FAILURE OF A LOW TEMPERATURE AMMONIA LINE

Pipelines carrying low temperature liquids can fail due to freeze-thaw pressure. Eliminating water from the pipe sleeved area, or inserting a non-freezing solution can prevent damage.

R. W. Miller and L. V. Caserta
American Oil Co.
Texas City, Texas

Transportation of low temperature liquids for long distances is becoming more common with the use of atmospheric storage for propane and ammonia. Often these liquids are transferred at sub zero temperatures from a remote storage facility to a using unit or dock area. Lines carrying cold liquid are usually well insulated to reduce heat in leakage and, as a result, are normally located above grade. This article describes a failure in a low temperature ammonia loading line at a below grade sleeved road crossing.

The American Oil Co. ammonia complex at Texas City consists of two anhydrous ammonia plants, a 600 ton/day Kellogg unit and a 1,500 ton/day Chemico unit. Three 15,000 ton atmospheric storage tanks are adjacent to the units along with loading facilities for rail, truck, barge, and ocean going tankers, Figure 1.

The ammonia barge/tanker loading line, about 4 mi. long and constructed in late 1963, was probably one of the first ammonia pipelines. It is made from 8 in. schedule 30, ASTM, A-333 designed to transport -28°F ammonia from the storage tanks to the dock area. The line runs at grade through a congested refinery and industrial area in which many horizontal and vertical expansion loops are provided. In addition, there are six underground road or track corssings before reaching the docks. At 150 ft. flare was installed in the dock area for use in conditioning the dock line, venting ships, etc., Figure 2.

Ammonia line crash

This low temperature ammonia loading line developed a crack at a below grade sleeved road crossing, but fortunately the leak was detected before it became a major problem. The line was pressured, purged, repaired, and returned to normal service.

The ammonia barge loading line is insulated with preformed polyurethane and laid on concrete piers just above grade. At road and track crossings, the line goes below grade in 12 in. pipe sleeves as shown in Figure 3.

Parts of the line runs underground for short distances. These portions of the line are vinyl wrapped for corrosion protection. The 12 in. sleeve is swedged to the 8 in. line with rubber casing seals at each end. Concentric support insulators are spaced in the sleeved section. The sleeve is vented at both ends, one venting from the top and the other from the bottom of the sleeve. Cathodic protection is provided.

The portion of line that failed was buried under a well-travelled state highway at a depth of about 8 ft. The normal water table in this area is 2- 4 ft. below grade and, as a result, the sleeved section of the cold ammonia loading line is always submerged in water. Flow through the line is intermittant so the line is alternately very cold or ambient depending on the loading situation. The line is in use about 15% of the time.

When the leak at the crossing developed, ammonia vapors started pouring from the vents on the pipe sleeves. To make repairs the dock line was depressured and purged with nitrogen. It was cut on either side of the road crossing outside the sleeve area, and this section of line pulled out for inspection and replacement. A portion of the line 8 ft. long was collapsed causing a crack in a circumferential weld. This is the leak from which ammonia vapors escaped to the sleeve vent. Figure 4 shows a damaged section of the pipe. The pipe is much too strong to collapse from a vacuum and, besides, a vacuum would be difficult to produce.

Freeze-thaw cycle

Calculations of forces necessary to collapse the pipe section indicated a high external pressure was required. The only sequence of events that could produce this high external pressure was a freeze-thaw cycle between the pipe sleeve and the pipe. The pipe section and sleeve were well below the water level, and it is probable that the casing bushings leaked. The sequence of events postulated for the failure is shown below:

1. Water seeps between the pipe sleeve and line when the line is at ambient conditions.
2. Water inside the sleeve freezes when -28°F ammonia is pumped throught the line. Force of ice indents 8 in. ammonia pipe while being contained by 12 in. external pipe sleeve.
3. Ice thaws when ammonia loading line is idle. Sleeve space refills with water.

Cycle reoccurs when cold ammonia is pumped through line until total collapse.

It is interesting to note that this failure developed four years after the line was put in service. If the sleeve seals were leaking from the start, it may have taken many cycles to create the indentation and leak. In the case of our barge loading line, when the collapse became severe, the line cracked. It is possible that the line would not crack but only restrict flow. A blockage of this sort would be difficult to locate in a 4 mi. line except by radioactive pigging.

Similar failures have occurred in steam heated pipe in pipe exchangers located in freezing climates. The condensate trap ceases to function and the condensate freezes in the outer portion of the heater. The inner pipe will collapse before the outside pipe will fail.

Preventive measures

To prevent future problems with our ammonia barge line, the following changes were made.

1. Efforts were made to make the seal between the sleeve and pipe more watertight.
2. An ethylene glycol antifreeze mixture (50 per cent solution, -37 F) is added to the sleeved portion of the line.
3. Level of antifreeze is maintained in vent pipes. Level glasses are installed above grade on the vent pipes. Antifreeze liquid in the sleeve is always at higher pressure than ground water.
4. A pig was routed throught he entire length of line to search out unknown indentation of the line at other underground road or rail crossings.

These other sleeved road crossings on our barge line have not been inspected beyond pigging. We have added the glycol solution to all underground pipe sleeves and check levels frequently. Antifreeze is added when required. This preventive measure is bothersome and other possibilities are being considered.

From our experience with the ammonia barge loading line, it is possible that any below grade sleeved pipe handling low temperature material where water can accumulate in the sleeved area can develop a collapsed inner pipe. Provisions should be made to remove conditions which sould cause the line failure by:

1. Eliminating water from sleeved area.
2. If water cannot be eliminated, put in a non-freezing solution to prevent damage.

Two years have passed since our initial pipeline failure. No similar problem has occurred at any of our sleeved road corssings. The monitoring of the glycol in the sleeved section is adequate for our existing system. New installations of low temperature lines in wet areas should be designed to positively eliminate water from any encased sections.

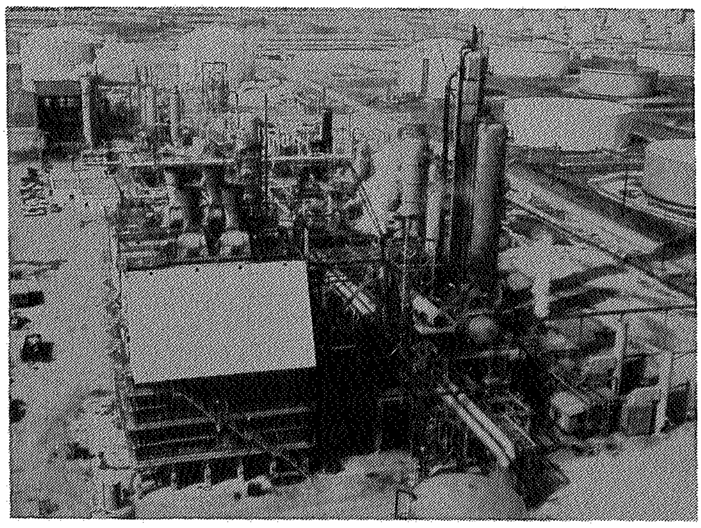

Figure 1. The American Oil ammonia complex at Texas City, Tex.

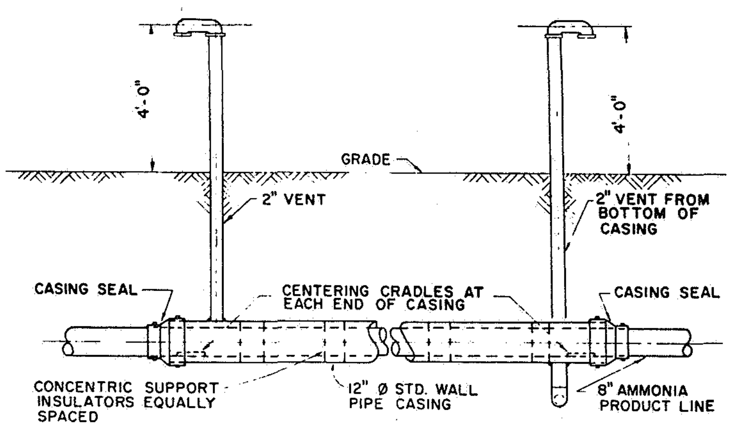

Figure 3. Design of an ammonia pipeline for highway crossings.

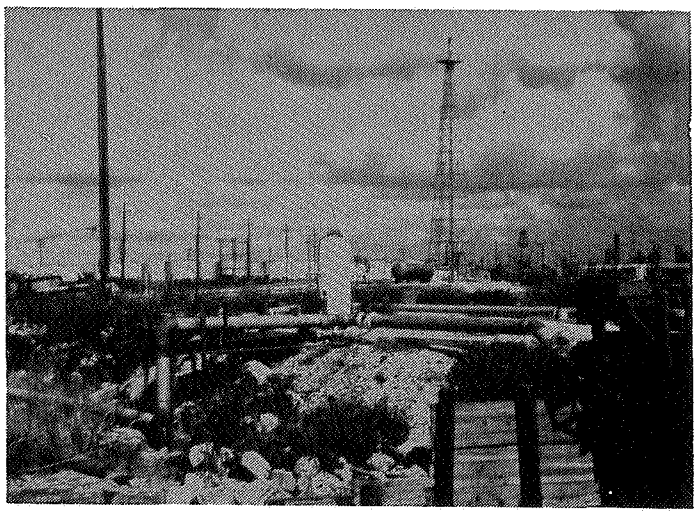

Figure 2. The ammonia line is shown in the foreground, the ammonia flare in the background.

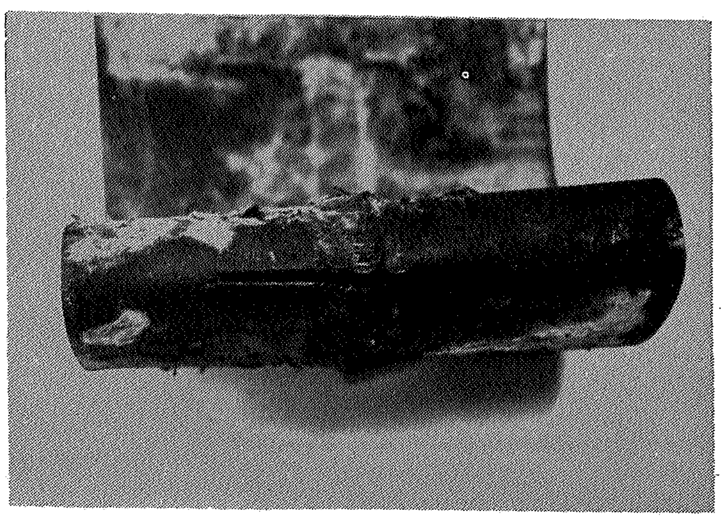

Figure 4. Damaged section of the pipe.

DISCUSSION

Q. How did you insulate the line that went underground and was submerged below the water level so that you didn't get water in other areas reaching the line?
CASERTA: We wrap underground lines with vinyl tape. Water does reach the line; however, we have had no problems with line indentation in unsleeved runs.
Q. Well - don't you get ice forming underground around your pipe? Not at the casing area, but at other zones?
CASERTA: Yes.
Q. And that doesn't give you any problems?
CASERTA: No, it does not. We assume that the porosity of the soil is such that pressure sufficient to collapse the pipe is not developed as it is when an outer casing contains the ice.
Q. Could you tell us about the failure itself. Was it a brittle fracture, or a ductile fracture? And a little bit about the procedure you used to weld this line when it was installed?
CASERTA: The failure was a crack running across a weld, and as far as the type, it was a ductile fracture. Perhaps we have someone here who may be familiar with details of the installation. Do you know, Bruce?
M. B. STERLING, Madras Fertilizers: This line was put in by American Oil Co. according to their specifications. The pipe itself was A-333 — grade zero — and I believe that's given in the talk. The welds were not stress relieved. And I cannot give you any more information than that.
Q. Why did you case it in the first place? Why couldn't you go to a heavier wall thickness and leave it uncased?
CASERTA: Well, this is a good question. I believe we're required to case certain lines under rail and highway crossings. This is the only reason I have for it. We have crossings within the refinery proper that are not cased, but once outside the refinery area we cross residential and industrial sites — railroad tracks, highways, et cetera. These are caused, and I believe this may be a requirement.
Q. I'm not sure I understand the whole problem here. How'd the water get into the casing? Was there a crack in the casing, or did it seep in through the end?
CASERTA: The casing is, of course, completely underground where the 8-inch line enters the 12-inch casing. There is a rubber closure which slips on the end of the casing, and they're called "casing seals". These casing seals are attached to the sleeve and the pipe. How well they're attached, I guess, would govern the amount of water that leaks in. Ours apparently were not too tight. And water seeped in, we speculate, around the casing seal and entered the sleeve.
Q. How do you explain the complete collapse of the 8-inch pipe? Was that due to the crack you had?
CASERTA: No. We think a freeze-thaw cycle occurred. First the casing is full of water. Then the cold ammonia goes through it, forms ice which develops pressure as it expands, and indents the pipe. Then, of course, when the loading is completed, the line is depressured and warmed up, then the ice will melt, allowing the entire new volume to be filled with water. This then re-freezes on the next loading. And this successively happens, we speculate, until the line is collapsed, and then finally - probably on the last cycle, it cracked.

Caserta

Miller

DISCUSSION

Q. Did you ever consider using part of the process condensate as makeup water to the CO_2 removal section?

COOPER: I think when the initial study was made that was considered, but the final decision was to put it in disposal wells. This is being reconsidered again.

LOU CASERTA, American Oil: We will install a flare in our storage area to burn ammonia vapors, and we have been told by a flare vendor, for example, that we can readily burn 25,000 lb./hr. or so, perhaps as much as 50,000 lb./hr. with a special-design tip. Our research people at Whiting are checking this out.