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Ammonia Tank Floor and Foundation Failure

Repairs and inspection after the incident support the conclusion that inspection during construction should be independent of the contractor.

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Camex, Inc. currently owns and operates an 80,000-ton anhydrous ammonia refrigerated terminal in the northwestern Iowa cornbelt. The terminal is served by the Mid-American Pipeline System (Mapco) and common carrier trucks. It is fully automated and designed for unmanned operation during all phases of product transfer.

In mid-1973, preparations were made to empty and enter the 190-ft. diameter, 40,000-ton ammonia storage tank. Ammonia vapor was present at various points around the lower portion of the tank exterior, and the concrete foundation was deteriorating rapidly. The tank had been entered and repaired once, as reported in the 1971 AIChE meeting here in Atlantic City. Ammonia throughput had been 122,000 ton since the repair. This article covers two separate repairs, one on the tank bottom and another on the concrete foundation.

Tank bottom repair. The tank was emptied of its liquid contents as much as feasible. The undertank heaters were turned on continuously, and the remaining liquid was evaporated by heating. When the liquid had evaporated, the lower manway was removed and two refrigeration compressors were used to draw ammonia vapors out of the tank.

As vapors were withdrawn, air entered through the lower open manway. The tank contains 2,401,250 cu.ft. of vapors, corresponding to 116,000 lb. of ammonia. It took nearly 11 hr. to remove the majority of the vapors. The top manway cover was then removed, and a 2,800-cu.ft./min. fan was connected to the lower manway for the final air purging.

After entry into the tank was proven safe, the cleanup and inspection crews commenced work. They removed 1,890 lb. of pipeline rouge from the tank bottom. Some water was present in puddles. No oil was noticeable, except as a thin color film on the water puddles.

The tank bottom was non-destructively tested by ultrasonic, magnaflux, vacuum box, dye penetrant, and X-ray methods. The tests revealed 34 out of 36 footer plate butt-weld seams were defective, several of which were visually cracked and leaking. Several damaged areas were repaired in the center of floor sheets where accidental arcing had occurred during construction. Other minor repairs were made in suspected weldment areas. A total of 37 weld repairs were made, some of which probably did not leak.

Improper welding seen as one cause

The footer plate butt-weld failures are thought to be a result of improper welding technique. A copper back-up bar was placed under the butt groove for heat dissipation, then a fillet weld was made from the top in a horizontal position. Many of the weldments had large nodules hanging from their underside as a result of excess electrode current. Porosity, lack of fusion and penetration was also prevalent in most welds.

The repair procedure followed was to remove a 16-in. square section of floor plate adjacent to the footer plate butt weld, grind out the old weld on the inside of the tank, arc gouge the weld on the outside of the tank. A hole was bored horizontally through the concrete immediately below the weld in the footer plate to facilitate welding and allow X-ray inspection. A back-up strap was placed under the weld prepared zone, which was re-welded and examined by X-ray. The 16-in. square hole in the floor plate was then patched with an 18-in. brake-formed square plate lap-welded in place. Welding electrodes used were AWS No. E-7018-LH.

During the preceding operation period of the tank, considerable quantities of a blue substance came out from under the tank and ran down the side of the foundation. At the time, this caused serious concern. This later was explained as the action of ammonia and water on the copper deposited initially on the underside of the footer plate weld. A copper backing bar was used during construction of the footer plate weldment.

One section of the floor plate was cut loose on three sides in the door sheet area and temporarily elevated. Nearly 1,000 lb. of sand was placed in a 4-in. sunken area, then the floor plate was re-welded into place. This repair was adjacent to the door sheet and in the same area where a 16-in. weld was overlooked during construction. This was found during water test, but too late to prevent serious saturation to undertankment. It is felt that because of the water saturation, the undertank heating energy requirement is at least twice what it should be.

Foundation repair. The foundation displayed extreme spalling, particularly in the southern quadrant. The spalling action is thought to be the combination of several factors; namely freeze/thaw (physical) and ammonia/water (chemical). The design places the tank footer plate on the concrete foundation, separated only by a ⅛-in. thick asbestos strip and felt paper moisture barrier. The foundation is cooled by the tank contents by conduction. During certain periods in the daytime, particularly in the summer, the foundation on the south side of the tank will absorb enough heat from the sunlight and warm air to cause its skin temperature to rise above freezing. Ammonia, being present in the atmosphere as a result of tank bottom leaks, combines with the sweating action moisture in the concrete, which in turn causes aggregrate deterioration. During the nighttime, the foundation would cool on the surface to below freezing and complete a freeze-thaw cycle. This action was quite slow and threrefore took several years to produce severe damage.

The foundation repair procedure was simple and straightforward. All deteriorated concrete on the foundation sidewall was removed with pneumatic jackhammers. Additional re-bar was doweled into sound concrete with an epoxy gelling agent. The exposed concrete was treated with an epoxy bonding agent and new concrete was poured to the original configuration.

The repair immediately under the footer plate was made in 12-ft. sections alternating between repairs so as not to leave long unsupported areas of the tank sidewall. It was not necessary to remove the total thickness, and therefore a backside form always existed. The sound concrete was treated with an epoxy bonding agent. New concrete was poured to within 2 in. of the footer plate, then epoxy treated and tightly dry-pack grouted.

All repair concrete exceeded 6,000 lb./sq.in. compression, all dry pack grout exceeded 5,000 lb./sq.in. compression test. After the concrete repair was complete, the foundation area under the footer plate and on the ledge was sandblasted, then primed with epoxy thinned to 50% and topcoated with straight epoxy. This application is intended to seal the concrete from moisture since it will be quite cold and therefore possess a strong driving force for moisture penetration.

The multilayered aluminum insulation system was replaced as originally designed with a modification for accommodating a urethane foam insulation system on the foundation overlapping onto the original insulation system. A flashing strip was added 12 in. above the lower termination. Two inches of urethane foam was sprayed 2 ft. on the concrete and 1 ft. on the insulation system, tying into the flashing system. Elastomeric coating 45 mils thick was applied over the urethane to protect it from deterioration. An outer cell drain was installed in the insulation system to provide for condensate build-up. Thermocouples were installed in the concrete and sidewall insulation system to provide data for evaluation, the readings are exhibited in Table 1. Figure 1 shows thermocouple locations.

Table 1. Foundation-insulation temperatures °F (Jan.-July, 1976)

No.*	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
0	−7	−6	−5	−11	−5	−1	−2
1	7	10	9	15	16	22	21
2	15	26	24	28	36	38	34
3	14	16	17	22	29	30	30
4	−17	−15	−7	−11	−15	−16	−16
5	−6	4	−2	3	10	11	3
6	4	19	11	18	29	27	8
7	15	29	18	26	30	30	11
8	37	54	35	43	65	69	39
9	50	71	49	55	85	87	53
A	36	58	52	58	82	81	71

*Identification numbers of thermocouples shown in Figure 1.
A = Ambient

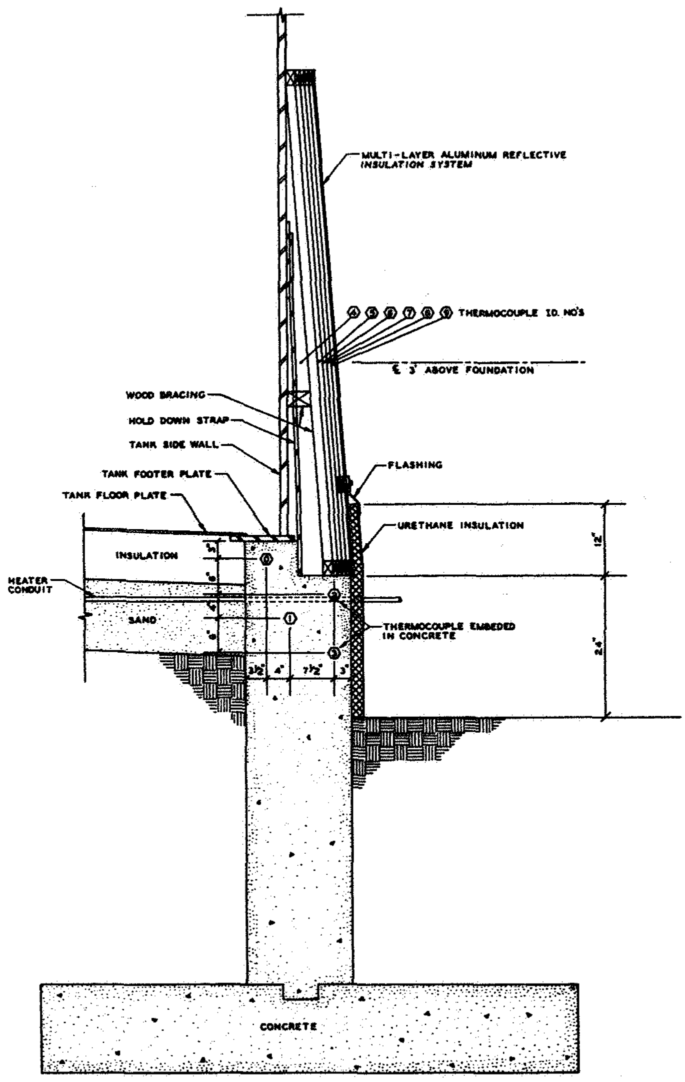

Figure 1. Section, showing concrete foundation, tank construction, insulation system, and thermocouple locations.

Conclusion

Generally, when a customer builds a tank of this type, very little third-party inspection is used. The vendor is relied upon to produce a good sound product. Some vendors have excellent inspection programs and others do not. The best arrangement with a vendor is where the inspection crew does not report to the erection supervision. Some type of construction inspection program independent of the contractor is suggested to give the customer the maximum quality.

The tank footer plate should never be set directly on the concrete foundation. A 2-in. treated oak board should be the minimum requirement for this application. This will reduce the heat conduction from the concrete ringwall appreciably.

Entering a tank of this type is not a problem if ample time is available. Some operators like to use nitrogen rather than air to purge with to eliminate the possibility of an explosion. Our experience has been with using air since we felt that no sparking devices were present in this area. Every effort should be made during the specification writing and erection to prevent the need for possible entrance into a storage tank.

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DISCUSSION

BILL SALOT, Allied Chemical: You indicated there were earlier repairs on this tank. What was the condition of the earlier repairs? Had any of them failed?

LICHTENBERG: No, the earlier repairs were mainly pinholes and none of them had reoccurred. This was a splitting of the weld seam in the footer plate. That's what caused us to go in the tank this time, and these—to the best of our knowledge—weren't present when we were in there before. Now it's probable that they were beginning to form and were under stress at that time, and we just didn't realize it.

SALOT: Were the earlier repairs made in the same way as the later repairs?

LICHTENBERG: Yes, sir. The only difference between the earlier repairs and the later repairs is that this time when we went in, we took a whole lot more pains to check everything that we could find in there to make sure that we weren't going to go in another time, because this was rather embarrassing going in this time even.

HAYS MAYO, Farmland Industries: Why did the weld seam split? Is it possible that it was overstressed?

LICHTENBERG: We think the reason why it split was because they were insufficient in the beginning. They weren't good sound welds. They were placed in there under high heat conditions, it was obvious, and also they weren't full penetration—they just weren't good welds. They were very poor welds.

MAYO: Did you have any appreciable amount of settlement of the tank itself? Would you expect the settlement resulted in over stressing?

LICHTENBERG: No, we haven't seen any signs of settlement in the ring wall. No of course we have floor deformation, and settlement in the under tank fill, but we did not see anything as a result of this. In fact, the tank looked real good inside. The only thing that we really saw in there was a crack right down the center of the weld. And when we looked at the weld, the weld was quite shallow. It wasn't a good weld. It was hot rodded in, as they talk in tanky language.

MAYO: What order of magnitude of settlement did the tank experience?

LICHTENBERG: You are speaking about the foundation, or the under tank floor?

MAYO: I'm really talking of the differential between the floor and the foundation.

LICHTENBERG: This varies quite a bit in that particular tank. We ran a topo in there. We had a survey team going in with the transit and I think that we are looking at about six inches—as one of the deepest areas that we have. And this seems to occur right off the edge of the—the concrete ring wall. You go out off the ring wall and then down, and then you go back toward the center of the tank.

MAYO: Now this split that occurred, was this in this region of maximum differential settlement between the floor and the ringwall?

LICHTENBERG: No, the failure we had was on the footer plate and the footer plate doesn't hardly get out into the floor. It only goes out from the side of the tank something like 12 or 14 inches. And this is the area. Now the crack did not propagate clear back to the sidewall of the tank—it just went back about 6-8 inches. And this is really all we saw. It was kink of strange, but—

MAYO: I'm inclined to think though that differential settlement between the floor and ringwall resulted in relatively high stresses in the weld that split and that these high stresses were a contributing factor in the failure of the weld.

LICHTENBERG: Well this is probably true, and the weld would have withstood this stress had it been a good weld.

RON DYE, UKF, Great Britain: What code of prSctice was the tank built to?

LICHTENBERG: It was API 620 R.

DYE: Then doesn't the provision of the code cover for such eventuality as this, because to me this sounds quite frightening and what has been done to prevent it occurring again?

LICHTENBERG: I think since this time the tank contractors have improved their inspection program, for one thing. Secondly they have changed their welding technique in this area. They weld these footer plate welds differently now then they did at the time of construction of this tank.

DYE: Is there any move within the United States to set up a committee of users to develop a code of practice for tanks? And the use of ammonia?

LICHTENBERG: Well the Fertilizer Institute pretty well covers this and they work very well at it, and are very good at it. Also there's a lot of effort made here in this meeting, but as far as having it pinpointed organized toward the storage, particularly cold storage of ammonia, not to the best of my knowledge. Now there are several standards that cover the construction of one of these tanks, but I know of no committee working on a specific project of this nature at this time. But again, I must qualify myself in that I don't know everything that's going on in these committees.

DYE: The reason why I posed that question was that in the United Kingdom, under the auspices of ICI, through the Chemical Industries Association, such a committee was set up, and has done quite a good job to date in drawing up, setting codes of practice. And you know, the purpose of it is to prevent tank fabricators, vessel fabricators making mistakes that will reflect on the ammonia industry. And in our particular case, you know, the involvement of government legislation.

LICHTENBERG: I think that we have people that have standards for this, and I think that we have standards, and that we are reasonably covered by codes, and I certainly don't feel that we are inadequate in codes in this area. Others may have different opinions.