Failure in Secondary Reformer Vessel

Thorough investigation of ruptured shell of reformer in ammonia plant during repairs aimed at preventing future recurrences of the same problem.

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A water jacket does not protect a reformer vessel in ammonia plant service against refractory failure. This conclusion was reached as a result of a rupture in a secondary reformer shell of a 10-year-old ammonia plant.

The shell—1-3/8-in. thick and water-jacketed—was protected from hot gas by a 10-1/2-in. thick refractory lining. The rupture was 18 in. long by 1-3/4-in. wide. The ammonia plant, of 600-ton/day capacity, and built for Amoco Oil by M.W. Kellogg, went onstream in December, 1963.

The secondary reformer had been opened several times for inspections through the years, and hairline cracks had been observed in the refractory lining at the first inspection. These cracks did not appear to increase in size with age, and no repairs had been made to the refractory before the failure.

The reformer is a conventional vessel, 11 ft. 8 in. in diameter, with a smaller diameter quench section at the bottom and a catalyst support dome of fire brick, as shown in Figure 1. The vessel was built in accordance with ASME Code, Section VIII. It was constructed of ASTM 212, Grade B, fire box quality, carbon steel plate, 1-3/8-in. thick, and was stress relieved and fully radiographed. The original lining was a 10-1/2-in. thick, single layer of a proprietary, low-iron, refractory, poured in place over 3/8-in. diameter, Type 304 stainless steel (T) studs. The studs were in rows 9 in. apart and staggered on 36-in. centers. A transfer line as well as the vessel was protected with the water jacket for protection against overheating. The transfer line jacket was a low-level alarm and the makeup water flow to the jackets is recorded.

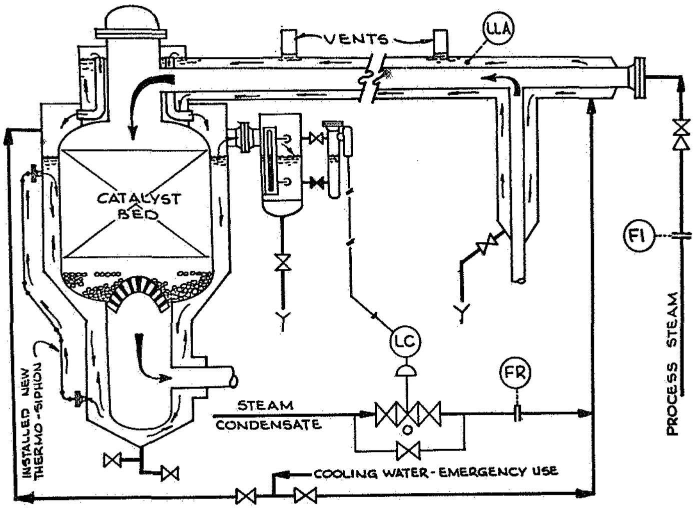

Figure 1. Reformer water jacket cooling system.

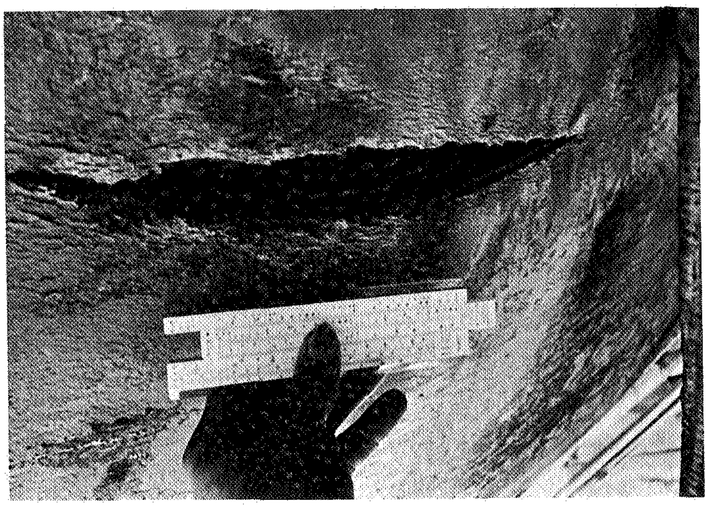

Figure 2. Secondary reformer – rupture in vessel wall.

Figure 3. Secondary reformer – refractory inside the bulged section of shell.

At 6:00 pm, October 27, 1973, the shell ruptured, and the plant was promptly shut down with no other damage. Fortunately no equipment was in the path of the escaping hot gases. A section of the shell wall about 6 ft. high and 18 ft. in circumference was severely bulged, and the final rupture, shown in Figure 2, measured 18 in. in length and 1-3/4-in. in width. The internal refractory was relatively undamaged and had not deformed with the tower wall, as illustrated in Figure 3. The rupture was about one ft. above the catalyst bed opposite a crack in the internal refractory lining, as shown in Figure 4.

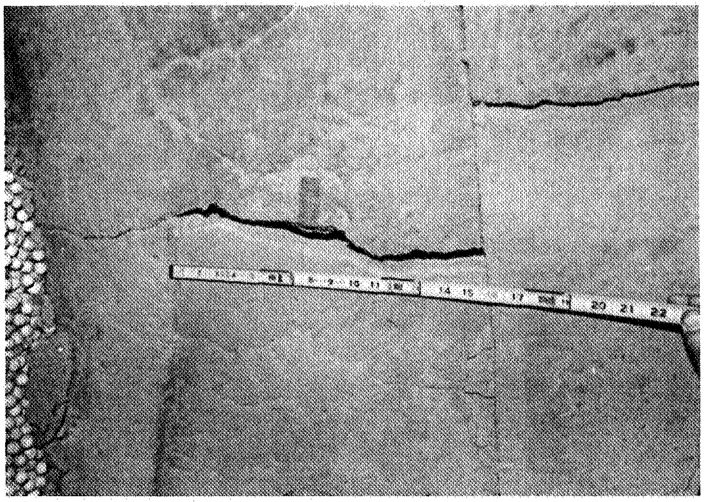

Figure 4. Secondary reformer — crack in refractory at location of shell failure.

An overall view of the shell, including a temporary patch installed to oxidize the catalyst, is shown in Figure 5. It will be seen how the vessel wall had bulged, thus contacting the water jacket.

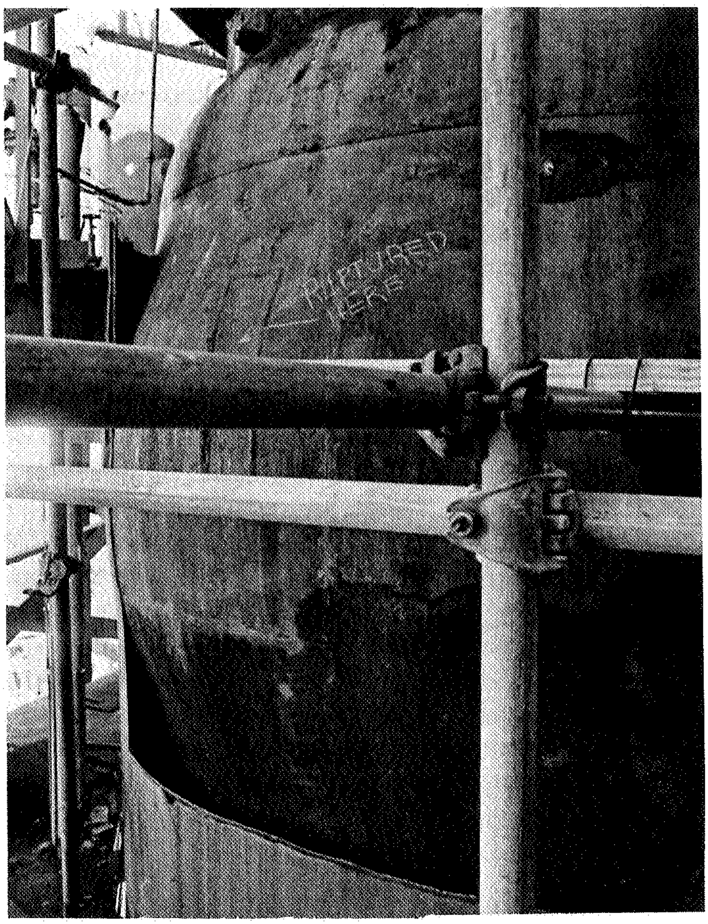

Figure 5. Secondary reformer — bulged shell at location of rupture.

The shell failure occurred when heat radiated to the shell through the crack in the refractory lining. An initial thermal crack in the refractory may have been enlarged gradually by successive thermal cycles, and the collection of debris in the opening, until the wall became overheated and the failure finally happened. Because of the fine grain structure of the metal in the area of the rupture, we believe the shell was exposed to hot gas for a short time, probably only a few minutes. The water then was boiled from this area in the external water jacket, allowing the vessel shell temperature to rise to 1,500-1,600°F. The transfer line water jacket level was observed to be normal about an hour before the failure. We have therefore concluded that the failure resulted from short-time high-temperature stress rupture. There was no evidence of hydrogen attack in the metal samples.

Repairs to the vessel shell were made by replacing the bulged area with an ASTM A-515, Grade 70, fire-box quality, carbon steel plate approximately 6 ft. 10 in. high by 18 ft. 10 in. in circumference. The new plate was double beveled and butt welded in place with E-7018 electrodes, the root pass being made with E-6010 electrodes. A magnetic particle inspection was made at the root pass, at the back chipped surface, on both sides of the weld halfway out and on the completed weld. Preheat and postheat were completed by using electrical resistance coils. Thermocouples and a strip chart temperature recorder were used in maintaining a uniform temperature in the vessel wall. The preheat temperature was held at 200°F during all vessel shell and stud welding. Postheat was held at 1,150°F ± 50°F for 2 hr. after all welding was completed.

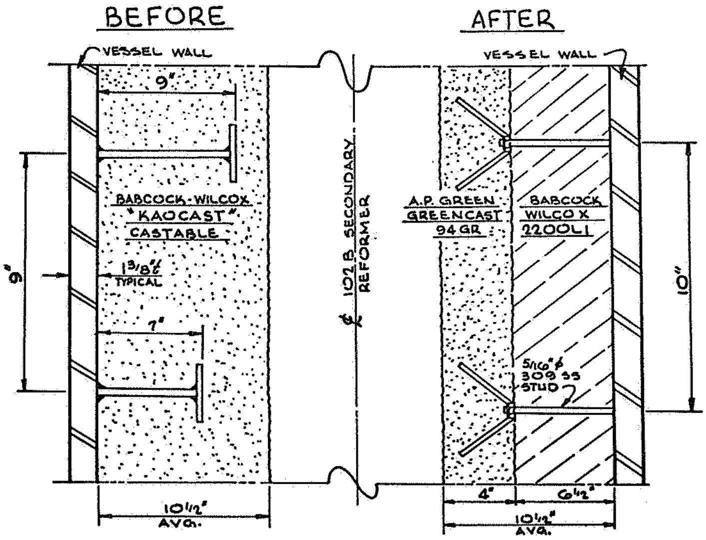

Figure 6. Comparison of old and new refractory systems in ammonia plant at Amoco's Texas City facilities.

The monolithic refractory lining was replaced with a two-phase system. This will reduce the amount of heat transferred to the metal wall and will also reduce the probability of refractory cracks propagating to the vessel shell. Refractory lining and studs were removed and the old stud wells were ground smooth. The interior of the vessel was sandblasted. Approximately 1,000, 5/16-in. diameter, No.

309 stainless steel studs with 3-in. "V" anchors were installed in rows 10 in. apart, staggered on 10-in. centers. The two-phase refractory system consists of 6-1/2-in. of an insulating refractory applied to the shell, followed by 4 in. of an alumina castable refractory. Both materials were gunned in place. A comparison of the old and new refractory systems is shown in Figure 6.

After consultations with M.W. Kellogg, Amoco installed thermal siphons on the water jacket. These consist of four 3-in. diameter pipes spaced 90° apart, each connected to the top and bottom of the jacket. Their purpose is to increase the cooling and water circulation in the jacket.

The reformer has been in operation since Dec. 12, 1973, with no further problems. Boiling of water inside the jacket appears to be reduced.

We would recommend that other ammonia plant operators critically inspect the secondary reformer refractory and repair or replace it if cracks appear to be enlarging. #

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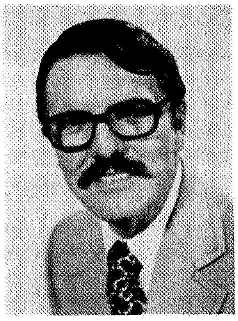

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