounded each other, resulting in the total failure.

Background leading to the failure

Original specifications called for three 2-in. thick layers of foamglass block 5 ft. high around the perimeter, and two 2-in. layers on the remainder of the sidewalls and roof. The system had an expansion joint 6 in. wide, of light density fiberglass, around the perimeter of the tank where the sidewall meets the dome. The ends and sides of the foamglass blocks were to be dipped in hot asphalt and fitted so that the blocks were fully adhered and sealed to the adjacent blocks in such a manner that no holes or voids existed. The side of the insulation next to the tank was to be dry and to act as a free-standing wall. The joints and faces of each successive layer were staggered and adhered to the previous layer with hot asphalt. The foamglass blocks were then banded with a 3/4-in. x 22-mil stainless steel band on 24-in. centers, covered with glassfab and a mastic coating. The mastic was then given a white vinyl weather coat.

Original construction of the insulation and coating took place when temperatures ranged from +15°F to -30°F. The entire sidewall area of the tank was boarded in with polyethylene sheets and heated. During this construction period, the boarding was damaged several times and once during a snow storm approximately half of it was destroyed, allowing moisture and cold temperatures to penetrate the uncured mastic and the unprotected foamglass. This was the first source of moisture and the first step, we believe, towards the ultimate failure.

Approximately two years after construction was complete, cracks in the white vinyl coating started to appear and water blisters became numerous. At that time it was thought that cracks resulted from thermal expansion of the tank as it warmed up during removal of ammonia in the shipping season; the cracks in the vinyl were probably allowing rain to enter and collect behind the coating. This, however, was not the case. Numerous core samples were taken throughout the sidewall and roof insulation. Every sidewall core contained moisture, some to the point of saturation. The cell structure of the foamglass was in most cases completely broken down by the freeze-thaw cycle of the moisture as the tank level and ambient temperatures fluctuated.

Severe bulging is experienced

During spring of 1970, areas of the foamglass began to bulge out between the bands. Again the water blisters appeared as the tank level decreased. It was decided to remove the failed sections of foamglass, install more bands and recoat the vinyl to preserve the vapor barrier in an attempt to save the remaining portions of the insulation.

As the repair work progressed, the second and third reasons for the ultimate failure became evident. The expansion joint at the junction of the sidewalls and dome contained light-density fiberglass insulation. The fiberglass was originally 4 in. thick by approximately 6 in. wide, but due to expansion of the insulation, it had been compressed to approximately 2 in. wide by 2 in. thick. The expansion joint had become saturated with moisture which would not allow it to expand to fill the void. In some areas it was found the moisture had frozen and produced ice up to 3 in. thick.

There were actually two sources for the moisture, assuming the vapor barrier was intact. The first would be through the vapor barrier even if it was basically sound, because of the extreme vapor pressure differential across the membrane once the fiberglass insulation had been compacted, exposing steel at -28°F.

The second source was through a thermal short. The roof insulation and wall insulation were separated by a horizontal 3-in. wide by 3/8-in. thick flat bar which supported the roof insulation. The flat bar was not insulated though it was covered with the vinyl coating, again, in our

opinion, causing a high vapor pressure differential and thus resulting in condensation of ambient air.

The final reason for the ultimate failure was the poor workmanship of installing the foamglass and caulking the joints between each block. In a lot of instances, there was no asphalt at all between the edges and/or between the faces of adjacent blocks, again resulting in a high vapor pressure differential and thus moisture condensation.

Ultimate failure after some four years

The foamglass insulation began to sag and buckle on June 11, 1971. On June 18, 1971, before anything could be built to support the sagging section, the entire top half of the insulation fell from the tank. The failure initiated at the bulged section and progressed around the tank in a clockwise direction as viewed from above. The remaining insulation was pulled down to the 8-ft. level, where solid ice was encountered. See Figure 1.

The tank level at this time was 1 ft. 6 in., and we had not experienced any high winds prior to the insulation failure. The ultimate failure was the direct result of the moisture permeating the vapor barrier. This caused the insulation cell structure to be broken down by the freeze-thaw cycle, and as we lowered the ammonia level inside the tank, the ice, which was the only structurally sound element in the system, melted, resulting in the system's collapse.

Samples retrieved from the rubble clearly indicated that poor workmanship had prevailed throughout the project. Numerous samples indicated no asphalt and no adhesion between adjacent blocks. Core samples taken from the blocks showed complete breakdown of the cell structure and most cores were saturated with water. Core densities of the foamglass were as high as 21.00 lb./ft.³ as compared to a published density of 8.50 lb./ft.³.

The remaining foamglass on the tank was removed and squared off at the 8-ft. level, where a structural steel support ring was installed to support the new insulation system. This ring was necessary because the storage tank could

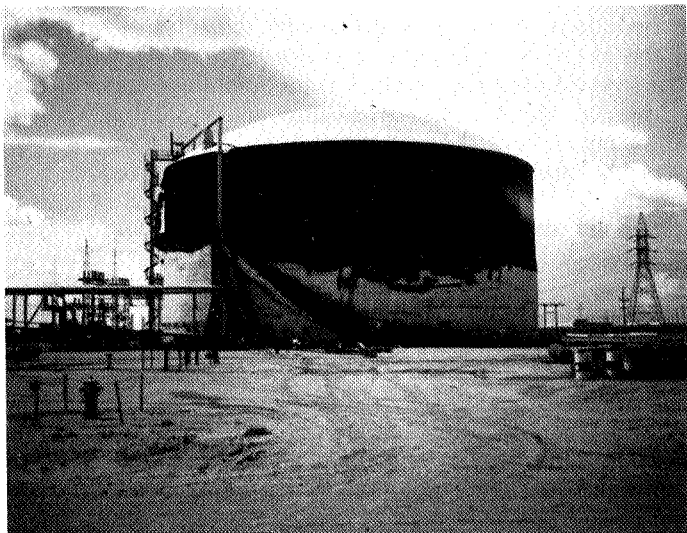


Figure 1. Condition of tank on Monday, June 21, 1971, immediately after the failure but before repairs. Photo of west side of tank.

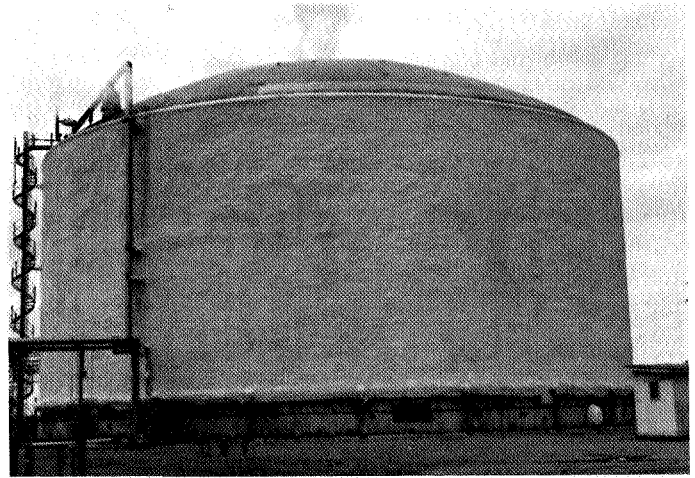


Figure 2. Tank in April, 1972, after repairs were completed.

not be taken out of service to obtain a firm foundation to support the insulation.

After numerous insulation systems were investigated, polyurethane foam sprayed in place was chosen for the following reasons:

1. Sprayed in place urethane forms a monolithic membrane so that moisture has no joints in which to permeate.
2. Superior insulating qualities of urethane with its 'K' factor of 0.12 vs 0.4 for glass brick.
3. The urethane sprayed in place is adhered to the tank wall and thus does away with an expansion joint and removes the possibility of any corrosion occurring.

Simplot, after consultation with a number of other storage tank operators and material suppliers, produced a design for the urethane structure which it believes is the best system available.

The tank was first sandblasted and then prime-coated with an epoxy paint to insure excellent bonding of the urethane. Around the roof insulation support, lugs were spot-welded from which rows of wire mesh were hung which were then tied together to form a continuous mat around the tank.

The wire mesh serves three purposes. First, it gives the urethane needed tensile strength. Secondly, if the bond is lost between the urethane and the tank, there would still be a rigid monolithic membrane resting on the support ring at the 8-ft. level. Thirdly, during low-pressure storage of ammonia, temperature stratification takes place; therefore, the wire mesh will act like a temperature rod in concrete, allowing temperature gradients to equalize and thus reduce thermal stresses.

As the urethane is applied, gaps are left between each section to allow the urethane to expand and cure fully, reducing any unnecessary stresses. The urethane was then coated with a 26-mil. vapor barrier and a 10-mil. white Hypalon weather coat. See Figure 2.

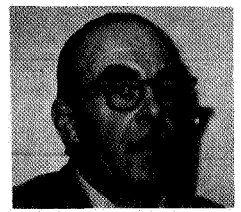
Inspection after two years shows good performance

Core samples were removed from different levels to check the urethane system after two years in service. All samples were found to be as expected: dry, adhesion to tank excellent, coating levels higher than specified at a total of 36 mils, and density of cores slightly less than that

recorded as a quality control check during construction. This indicates that the vapor barrier is functioning as published. Since we have experienced numerous complete cycles of temperature extremes and inventories in the tank, we have every reason to believe that the design will continue to perform in a satisfactory manner. #



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DISCUSSION

L.L. LOPER, Vertecs Corp.: Our company had the privilege of installing urethane foam and a butyl rubber vapor barrier coating on the 20,000 ton liquid ammonia storage tank just described. In paper number 57-a, "Survey of Atmospheric Ammonia Storage Design Practices" presented by Clay Hale of Adtek, Inc. of Kansas City, Mo., you heard a discussion on the wide spread usage of urethane foam insulation systems and a recent survey to determine the effectiveness of this relatively new insulation method. Out of 150 tanks checked, 25 or 17% were insulated with urethane foam. Of this group 6 were reported as having a major problem, three having minor problems, leaving 16 as acceptable for the operating function. You heard also that Farm Land Industries were building four new liquid ammonia storage tanks at this time with urethane foam as the insulating system. It would appear then that the performance of this method has been established and it is now being applied more frequently. As the dollar value of stored products and the cost of maintenance increases, a low initial insulation price is not always the factor in selection.

Since the first installations of urethane foam for ammonia tank insulation in 1966-67, as reported on by Pritchard and others; significant advances in technology have developed. The reliability of the insulation system (closed cell rigid urethane foam) is now recognized as the result of improvements in the basic chemistry and manufacturing processes; refinement in the application equipment; and specially trained personnel, sales engineers and mechanics.

As the chemistry of urethane foam systems is better known through increasing usage, specific formulations have been developed to provide physical characteristics needed in the service contemplated. For example in the low temperature liquid ammonia storage tank with a minus 28°F interface operating temperature (and frequently an external temperature in the same degree), greater resilience in the foam is needed to resist the thermal contraction forces. Shrinkage due to low temperature exposure and the resulting cracks caused by internal stresses exceeding the tensile strength of the material, was one of the earlier difficulties reported in urethane foam systems. This is not unique to urethane as other insulating materials also shrink under low temperature exposure; for example cellular glass has a coefficient of thermal expansion three times that of urethane foam.

A second improvement in the chemistry of urethane foam was to develop adequate adhesion to cold substrates. Early spray foam formulations did not have sufficient internal heat generation to provide the temperatures necessary for polymerization and overcome the heat loss into the substrate. This was a particularly serious problem when spray applying urethane foam to concrete or steel surfaces. This refinement has extended the time of application and simplified application procedures significantly. A corollary improvement partially brought out by the faster cure at normal temperatures is a smoother exterior surface. This is significant for the effectiveness of vapor barrier coatings. Pin holing and pockets without coating have been virtually eliminated.

Another basic system improvement since the 1966-67

era has been the development of reliable self-cleaning airless spray equipment, providing proper heating and metering of the chemical components. Within the last few years, this equipment has emerged as the dominant machine in use in the industry with placing rates of 15 or more pounds per minute, or about 90 board feet per minute.

A third advance in urethane foam technology is the improvement in operating personnel performance. This has been brought about by management recognizing that a higher degree of intelligence is needed to operate the sophisticated machinery (generators, air compressors, and foam spray units) and with that comes an understanding of the chemistry and the physical phenomena involved in providing an effective insulation system. Most qualified mechanics have attended one or more schools teaching the specifics in applying urethane foam. In our experience this training of higher paid mechanics to make urethane foam application specialists has produced excellent work. Good applications assure the owner that performance will be provided.

In the last decade a second major improvement relating to low temperature storage, particularly atmospheric liquid ammonia storage tanks, is in the vapor barriers available. Butyl rubber can be applied in two coats to a 20 ml thickness, providing a vapor barrier with ten times the resistance to vapor penetration over earlier asphaltic coatings. The high solids content of butyl formulations provide self-sealing and virtually eliminate pin holing possible with earlier vapor barrier materials. Application equipment improved likewise, airless spray guns using hydraulic pressure for atomization.

Lastly under the improved materials system category, is the recognition of the composite action of the urethane foam and butyl rubber vapor barrier application. The seamless nature of both materials provides a uniform temperature drop and a uniform vapor resistance across the total thickness material. One engineering acquaintance stated that the success of the vapor barrier over urethane was due to the insignificant temperature drop across the vapor barrier due to the excellence of thermal insulation. This minute temperature drop would definitely affect the vapor pressure differential across the film and in general reduce or eliminate the major driving force. With mechanical stresses absorbed by the inherent resiliency of the urethane foam, dimensional stability for the vapor barrier is provided well within the limits of its elasticity. Excessive expansion or contraction movement being eliminated prevents cracking of either the vapor barrier or underlying insulation. A final result of the above knowledge and performance over the years of experience gives our management the confidence to provide five year guarantees on sensitive installations.

Despite the positive assurances stipulated above, there are pitfalls in the application of urethane foam well known to all experienced contractors. The surface to which the urethane foam is to be sprayed is critical in that it must be unaffected by a rapid increase in temperatures due to the exothermic reaction of the urethane foam.

Coal tar or low-melting point asphaltic primers must be avoided as the adhesive strength developed will be inad-

quate to resist the shrinkage forces created by the cooling foam. Urethane systems must be selected for the application intended which means that a universal material for building insulation may not be suitable for hot tanks or cold tank applications. The spray equipment must be properly adjusted for the system used, hose heating elements for the application rate required. Improper use of the older solvent flush spray head has produced faulty foam after a period of time due to residual solvents carried over from

the flushing operation. A final pitfall might be called determine's the proper use of the material from a fire safety stand point. While low flame spread materials are widely available, even these will burn under the exposure of an adequate external fuel source. Therefore in fire sensitive areas suitable coatings must be provided over exposed foam to prevent the rapid surface temperature build up and resulting combustible gas emmision.