LOSS OF INSULATION ON AN AMMONIA STORAGE TANK

Expansion joint action caused insulation to break away; necessary to rebuild completely

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In the summer of 1965 we experienced the collapse of a considerable quantity of the sidewall insulation of one of our 15,000 ton ammonia storage tanks.

This particular event was probably the final result of a whole series of miscellaneous troubles suffered by the insulation on this particular tank and the sister tank that had been constructed in the summer and fall of 1961.

The two tanks in question are 140 ft. in diameter, with 48 ft. sidewalls, covered with 112 ft. radius umbrella-type roof. They are so located that there is a space of approximately 20 ft. between them.

Probably just a little bit of the history of this insulation might help you to understand what ultimately happened to us, or at least what we think was the cause of it.

How it all started

The original construction plans called for the sidewalls to be insulated with two 2 in. layers of foam glass block, which in turn was to be covered with corrugated aluminum sheets. The roof of these was to be covered with two 2 in. layers of foam glass block and that, in turn, was to be covered with a coating made up of glass cloth and a mastic material.

The insulation contractor on this job had embedded a series of 1 in. x 2 in. wooden strips in the outer layer of the insulating block. It was his plan to use these wooden strips to anchor the metal screws holding the sheets of corrugated aluminum siding in place. Just a few days after he had installed the metal jacketing on the first tank, a moderately high wind, which is common to the Nebraska plains, was experienced. This wind proceeded to relocate approximately half the aluminum sheets from the tank to the south fence of the plant. After considerable wringing of hands and discussion, the project engineer for the contractor finally made the determination to remove the rest of the aluminum sheets and to cover the sidewalls with a coating made up of glass cloth and mastic similar to the roof covering. This whole insulating job was accomplished in very miserable weather since we had experienced a fairly early winter in Nebraska that year.

Bad bulging occurred

The insulation on the tank we are discussing developed a badly bulged area about eight months after it had been in service. The center of the bulged area was approximately 12 to 15 ft. above the ground in an area below the cluster of nozzles that were installed on the tank. Investigation showed a layer of ice as thick as 4 in. had built up in the bulged area. Remember, this bulged area was approximately 12 ft. above the ground.

The insulation in this bulged area was replaced by the contractor under the terms of the usual contractor's guarantee.

During the next two years of operation we had noticed continuing indications of poor moisture rejections by the insulation covering on these tanks. On many mornings when a heavy accumulation of dew made the tank roof wet, isolated blisters under the glass cloth could be noted up and down the sidewalls. Several different attempts were made to improve this general condition by the use of additional coatings of the white insulation covering that had been installed over the glass cloth and mastic. These attempts proved relatively ineffective and continuing signs of deterioration of the glass block could be observed.

Following the spring and summer shipping season of 1965 it was decided that major repairs to this insulation should be attempted. After we had emptied the tank and allowed it to start to warm up, a small section of scaffolding was erected in order to permit a closer inspection of the various areas of the tank insulation.

More serious than anticipated

During the afternoon of August 17, 1965, a rip in the glass cloth in the northwest quadrant of this tank took place. At this time an approximate 16 ft. length of insulation sagged a distance of approximately 2 ft. Of course, we realized at that time that we had more serious problems than we had anticipated.

While discussions were going on as to what form the ultimate repairs should take, we moved the insulating crew and the scaffolding to the adjacent tank to begin patching several small cracks in its insulation covering.

One nice, calm Sunday morning, August 29, to be exact, I had just started down to the plant to see what had been accomplished the day before, when an avalanche of broken insulating block on the south side of this problem tank commenced. The collapse took place in a relatively short time with approximately 40% of the sidewall being exposed before the pieces stopped falling. Large sections of the sidewall insulation would take turns breaking up and sliding down over the lower levels of insulation, or in a few isolated cases they wedged down between the tank and the inside layer of insulation.

The bands that had been installed over the block during original construction were of the expandable type and they stretched so they were still embedded in the mastic covering which was at this point laying on the ground.

Expansion joint installed low

While inspecting the tangled mass of bands, broken-up blocks, and mastic impregnated fiberglass we began to piece a few bits of information together. After considerable measuring and piecing several sections of this broken insulation back together, it became quite obvious that the expansion joint in the sidewall insulation of this tank had been installed approximately 16 ft. down the side of the tank. This fact was confirmed by stripping a small section of the glass cloth and mastic off the neighboring tank.

After finding this, we concluded that the wall of the tank had expanded upwards to the point that the glass cloth and mastic coating had been trying to lift the top 16 ft. of the sidewall insulation. This material was fairly light, but that is still quite a load. The glass cloth must have torn, allowing the sudden release of some of the sidewall insulation, which, in turn, started the whole collapsing process.

Further investigation of these broken blocks that were now exposed gave considerable indication that many of them had been cracked during the freezing and thawing cycles that had been taking place during the use of the storage tank. Many of them had cracked in the grooves which contained the 1 in. x 2 in. strips that the contractor had left in place after the original covering had blown off. This wasn't the only place, however. There were many, many signs of old cracks in the blocks due to the minute settlement.

Since the tank in question had been emptied, our operations were not seriously affected by the failure of this insulation. We can only speculate what the results might have been had the tank been in normal operating condition.

Decided to rebuild completely

We decided to strip the remaining insulating block from the tank and rebuild completely. The old insulation was replaced with an inside layer of 2 in. foam glass blocks, followed by a 3 in. layer. This time we used ¾ in. solid stainless steel bands placed on 2 ft. centers to keep the glass block in place, as well as the sealing material between the joints.

We did not reinstall a mastic coating, but corrugated aluminum sheeting has been used. The metal bands reinforcing this aluminum jacket were originally placed on 3 ft. centers, but we experienced a little trouble during a strong wind period so we have increased the number of bands to 12 in. centers.

We have gone to a lot of extra trouble in the design of the expansion joints for all three of our tanks that are covered with foam glass block. We have gone to the other two tanks and filled in their old expansion joints with solid block, then installed new expansion joints near the roofline of the tank.

Now that we have experienced a year's complete cycle of temperature extremes and inventories in the tank, we have every reason to believe the revisions we have made have been performing in a satisfactory manner. We have no further signs of deterioration either on the tanks recovered or the two adjacent tanks.

Discussion

Q. Could you give us an approximate idea of what sort of time was involved in the repairs that you undertook and what sort of costs you involved?

Hoffman: The time involved took nearly three months in our particular case. The costs, since they were mixed up in some repair work we were doing on the two additional tanks at the same time, are hard to pin down: but it was in the neighborhood of $100,000 for this work.

Q. Do you feel, however, that you now have a sound construction and a long life ahead with the insulation as it presently is installed?

Hoffman: We feel that it is much better than we had to start with, and we are anticipating perhaps a 10-year life before we have to make major repairs again.

Q. Before the installation of the glass blocks, was the metal surface sand-blasted and coated with anything?

Hoffman: I don't believe it was sand-blasted, but it must have been primed with a coating. There were very few signs, if you were wondering, that the block had attached itself to the walls of the tank. Only in a very few areas were there signs where block had stuck to the tank in any place.

Q. I believe that one used to encounter pitting corrosion behind insulation on ammonia storage tanks, and it is possible perhaps that in the upper part of an ammonia storage tank one might get warm enough to have liquid present occasionally. Has anyone noted corrosion behind foam block or similar types of insulation on the surface of these tanks?

Hoffman: I might add that during the cleanup and inspection of this tank in question, in about the upper 10 ft. of the tank, there were signs that corrosion was beginning to take effect. That was the reason we brushed and reprimed.

R. E. Butikofer (American Oil Co.): About two years ago we sand-blasted and covered a 65 ft. sphere with about ¾ in. polyurethane. This was done for surface protection rather than for insulation. We find that while, in general, the coverage was good, we do have some spots where moisture has permeated the polyurethane.

The following year we covered a second 65 foot sphere and this application seems to be standing up very well. The difference is that we learned to properly seal the exterior of the polyurethane. We learned this rather dramatically.

At the same time the first sphere was covered, we also covered an ethylene drum with the same material. This was very poorly protected from the standpoint of a sealer. As a result, the insulation is water soaked and ice can actually be seen through the insulation.

We feel polyurethane is good surface protection and good insulation, but it does require careful sealing.

Hoffman: After inspecting the rest of our tanks, we are of the opinion that these nightly moisture problems on the roof just seep in the sidewalls if there are any openings there at all. You are going to get moisture inside, and as the level in your tank rises and falls, in the summertime particularly, you are going to find times when you do have free moisture trying its best to get through this insulation, no matter what it is.

Discussion

D. L. Stockbridge (Armour Agricultural Chemical Co.): I have a letter from Frank Wilson indicating that he has had people ask him questions about some cracks that they have heard of in high strength steels being used for storage of ammonia in spheres and tanks.

I asked Frank to be more specific and he said that he can't be too specific because it has been more or less rumors that he has heard. He thought that maybe some folks from Coastal Chemical might have something to report on this.

Elon Nobles (Coastal Chemical): We haven't had any failures in this area in ammonia storage. Now we have evidence, some fear, of a number of cracks appearing and it gives us concern where we are using high strength steels to replace the formerly used soft carbon steels in vessels -- points of attachment from a multi-layer shell to a forging head. In many of these areas we still use rather arbitrary formulas to establish what the stress is and can't determine it exactly.

For example, in a recent vessel that was made for us, while we were still hydrostatic testing it, we came into a crack that was maybe two inches long and it didn't seem too obnoxious so we started to grind it out. This was up in the major shop and before we had finished, we severed the whole head of the vessel 4 feet in diameter and 6 inches thick, trying to get rid of this little crack which just propagated itself because of the peculiar metallurgy conditions that were present.

This is I think what is referred to as our concern – chiefly one of whether there is any unknowns in this area of using 100,000 pound steels where we formerly used soft carbon steel in relation to using arbitrary formulas to determine stress.

I think there has been some concern in other persons minds also in forging stresses, forging cracks that we have all heard about.

F. W. S. Jones (Canadian Industries, Ltd.): This is a very interesting point. I believe that about 1954 there was some evidence of cracking in nurse tanks in the southern states in heavily cold worked regions of cold formed heads. There was a subsequent investigation indicating that residual stresses normally encountered in fabrication were insufficient to promote such stress corrosion cracking but the higher value stresses generated in cold forming heads could achieve the necessary residual stress values.

I believe that an Agricultural Ammonia Institute recommendation now indicates that it would be desirable to stress relieve severely cold formed equipment, for anhydrous ammonia service.

However, if one does use high-strength steel for anhydrous ammonia containment, they already have relatively high yield strength values — they have 70,000 or 80,000 lb./sq.in. and it is conceivable that any fabricational forming stresses will be sufficiently high to provide a possibility of stress-corrosion cracking. In other words, the residual stress threshold will inevitably be high enough in unstress-relieved high tensile steel fabrication.

Stress-corrosion cracking of carbon steel and high-strength steel when used for anhydrous ammonia storage tanks has been investigated by A. W. Loginow and E. H. Phelps of our Applied Research Laboratory (Corrosion, 18, No. 8, pp 299t-309t, August 1962). Data from their tests indicated that steel tanks used in the non-stress-relieved condition for storing anhydrous ammonia at atmospheric temperature are subject to stress-corrosion cracking when air with normal amounts of carbon dioxide is present as a contaminant in the anhydrous ammonia. Stress-corrosion cracking can be inhibited in atmospheric temperature systems by adding at least 0.2 wt.% distilled water to the anhydrous ammonia.

It might be interesting if U. S. Steel or others have people present that have thought about this point and are prepared to comment, to have them say something.

R. T. Jones (U. S. Steel): We agree that fabricational stresses in vessels may be high, on the order of the yield strength of the steel, and that these stresses are an important factor in stress-corrosion cracking.

As far as we have been able to ascertain, stress-corrosion cracking does not occur in tanks used for storing anhydrous ammonia at low temperatures and near atmospheric pressures. As you know, this type of storage system usually contains vapor recompression equipment in which air and other noncondensibles are continuously removed and, thus, air is not available to cause stress corrosion.

F. W. S. Jones: This suggests, then, that providing one stress relieves the high-strength steels, all is well. But you would then perhaps by inference not recommend their use in the unstress-relieved condition.

R. T. Jones: To avoid stress-corrosion cracking in either low-or high-strength steel vessels used for storing anhydrous ammonia at atmospheric temperatures, the paper by Phelps and Loginow mentioned previously recommends stress relieving as one precautionary measure that should be taken. In addition, it is recommended that care be taken to prevent air contamination and that a minimum of 0.2% water be added to the ammonia.