Primary Reformer Transfer Header Failure

Metallurgical examination after the failure revealed that the pressure wall failed from a short time creep-rupture under conditions of rapidly increasing temperature.

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Terra Chemicals International, Inc. operates a 600 ton/day anhydrous ammonia plant near Sioux City, Iowa. The plant, designed and constructed by the M.W. Kellogg Company, commenced operation in June 1967.

In this facility, the primary reforming of the natural gas feedstock takes place in a down-fired furnace containing five rows of HK-40 alloy catalyst tubes welded to Incoloy collection manifolds in the bottom of the furnace. Risers of the same HK-40 alloy extend from the center of the collection manifolds through the roof arch of the furnace to an externally water-jacketed and internally-insulated hot gas transfer header. This 50 ft. long horizontal header is welded directly to the secondary reformer. In February 1971, the transfer header ruptured when the water level was lost in the jacket for a short period of time.

The rupture of a similarly insulated water-jacketed vessel in January 1969 was attributed to the failure of the internal insulation system *(1)*. The insulation voids found at that time in the transfer header were "pumped" full of bubbled alumina to effect a repair.

The transfer header has been routinely inspected on each major outage since that time. The last inspection prior to the recent failure was in September 1970, and indicated only minor evidence of shroud buckling, and of soft or missing insulation. The insulation in the header and riser areas is very difficult to inspect because of the internal shroud and the close quarters. Insulation was generally visible through the header shroud where the riser shrouds enter the effluent chamber. Random holes were drilled throughout the shroud liner to "probe" for insulation voids in other areas. None were found.

The jacket water system should, under normal circumstances, prevent overheat and failure of the pressure wall with some insulation voids as long as water is present in the jacket and film boiling is not occurring. The transfer header water jacket system is common with that of the secondary reformer. Chromate-inhibited cooling water is the normal make-up. The excess overflows into a collection trough attached to the side of the secondary reformer water jacket below the transfer header level. The water flow is maintained in excess of evaporation losses to keep a continuous overflow and insure against a low water level. A low level alarm was installed on the secondary reformer jacket with sight glasses on the secondary reformer jacket and the transfer header jacket at the end opposite from the secondary.

Events leading to the failure

Less than two hours prior to the rupture, a routine operational check indicated a normal water level and an overflow from the jacket water system. A few minutes before the rupture occurred, the area operator noted an apparent overflow from the water jacket, but an empty sight glass on the end of the transfer header. Inspection through the jacket water manway on the top of secondary reformer revealed that the water level had dropped to the level of the external trough, and was passing through a large split in the jacket into the trough at that point.

At this time, the noise level began increasing accompanied by the appearance of "steam" at high pressure escaping from the transfer header jacket. Before shutdown could be initiated, the header ruptured. The water-jacket low level alarm did not come on until after rupture. It was suspected that, because of long periods of high level from the constant overflow, the float had hung up.

Subsequent inspection revealed that considerable corrosion had occurred at the air-water interface in the collection trough on the secondary water jacket wall. The water escaping at this point into the collection trough, emptied the transfer header jacket. Because of the apparent insulation voids, the header quickly overheated and ruptured.

The 180^{o} return bends on the 6 in. header water-jacket vents had been replaced earlier with 45^{o} ells to direct flow away from the reformer penthouse and adjacent structures in the event of a catastrophic failure. This revision undoubtedly reduced the damage to the penthouse area. There were no injuries to personnel.

The 30-inch O.D. x 0.750 in. wall transfer header, was fabricated from ASTM A-285 Gr C FBQ steel. It was internally insulated with 4.25 in. of Insulag insulation lined with a 0.125 in. type 304 SS shroud. The rupture occurred between the third and fourth risers, counting back from the secondary reformer. The general direction of the force of the rupture was north towards the convection section of the furnace. The transite in the northeast, the northwest and part of the penthouse roof was blown out.

The rupture of the header pressure wall was 42 in. long and 24 in. in width at the maximum point. Bulges and deformations extended for several feet in each direction of the rupture. The thermowell for the third riser and part of the collapsed internal 304 SS liner was protruding through the rupture.

The top weld seam of the water jacket was split open 13.5 ft. A large percentage of the insulation was gone, much of which probably blew through the rupture and the header was "sagging" in the area of the rupture. A metallurgical examination of the metal in the fractured area indicated that the pressure wall failed from a short time creep-rupture under conditions of rapidly increasing temperature reaching 1,200-to 1,300°F, and that it was at this temperature for, at most, a few hours. Hydrogen embrittlement did not contribute to the failure. The pressure wall had necked down from the original 3/4 in. thickness to about 1/8 in. at the fracture.

Transfer header repair

Because of the severity of the damage, it was necessary to replace all of the stainless steel shroud and insulation and a 10 ft. section of the pressure header in the failed area. This included replacing insulation in the risers and repair or replacement of the damaged shroud liner in the risers.

The water jackets were cut off each riser to clean out accumulated sludge in the bottom of the jacket. Holes were cut in the riser pressure walls in the carbon steel piping just above the Incoloy cone to clean the remaining Insulag insulation from the risers. The plugs were then rewelded in the holes, and the risers reinsulated with bubbled alumina. The conical gas shields were rewelded in place in the top of each riser.

The new 10 ft. section of the 30 in. O.D. transfer header was welded in place simultaneously with the installation of the shroud and conical gas shields in the end of the header towards the secondary reformer. The holes for the third and fourth risers were made in the new piece, positioned over the risers, and welded in place. Reinforcing plates were trimmed and welded in place on the risers and transfer header.

The shroud and conical gas shields were redesigned for the transfer header. With field installation, it is necessary to work away from the secondary reformer instead of towards it, as was done for the original shop fabrication of the header. The installation of the 20 in. dia. shroud and welding of the conical gas shields in place were the most difficult and time consuming parts of the repair. The conical gas shields were welded to each section of the shroud in the shop and then covered with cardboard and shellacked. There was difficulty in getting the shroud sections in place in the header because the conical gas shields would not pass over obstructions caused by chill rings that had been welded to the side of the 30 in. pipe at the manufacturer's original refractory pour holes, and because the pressure pipe of the risers extended into the 30 in. header. The header was not round and this caused distortion of the shroud as the conical gas shield was welded in place. This made it difficult to fit the next section of shroud into the slip joint collar of the preceding section.

Screwed, 2 in. 3000 lb. couplings were welded into the top of the pressure shell near the conical gas shields for insulation ports. These were later plugged and backwelded.

Altogether, 13,500 lb. of bubbled alumina (Alfrax /53) was poured into the risers and transfer header to replace the original Insulag insulation. Because of the higher density of the bubbled alumina over the original Insulag insulation, it was necessary to revise the transfer header spring hanger settings.

The catastrophic failure of the transfer header also caused disintegration of the primary reformer catalyst, requiring its replacement. The mixer was torn off the secondary reformer nozzle and the secondary reformer catalyst was "stirred up", the bed had shrunk about 4 ft. and considerable portions of the catalyst were fused together. Evidence of the reverse-flow caused by the sudden depressurization was also present in the high temperature shift converter, but was not believed serious enough to require repairs or catalyst replacement at that time.

Weather contributed to the difficulty of the repair. The low ambient temperatures and adverse weather conditions at times reduced labor productivity to a standstill increasing what was already a very costly and time consuming effort.

Curing and drying of refractory

For the initial cure of the refractory, it was held at slightly under 100°F from the time it was initially poured until the drying out procedure was begun. This was a minimum of 24 hr. on the most recently poured refractory. The temperature was maintained by using propane heaters connected directly to the water jacket or under canvas tarp shelters constructed around the repair area.

As repairs and the curing were completed, air was put through the primary reformer to increase the temperature 50°F/hr. to 200°F by using the process air compressor and lighting the furnace arch burners as required. It was held at 200°F for 3 hr. with the air venting upstream of the blocked in high temperature shift converter.

At the end of the 3 hr. period, the temperature was increased at a 75°F/hr. rate to 650°F, and held for an additional 6 hr. (Because of a possibility of igniting the graphite on the new secondary reformer catalyst, limits of 400°F and 50 lb./sq. in. gauge were imposed on the secondary inlet while using air to dry. As a precautionary measure, when the outlet reached 300°F, the air was slowly backed out and replaced with steam. At the end of 6 hour, 650°F drying period, the outlet was increased 75°F/hour to 1,300°F. At this point, the drying was considered complete, and the normal startup procedure initiated. #

Literature cited

1. Atterbery, J.R., *Ammonia Plant Safety*, a CEP technical manual, **12**, 34, AIChE, New York (1969).