Ammonia Storage Tank Repair

Had it been possible to close the tank's block valve during the overflow, much of the ammonia spillover could have been retained.

J.G. MacArthur
Willchemco, Inc.
Tulsa, Okla.

TANK NUMBER: 35

SHEET NO. 10 OF 10

	114 FEET	115 FEET	116 FEET	117 FEET	118 FEET	FEET
IN.		IN.	IN.	IN.	IN.	IN.
.88	34,710.11	35,015.33	35,320.56	35,625.79	35,931.02	
.24	34,716.47	35,021.69	35,326.92	35,632.15	35,937.38	
.60	34,722.82	35,028.05	35,333.28	35,638.51	35,943.74	
.96	34,729.18	35,034.41	35,339.64	35,644.87	35,950.10	
.31	34,735.54	35,040.77	35,346.00	35,651.23	35,956.46	
.67	34,741.90	35,047.13	35,352.36	35,657.59		
.03	34,748.26	35,053.49	35,358.71	35,663.95		
.39	34,754.62	35,059.85	35,365.07	35,670.31		
.75	34,760.98	35,066.20	35,371.43	35,676.66		
.11	34,767.34	35,072.56	35,377.79	35,683.02		
.47	34,773.70	35,078.92	35,384.15	35,689.38		
.83	34,780.05	35,085.28	35,390.51	35,695.74		
.19	34,786.41	35,091.64	35,396.87	35,702.10		
.54	34,792.77	35,098.00	35,403.23	35,708.46		
.90	34,799.13	35,104.36	35,409.59	35,714.82		
.26	34,805.49	35,110.72	35,415.95	35,721.18		
.62	34,811.85	35,117.08	35,422.30	35,727.54		
.98	34,818.21	35,123.43	35,428.66	35,733.90		
.34	34,824.57	35,129.79	35,435.02	35,740.25		
.70	34,830.93	35,136.15	35,441.38	35,746.61		
.06	34,837.28	35,142.51	35,447.74	35,752.97		
.42	34,843.64	35,148.87	35,454.10	35,759.33		
.77	34,850.00	35,155.23	35,460.46	35,765.69		
.13	34,856.36	35,161.59	35,466.82	35,772.05		
.49	34,862.72	35,167.95	35,473.18	35,778.41		
.85	34,869.08	35,174.31	35,479.54	35,784.77		
.21	34,875.44	35,180.66	35,485.89	35,791.13		
.57	34,881.80	35,187.02	35,492.25	35,797.49		
.93	34,888.16	35,193.38	35,498.61	35,803.84		
.29	34,894.51	35,199.74	35,504.97	35,810.20		
.65	34,900.87	35,206.10	35,511.33	35,816.56		
.01	34,907.23	35,212.46	35,517.69	35,822.92		
.36	34,913.59	35,218.82	35,524.05	35,829.28		
.72	34,919.95	35,225.18	35,530.41	35,835.64		
.08	34,926.31	35,231.54	35,536.77	35,842.00		
.44	34,932.67	35,237.90	35,543.13	35,848.36		
.80	34,939.03	35,244.25	35,549.48	35,854.72		
.16	34,945.39	35,250.61	35,555.84	35,861.08		
.52	34,951.74	35,256.97	35,562.20	35,867.43		
.88	34,958.10	35,263.33	35,568.56	35,873.79		
.24	34,964.46	35,269.69	35,574.92	35,880.15		
.59	34,970.82	35,276.05	35,581.28	35,886.51		
.95	34,977.18	35,282.41	35,587.64	35,892.87		
.31	34,983.54	35,288.77	35,594.00	35,899.23		
.67	34,989.90	35,295.13	35,600.36	35,905.59		
.03	34,996.26	35,301.48	35,606.72	35,911.95		
.39	35,002.62	35,307.84	35,613.07	35,918.31		
.75	35,008.97	35,314.20	35,619.43	35,924.67		

STRAPPED AUGUST 23, 1967

Figure 1. Strapping table.

On November 16, 1970, Gulf's refrigerated ammonia storage at Blair, Neb. overflowed, causing considerable concern to residents of the community but, fortunately, no serious injuries. One hundred sixty tons of ammonia were lost to the atmosphere and three city firemen were treated for fume inhalation.

Why did this accident happen? As in the case of most accidents, human error was the basic cause. Circumstances leading to the overflow were:

1. Shore tank inventory at the time the barges arrived was 32,213 tons. The barges were gauged at 3,081 tons, for a total of 35,294 tons. A check of the strapping table (Figure 1) indicated off-loading the barges would raise the tank level to 115 ft. 11 in. Please note this table gives no indication of maximum fill point. At 5:45 a.m., the shore tank gauge was read at 115 ft. 2 in. Approximately 10 min. later the operator noted vapor migrating from the tank area and initiated shutdown procedures for the barge off-loading operation. At the time of shutdown, three of the four barge tanks had been emptied, and the fourth tank was being pumped at a reduced rate estimated at about 75 ton/hr. This is equivalent to approximately 3 in./hr. rise in tank level. Barge stripping operations had started approximately 30 min. before the spill was detected. Prior to that time, off-loading was at a rate of 550- to 600 ton/hr.

2. At the time the barges were loaded for delivery, it was known the load would bring the tank level to over-design capacity of 35,000 tons. The strapping tables indicated there was room to hold the barge cargo, leaving 2 ft. 2-1/8 in. freeboard in the tank. The operating manual stated the high level shutdown alarm was located 3 in. below the overflow pipe inlet. Everyone concerned with the operation made the erroneous assumption that the last reading on the strapping chart was the elevation of the overflow pipe. You will note Figure 1 is listed as sheet no. 10 of 10. Had anyone looked at sheet no. 1 of 10, they would have found a note stating, "Table scaled from extreme bottom to rim of shell," which may or may not have triggered a question as to the location of the overflow. We will never know.

Failure of alarm and shutdown system

In retrospect, we now know the high level alarm and shutdown system failed to operate. We feel fairly certain the overflow discharge valve failed to respond to the design 2.2 lb./sq. in. opening pressure, and the tank level rose well above the overflow pipe before the relief valve opened. A check of the high level alarm system, after the accident, showed that after maximum deflection of the microswitch lever by the activating cam, an additional 10/1,000 in. displacement to the lever was required to activate the system.

In reconstructing events leading to the overflow, we need to list a few significant tank levels, Figure 2. (This figure is correct with respect to elevation but not to plan.)

Top of tank shell	118 ft. 1 in.
8 in. compressor suction line	115 ft. 11 in.
Bottom of hanging roof deck	115 ft. 7 in.
4 in. overflow line	115 ft. 1 in.
High level alarm	114 ft. 10 in.

Because of the rate of pump in at the time of the overflow and the amount of material lost and pumped into tank cars, it is apparent the tank level was above the overflow pipe for an extended period of time. We believe the overflow relief valve failed to respond to a pressure equivalent to a head of 110 ft. of ammonia (32 lb./sq. in.), and the level continued to rise until it reached the hanging roof at which point the instantaneous pressure increase (hydraulic slap) activated the relief valve. The ammonia level rose rapidly in the compressor suction shroud, spilling into the suction line and the compressor entrainment separator. Fortunately, shutdown procedures were timely enough to prevent any damage to equipment.

Once the overflow valve activated, ammonia discharged to the atmosphere for a period of about 2-1/2 hr. From the standpoint of vapor dissipation, atmospheric conditions could not have been worse; there was practically no wind and an atmospheric inversion existed. As a result, vapor migrated from the tank as a low-hanging cloud approximately 8- to 30 ft. in thickness and, at times during the period of discharge, extending over 9,000 ft. from the tank. Figure 3 shows the approximate area (about 900 acres) that at one time or another was covered by the cloud. In this figure, the Gulf terminal is designated "A". "B" is the dock about 1,000 ft. from the tank where the barge towboat stayed most of the time during the spill, and "C" is the nearest residence (3,800 ft. Fortunately, the sole occupant left for work at 4:00 a.m., thus missing exposure. "D" is a stock farm (5,800 ft.) where two hogs are reported to have died due to exposure, and cattle were reported "off their feed" for several days after the spill. At point "E", (9,300 ft.), where a county road was covered, a panel truck was observed driving through the cloud. The driver later commented that the ground fog was heavy and smelled bad. Point "F" (1,700 ft.) is the nearest habitation south of the terminal. This is a manufacturing plant which was closed and evacuated during the spill. The Agrico Chemical Co.'s ammonia terminal is located at point "G" (4,200 ft.).

Apparently, there was a very gentle breeze from the southeast which kept the cloud from covering or passing over the river and, about 2 hr. after the spill started, cleared the operation area sufficiently to allow tank car loading to be initiated. The cloud at no time crossed the railroad fill running in a northwesterly direction between the terminal and Blair. Although no residences in the town were evacuated, school children were sent home and several farm residences were evacuated after being alerted by the County Sheriff through a loudspeaker from a low-flying plane.

The local fire and rescue department were called when the spill started. A pumper truck was stationed as near the overflow valve as possible, and a continual stream of water was directed at the relief valve. There have been many discussions since the accident on the advisability of this procedure. The literature suggests using water only on small spills. In this particular case, we did not know the amount of the spill nor the dimensions of the pool. Again, in retrospect, we feel the use of water did little to contribute to the extension of the vapor cloud except to identify its

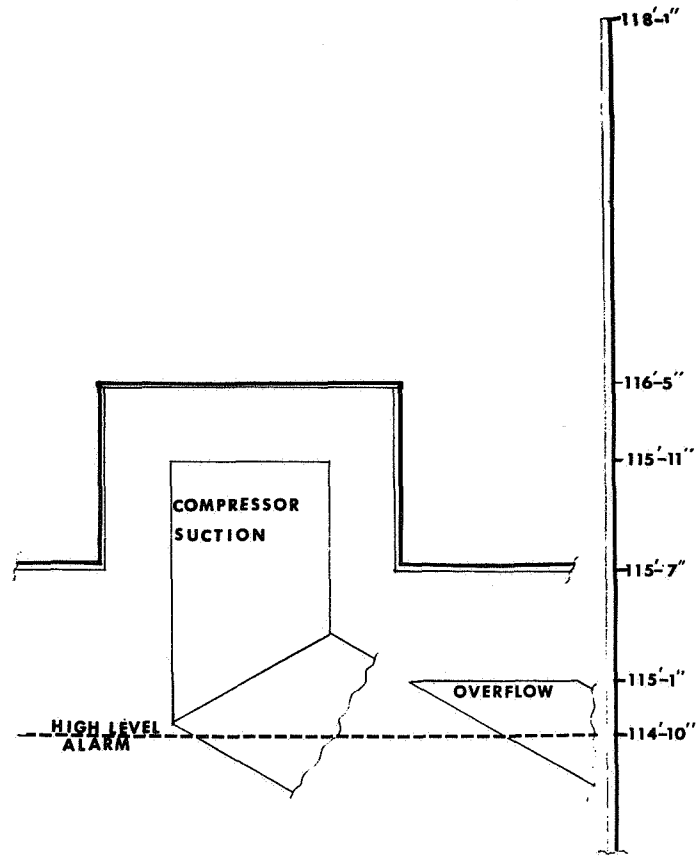


Figure 2. Cross section of ammonia storage tank.

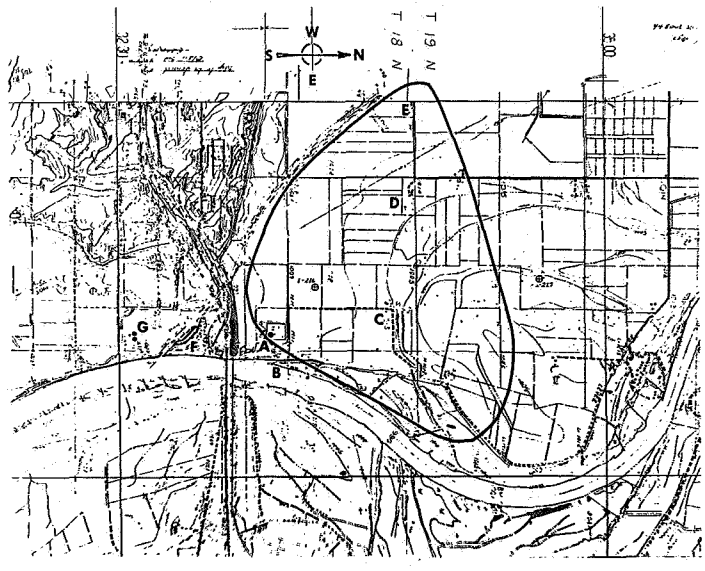


Figure 3. Map showing the approximate area covered by the ammonia cloud.

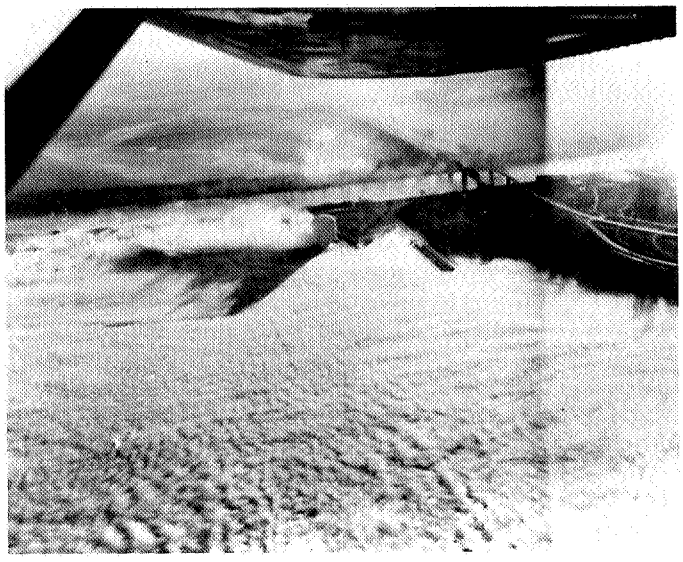


Figure 4. Aerial view of the ammonia cloud shortly after the spill.

presence. Had there been a control area under the overflow to limit the size of the pool, the use of water might have been questionable. With 6.5 acres of land inside the dike, however, it is doubtful if steady-state evaporation could have been achieved within a reasonable period of time. If this is true, then the addition of water was helpful in that evaporation was hastened and the area was cleared more rapidly than if we had depended upon ground and solar heat to vaporize the spill.

As mentioned earlier, the cloud covered a substantial area of the flatlands surrounding the terminal, Figure 4. Fortunately, however, aside from the deaths of the two hogs, and the upset of some cattle, the only other damage that resulted was a grass-burned area of about 4,000 sq. ft. under the relief valve. Undoubtedly because of the time of year, there was no vegetation damage noted in the area covered by the cloud.

Lessons learned

There is a lesson in every accident, and this one is no exception. Some of the things we became aware of as a result of this incident are noted below:

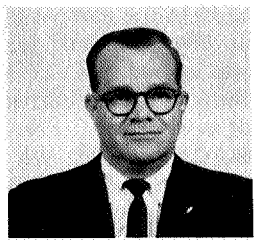
1. The high level shutdown alarm system is of questionable dependability. It is reported to activate within 2 in. of tape travel at a tank level of 100 ft. Our limited testing indicates the distance of positive dependability is more like 6- to 8 in.

2. Tanks equipped with overflow systems should have the relief valve and block valve separated by sufficient distance to allow closing the block valve when the relief valve is open. At Blair, the block valve is directly below the relief and showered with liquid ammonia during an overflow. Had we been able to reach the block valve, much of the overflow material could have been retained in the tank.

3. The local volunteer fire and rescue department of Blair is very well equipped to handled this type emergency, having sufficient self-contained air packs and rubber suits to operate efficiently. We did, however, add a rocket refueling suit to the terminal safety equipment, since we found rubber suits with outside air packs to be inadequate for sustained exposure at levels of vapor concentrations encountered during the spill.

4. We have concluded the best safety device for tank level is a reliable gauge, and so we are installing a back-up to the present Shand & Jurs tape gauge. Hopefully, we will be able to establish its reliability before something happens to the tape gauge.

Although the Blair incident resulted from a number of circumstances which are not likely to recur, we have taken measures to guarantee against another overflow. For example, to insure that the strapping tables are not overlooked, all of our charts have been "red lined" at the maximum load point. In addition, a procedure has been established to check high-level safety equipment when the tank level will exceed 112 ft. during a receipt, on the assumption that an overflow could occur under this condition. #



MacARTHUR, J. G.

DISCUSSION

Q. Did you go to any length to really confirm the fact that the animal had been killed by ammonia fumes rather than either a heart attack or any sudden alarm or that kind of thing?

MACARTHUR: No, we did not. The farmer was reported to have sent the carcasses to the Nebraska Board of Health for autopsy; we did not receive a report from that body.

Q. Has there been any action taken by the city of Blair or any of the groups in Blair as corrective measures to either help in situations like this or hinder, if you want to say?

MACARTHUR: For a couple of days following the accident there were comments of concern by local citizens. The environmental studies seminar at Dana College issued a nine point proposal to the city council, suggesting steps to be taken to protect local citizens and property from the hazards of ammonia; some of the points brought out by the students were good. One suggestion was that ammonia trucks be very carefully routed through the town of Blair. We had technical people present at the regular council meeting following the spill. They answered all questions frankly. We think we have retained good public relations with the city of Blair.

The city editor wrote a very helpful editorial on the fact that ammonia is a way of life, and that you can have accidents with ammonia, but you can also have accidents with automobiles. Although the situation as it developed was very serious, it could have been a lot more serious. Fortunately, everything worked out all right, and I think our relationships in the Blair community are back to normal. Yes sir.

Q. Could you tell me how long it was before the area was clear again, clear of ammonia and you could get around, and what was the temperature, the ambient temperature?

MACARTHUR: What was the ambient temperature? Well, the spill occurred about six o'clock in the morning. The ambient temperature was about 35 degrees. With respect to clearing the area, for the area around the tank inside the dike, it was about two and half days before we could get into that area without a mask. The compressor house and areas outside the dike, even the top of the dike, cleared as soon as the inversion lifted.

Q. What kind of level instrument did you have, and what was wrong with it? And secondly, what was it you added? I think you said you added a Shand and Jurs level instrument of some type.

MACARTHUR: We presently have a Shand and Jurs tape gauge. We are adding a DP cell type called a Digigauge. There was nothing wrong with the level indicator at all. The gauge told us the level in the tank. What was at fault was the high level shutdown alarm. We have a high level shutdown alarm on the tape gauge which, at 3 inches below the overflow, was supposed to activate a shutdown system. However, it was incorrectly set, and, as I said, we didn't check it. Of course, we did not establish the exact location of the overflow until after the accident. Yes sir.

JOHN LIVINGSTONE, ICI, Billingham, England: Two points I'd like to raise if I may. The first one is that the incident seems to have started with a relief valve which seems to have lost its significance in what you've been talking about. The relief valve didn't, in fact, first lift at its design lifting pressure. Did you ever determine why it didn't lift?

The second question I'd like to ask, if I may, is that the philosophy of putting a block valve underneath a relief valve is something that certainly in England is very highly frowned upon. So when you find that you have a relief valve lifting, one would have thought the last thing you wanted to do, if it is lifting, is to shut a block valve and then definitely overpressure a vessel that might well have been overpressured in this instance.

MACARTHUR: I didn't understand quite the last part of your question.

LIVINGSTONE: The second part of the question. Yes, I'm asking what is this philosophy - why do you use one of putting a block valve underneath a relief valve in such a system?

MACARTHUR: Well, to answer your first question, we can think of no reason why this valve did not lift. It's a gravity weighted valve sitting on a sharp edge and it definitely should have lifted. It had never been lifted since installation. Possibly there could have been a temporary obstruction of some sort in the line. We don't know why it did not activate; all our calculations and the design write up on the valve indicate it should have lifted at 2.2 pounds pressure. But in reconstructing the incident, we feel sure the ammonia level was above the overflow for at least 30 minutes, yet the valve didn't lift.

Now as to why would you want to shut off the block valve when the relief valve opened? Well, in this case, we are talking about a liquid head pressure; I can understand why you would not want to block if you had a pressure relief valve blowing. But in this particular case, we were just holding head - we had an additional six inches of liquid head in the tank, had we been able to close the block valve we could have held that six inches of head until we could have pumped the material out into tank cars. I don't see that this would have done any harm to the tank.

ANON: I think I can perhaps explain about this relief valve. Perhaps you ought to explain that the relief valve is not a relief valve in the ordinary sense of the word, and it is a valve which is activated by the static head once the liquid overflows from the tank. I think Livingstone was under the impression that this was a pressure relief valve to safeguard the tank from overpressure. We don't have overflows in relief valves and our philosophy is to make sure that we know the level in the tank. I'd like to know what the philosophy in the industry in general is. Is it usual to have overflow in pipes with safety valves? Is it usual to have tanks like ours which have no device of this kind?

MACARTHUR: Well, or course, since the accident we've questioned the advisability of having an overflow. I believe, and people can correct me if I'm wrong here, the overflow installation is pretty much limited to those tanks which have hanging roof insulation; in other tanks, the tanks which have insulation on the roof, the load line is pretty close to the top of the shell. The hanging roof type have an additional two feet of free board as a thermal differential barrier, if you will, because as I understand it the metal of the roof is not the type that will take very low temperatures.

Perhaps somebody else who is more knowledgeable than I can comment on my statement. Is anybody here from CB&I? I guess we'll just have to go on what I said. Okay, the gentleman back of the slide there.

Q. In some test spills on liquified natural gas, it appears that the vapor cloud, the visible vapor cloud extends very much

further than the actual gas cloud. Do you think in your case the vapor cloud and the actual ammonia vapor covered about the same area or did the condensate drift further than the ammonia - the ammonia diffused?

MACARTHUR: All I have to go on is the reports we had. Whenever anybody got into the vapor cloud they could smell ammonia. Outside the vapor cloud there was no smell of ammonia until after the inversion lifted, then there was no cloud inside the diked area, but you could darn well smell ammonia when you entered this area.

L.V. CASERTA: American Oil Co.: In Texas City we have three 15,000 ton storage tanks. Each of these tanks is provided with dual relief valves on the domes. These are umbrella roof tanks with insulation directly on the roof. Each of the dual relief valves has full relieving capacity, and each relief valve has a block valve under it. We generally keep both valves in service, but we feel free to close off one of these for repair to the relief valves. They have malfunctioned occasionally. We're in a industrial/residential area, and when a tank relief valve malfunctions generally we're not the first to become aware of it. However, once aware of a problem, we can get on the tank, block the relief valve in, remove it, repair it, and return it to service.

I believe that in all of our installations in the Midwest it is standard to provide dual valves and to put block valves under them.

MACARTHUR: The relief valve I have been talking about is a four inch relief valve located at the end of the liquid overflow line. It's sole purpose is to lift under liquid pressure should you overflow the tank. The pressure relief valves on top of the tank are set for a pressure of, I believe, a pound and a half, where this valve is set for 2.2. So it should never lift due to anything except the head of liquid, in the overflow pipe. And we feel that it will never lift again except during tests.

P.J. SHOOK, Agrico Chemical. I just have a comment. We dip stick a tank when we get near the top. We take a half inch piece of tubing running through a swedge lock fitting, put in any type gaseous flow - we usually use nitrogen - "tee" in a sensitive pressure gauge, and you can tell exactly when it touches the liquid.