# Failure of a Boiler Pressure Shell

Deterioration of the refractory wall, aided by hammering of the shroud slip joints to facilitate tube bundle installation, is the most likely explanation for this failure.

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In August 1971, a leak was detected in one of the primary waste heat boilers (101-CA) in CSC's 1,000 ton/stream day anhydrous ammonia plant, Fortunately, this leak did not cause any injuries or a fire. The facility, on stream since October 1967, was designed and engineered by The M.W. Kellogg Co., Inc.

The two primary waste heat boilers in the plant are the major source of heat recovery and steam production. Located just downstream of the secondary reformer, the boilers recover waste heat from the reformed process gas on the shell side, producing a total of 278,000 lb./hr. of saturated, 1,500 lb./sq. in. gauge steam. This compares with a total of over 500,000 lb./hr. of 1,500 lb./sq. in. gauge steam produced in the unit.

The process gas stream leaving the secondary reformer is split equally between the shells of the two waste heat boilers. The gas enters each vessel at 1,800°F, and contains about 35% $H_2$ on a wet gas basis. The gas recombines, after leaving the 101-C's, at 750°F. to enter a single secondary waste heat boiler. Boiler feed water from the steam drum, at 1,500 lb./sq. in. gauge and 597°F, enters the bayonet tubes of each boiler through a single 18 in. downcomer. Satured 1,500 lb./sq. in. gauge steam leaves the scabbard tubes and re-enters the steam drum via two 10 in. risers for each boiler. This is a thermal circulation system with the steam drum located about 100 ft. above grade.

The shell of the waste heat boiler is about 22 ft. long by 49-3/8 in. i.d. The top 4 ft. 4 in. of the shell is fabricated from 1–3/4 in. plate as is the bottom 6 ft. 4 in. The middle portion of the shell is made of 15/16 in. plate. Both are A-212 Gr. B, FBQ steel, External to the shell is a water jacket with a 4 in. annular space.

The shell was line internally with 4-1/2 in. of "Insulag" (silica-based castable refractory). The refractory is protected by 1/4" rolled stainless stell plate. There are five sections of the shroud fitted together with slip joints; the top three sections are of Type 321 s.s. and the bottom two are Type 310. To prevent gas bypassing, there are five conical sections welded to the pressure shell and shroud (vapor stops) constructed of 310 and 321 stainless steel. The 20 in. i.d. inlet gas distributor is made of 310 s.s. and the 14-3/8 in. i.d. outlet shroud is 321 s.s.

The tube section of the waste heat boiler consists of 206 tubes on a 2-1/2 in. triangular pitch. The Bayonet (outer) tubes are 2 in. o.d. by #10 BWG, A-209 Gr. T1A. The maximum effective tube length is 17 ft. 4 in. and the minimum is 16 ft. 8 in. The tube bundle is supplied with five segmental baffles equipped with guides on the outer periphery.

### Sequence of Events Leading to Failure.

During our July 1971 turnaround, the tube bundles in both primary waste heat boilers were replaced. The shrouds of both vessels were severely warped, especially at the slip joints. To facilitate replacement of the tube bundle, the shrouds were notched and hammered back to the original i.d.

On August 4, 1971, at approximately 4:00 p.m., the field operator noted that there was almost no water flow on the overflow line from 101-CA jacket. He called the board operator who confirmed that the low-level alarm was on and had been on longer than usual. It had been a common occurrence for the alarms of all three jackets to "blip" on and off since plant startup. All three jackets are fed through a common meter and individual flows are adjusted according to the overflow.

At this particular time, the valve to 101-CA had to be opened wide in order to re-establish the overflow. During the remainder of the evening shift and the night shift, the 101-CA was periodically inspected and nothing out of the ordinary found.

At 8:00 a.m., on August 5, 1971, excessive steaming at the overflow pan atop 101-CA was noted by the field operator. Analysis with an MSA Explosimeter indicated the presence of combustible gases. Shortly thereafter, a bulge was found on the upper half of the water jacket. Orderly shutdown of the unit was initiated immediately and accomplished without any serious occurances.

A 3 ft. square window was cut out of the center of the bulged section of the water jacket. The pressure shell was flush against the water jacket at this location. A small crack was revealed at the first weld below the change in shell thickness (about 4 ft.). The crack was 1-1/2 in. long by 1/4 in. wide. A 1 ft. square section of the pressure shell, with the crack at the center, was cut out. The "Insulag" refractory at this point was crumpled and wet. Closer inspection revealed that the bulge went about three-quarters of the way around the pressure shell, and was about 5 ft. long.

It was decided at this point to remove the entire unit and send it to the Belmas Shop in Houston for repair. Prior to the July 1971 shutdown, new shrouds of 310 s.s. had been fabricated for each unit. One set of these was sent to Houston with the shell.

#### Repair of Vessel

Upon arrival at the Belmas Shop, the water jacket was removed and the vessel was cut circumferentially at the approximate center of the bulged area. The distorted area on each portion was cut off. A new piece. 7 ft. long, was rolled from 1 in. plate since no 15/16 in. plate could be readily obtained.

The new section was welded in, and the vessel hydrostatically tested before relining. The bottom portion of the shroud was installed along with the inlet nozzle shroud. The refractory used was "Greencast" 97L, manufactured by A.P. Green Co. The refractory at this location was poured through the inlet nozzle. The next three sections were lined by installing the shroud, then cutting a hole in the pressure shell, and pouring the refractory through this hole. The hole was plugged, welding the removed piece back in place. The last section was done by cutting a slot in the top lip of the shroud and pouring the refractory through this.

At this point the water jacket was replaced, and the entire unit moved to a furnace for refractory curing at 250°F, for 16 hours. All work was done with the vessel in the horizontal position.

The vessel was returned to Sterlington, La. and installed in the unit. The only problem encountered was the nozzle alignment was off about 1/4 in. at the bottom. Both nozzle welds were x-rayed and the outlet weld was found to be cracked. This was repaired and passed inspection the second time. Refractory was poured in the transition section from the secondary reformer to the 101-CA through a 4 in. spout provided for this purpose on the reformer side of the field weld. Both welds were stress relieved, the water jacket replaced, and the unit returned to service.

The outage resulting from this failure was 19 days. Shop and travel time took 10 days.

#### Probable Cause of Failure

We feel that the most likely explanation for this failure is that the refractory had deteriorated sufficiently to allow the wall temperature to exceed the design limits. This deterioration was aided by having to hammer the shroud slip joints to facilitate installation of the tube bundle. It is not known whether the vapor stop welds were broken before overheating and distortion. If they were, this hastened the failure.

After considerable thought and analysis, the only operating change made was the installation of separate flow meters to each of the three water jackets. Also, a sufficient flow of water is maintained to prevent the low level alarms from coming on periodically. However, if what we surmised as the cause of failure is in reality what happened, neither of these steps would prevent recurrence. We do not have any evidence to indicate that loss of water level caused the failure. We also believe that the refractory in the rebuilt unit is superior to that in the original installation for this type of service. #

# DISCUSSION

**W.K. TAYLOR,** Canadian Industries, Ltd.: I just thought I'd comment on how we operate water jackets at C.I.L. We have rotameters and we maintain a flow of approx. 50 gallons per minute of surface condenser water to each jacket. The water overflows the jackets so we don't let the water boil, and we now recover this water in the water treatment plant, so this is no loss. Once a week we do a heat balance and measure the heat loss through the insulation. Using this technique, we have been able to schedule two reinsulation jobs of waste heat boilers on plant turnarounds. We feel this is a better way of operating. Even if you do have a momentary loss of water flow, the jacket will still be protected as the water starts to boil.

**E. A. GEORGE,** Imperial Chemical Industries, Ltd., Billingham, England: We're using Incoloy 800 in the shroud, and our main problem has been slipping of sections of it, rather than major buckling. The sections telescope and open up the expansion joint, and we invariably make sure that we seal the entire shroud. We certainly would make sure that there was never a gap through which the gas could see the installation behind. We also monitor the heat transferred to the water jacket on a regular basis; and we have, in fact, got up our sleeves a contingency plan for relining one of these shells completely in a refractory brick lining, although we have a limited debate amongst ourselves as to whether this would or would not need a shroud. It's quite possible that it wouldn't. We haven't yet had to use that. If we have to do major relining, then we would probably go to an all-brick type refractory lining.