Failure and Repair of an Ammonia Separator

When leakage is discovered in a high pressure vessel, shutdown should be fast, but orderly. An emergency shutdown might cause shocks which could result in massive failure.

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The completion of an annual ammonia plant turnaround, one in which a number items that had been giving trouble for years are found to be in good condition, and during which only the major item not on the schedule turns up, is an exhilarating experience. We were in just that position on Saturday, August 21, 1971. All maintenance work was complete, the front end was heating up, and we expected to regain full production Monday morning. Start-up went so well, full rate was actually attained at midnight, Sunday.

Upon arriving at work Monday morning, my thoughts were on getting the paper work, which had accumulated during the turnaround, cleared up as I had made plans to attend the AIChE National Meeting in Atlantic City. A few minutes after 8:00 a.m., the phone rang, and I was told, "Come to the ammonia plant, quick. We have trouble." That morning an operator had found liquid ammonia coming from beneath the insulation of the secondary ammonia separator. This was indeed trouble.

Compression was backed out of the synthesis loop as gently as possible and we began depressuring the loop. After the separator was blocked in, a continuously falling liquid level, as shown on the recorder, indicated a leak in the lower shell or nozzles. We hoped to find a failure at one of the nozzles, but removal of the insulation showed the ammonia to be coming from one of the bottom weep holes in the multi-layer shell.

A company familiar with this type construction was contacted and tentative arrangements were made to make the necessary repairs. The remainder of Monday and Tuesday were spent contacting other companies in the ammonia business and all known salvage companies in an effort to locate a surplus vessel which could be used. A number of vessels were found, but none could be used without extensive modification to the vessel and the piping.

Operations had purged the vessel by Tuesday morning and work was started to cut it out. The welded connections were cut, instrumentation removed, and the separator was lifted out and loaded on a truck by 4:00 p.m., Tuesday. Arrangements had been made with the company making the repairs to receive the vessel on Wednesday morning, but due to failure of the trucking company to take the vessel straight through as promised, delayed arrival at the shop until late in the afternoon.

I arrived at the repair shop on Thursday morning expecting to find work started on cutting the bottom head off and was met with a surprise. Although an inspector from our insurance carrier was there, it was necessary for me to sign an "indemnity clause" before any repair work was started. Since this clause stated that we must take full responsibility for the repairs, the adequacy of the vessel following repairs, and supervise and conduct all tests following repairs, our insurance carrier's home office, our insurance broker, and our management were consulted. Permission was then given to sign the agreement. This made it a necessity that we stay with the job and be available for consultation at all times, since the work was set up on a 24 hr., seven-day week basis. It is important to plan for such contingencies ahead of time. Because we did not, approximately 18 hr. were lost from the time the vessel arrived until the agreement was signed.

A project team, consisting of a project manager, a welding engineer, and a manager of production planning was assigned to the job and instructed to keep the repair work moving at all times. We sat down together and discussed our approach to locating the leak.

Ammonia Plant

This facility is a 350 ton/day design capacity unit which went on stream late in 1963. Reforming and CO_2 conversion are typical of most units. MEA is used for CO_2 removal followed by methanation. Compression consists of two 5,500 h.p. synchronous motor driven, eight throw reciprocating compressors. The synthesis loop operates at 5,000 lb./sq. in. gauge. Modifications made since original start-up have increased the unit capacity to approximately 400 ton/day.

The secondary ammonia separator is of typical

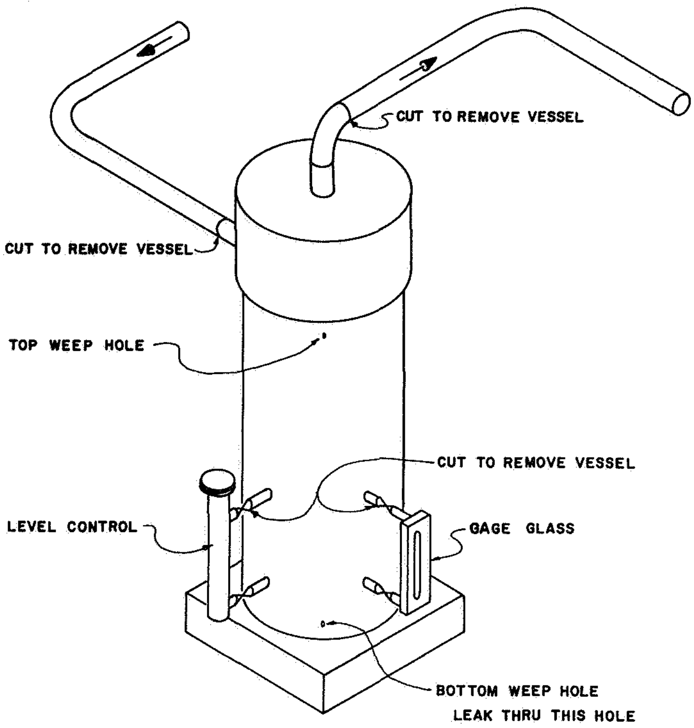


Figure 1. Separator orientation.

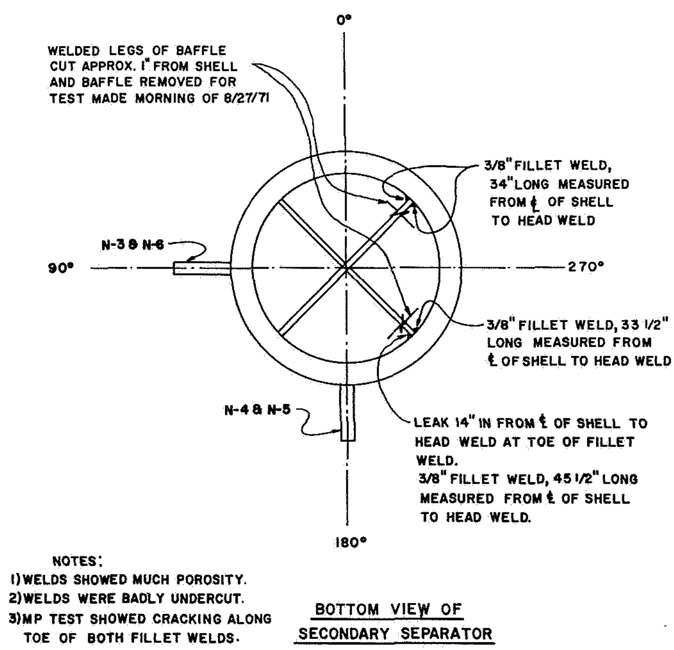


Figure 2. Location of leak on inner shell.

multi-layer construction, having an inside diameter of 26 in. and a tangent to tangent length of 10 ft. 1/8 in. with internally machined 2:1 ellipsoidal heads. A tangential inlet nozzle is located on the upper shell and the outlet is centered in the top. Other shell nozzles are two connections for a gauge glass and two connections for a level transmitter. There are two liquid ammonia outlet connections in the sides of the bottom head. Internals consist of a conical section in the top and a set of disengaging baffles in the shape of a cross in the bottom. Two adjacent legs of the baffle are welded to the inner shell with fillet welds. The inner shell is 1/2 in. thick, having a tensile of 85,000- to 105,000 lb./sq. in. and the outer wraps have a tensile of 105,000 lb./sq. in, minimum. Total wall thickness is 3-1/8 in. Both heads are forgings. Four weep holes, two in the top of the shell and two in the bottom of the shell, are drilled through the outer wraps to the inner shell. The leak was discovered at one of these weep holes.

Disassembly was started by drilling a 3/8 in. hole in the center of the shell to bottom head weld. This provided a starting hole for burning the bottom head off because we felt certain the leak was below the upper gauge glass connection and it would not be necessary to remove the top head.

The vessel was laid horizontally on powered rolls and the starting hole was drilled. While drilling the hole, one of the liquid ammonia outlet connections which was facing down, leaked several quarts of oil on the floor. With an unknown quantity of oil in the vessel, there was concern about burning the lower head off. It was decided to use a continous inert gas purge of argon on the inside during the burning. All nozzles were taped closed and a water manometer was connected to one lower nozzle to assure a positive internal pressure at all times. Asbestos strips were used to fill the cut as it was being made and prevent losing the purge. The head was burned off in this manner and when the head was removed, several more quarts of oil came out of the vessel.

Both legs of the baffle which were welded to the shell were cut and the baffle was removed. Due to the heavy oil film on the inside, it required two steam cleanings and a solvent wash to prepare for trying to find the leak.

Following cleaning, a visual inspection was made with no results. We did find the fillet welds which attached the baffle legs to the shell showed severe undercutting and much porosity. A preliminary magnetic particle test did not locate the leak, and it was decided to drill and tap the four weep holes, put 100 lb./sq. in. gauge air in the shell layers, and check the inside with Leak-Tec.

Air was put into the hole where the leak had shown up in operation and pressure gauges were installed in the other holes to show where the layers had been pressured. Pin hole leaks were found 14 in. in from the shell bottom and at the toe of one of the fillet welds. Another magnetic particle test along these welds showed cracks along the toes of all four fillets.

The old welds were ground flush and another magnetic particle test run to layout the shell grinding. We had to grind 36 in. of shell along one baffle weld and 19-1/2 in. along the other in order to remove the cracks. Of this, 8 in.

on one weld was completely through the inner shell thickness.

Repair

Most failures of multi-layer vessels having the same shell material as ours and internals of high tensile material, have occurred at a shell attachment and along the heat effected zone of the weld. This is due to the relative brittleness of these high strength materials. Our failure followed this pattern. For these reasons, it was decided to use a more ductile repair material and E 7018 electrode was chosen. E 7018 consistently shows a tensile of 83,000- to 85,000 lb./sq. in. gauge in the as-welded condition, and this compared favorably with the lower tensile of 85,000 lb./sq. in. gauge of the shell and provided the ductility desired. A procedure was written using 150°F preheat, repairs made, and welds were ground flush with the inner shell.

A magnetic particle test, followed by using air to pressure the layers and Leak-Tec were run and no defects were found. The weld groove was then machined on the shell and bottom head. Baffles were repaired by welding strips of A 516-70 on the two legs cut off during removal.

The baffle was rotated 180° so the new material added to the baffles would be welded to the shell where no weld existed before. We did not want to weld to the shell repair. Baffles were welded in place with 3/8 in. fillet using E 7018 electrode and 150°F preheat. The length of these welds was 32 in. along both sides of each leg and was the limit a welder could reach comfortably and make a good weld. I feel the poor quality of the original welds was partially due to an attempt to weld the entire length of the baffle leg, which was 46-1/2 in. Due to the tight space in this small shell and with the baffle, the angle of the electrode in the holder necessary to reach that far in, caused metal to be blown out and contributed to the severe undercutting.

To prepare for the preliminary hydrostatic test, only the inner shell was welded to the head. All other nozzles were capped.

A problem with sweating between the exposed shell wraps was encountered when the vessel was filled with water, and it was necessary to circulate warm water through the vessel to equalize the shell temperature. After no more sweating was observed, the pressure was brought up to 2,210 lb./sq. in. gauge and held for 30 min. A visual check at pressure showed no leaks, and tissue paper put in the weep holes showed no pick-up of moisture. The vessel was drained and returned to the shop for the completion of the welding.

Final hydrostatic test consisted of pressuring the vessel to 7,800 lb./sq. in. gauge and inspecting for leaks. No leaks were observed.

Test caps were removed and welding grooves were machined on all nozzles. The vessel left the repair shop on Thursday, September 2, 1971, and was completely installed and ready for operation on Saturday, September 4, 1971. Our total outage was 13 days.

Lessons Learned

What can we learn from an experience such as ours? I

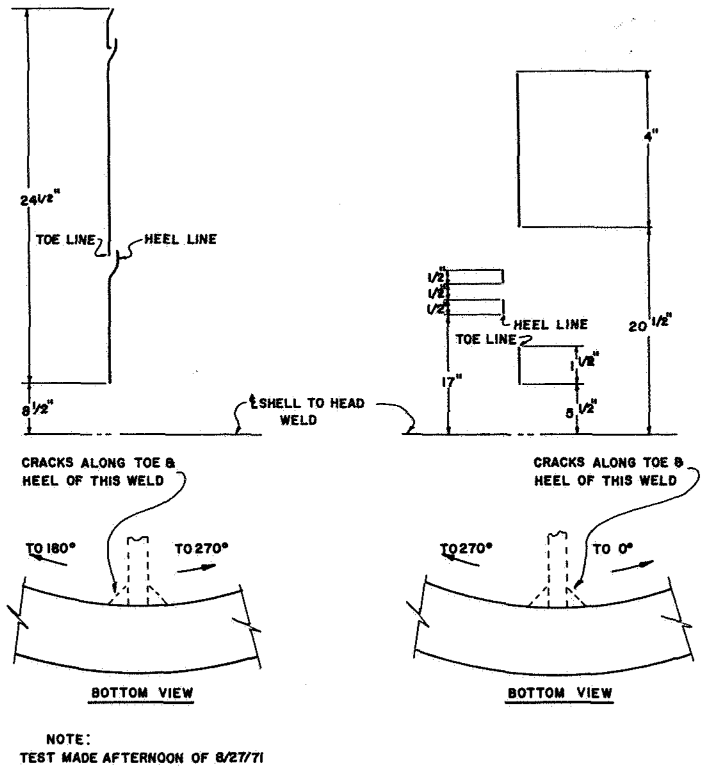


Figure 3. Cracks on inner shell.

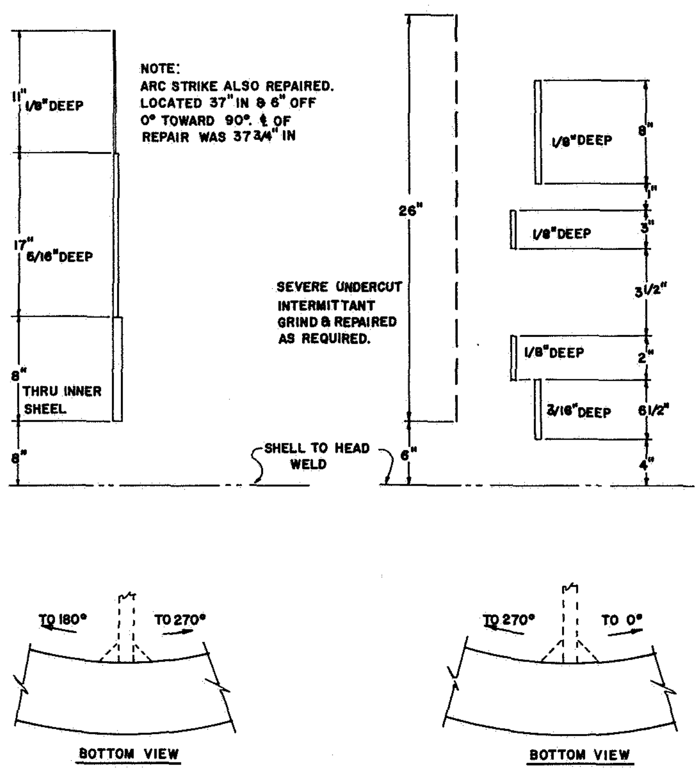


Figure 4. Grinding to remove cracks.

feel the following points should be remembered and planned for when faced with failures of high pressure vessels:

1. When the failure is discovered, make a fast but orderly shutdown. An emergency shutdown might cause shocks which could result in a massive failure.

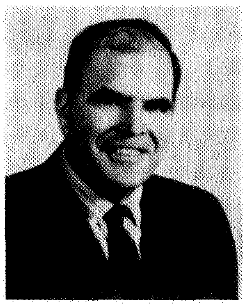
2. Be prepared to accept the responsibility for the repairs. You will need the full cooperation of your insurance carrier and your management. Under these conditions, have personnel who can make the decisions on the spot available to babysit with the repair.

3. Contact your state agency responsible for pressure vessels and get their blessing if the vessel is not covered by the codes, and is a special case.

4. Look at all vessels more closely from both the areas of design and material selection and the areas of actual mechanical assembly. Ask yourself questions such as:

a) Is that high tensile material up to taking the attachment of an internal baffle subject to vibration? b) Can that welder actually make a good quality weld in the space provided? c) How should I proceed with the assembly of the equipment, and is this procedure practical?

This type of analysis could do much toward the development of better equipment designs. #



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