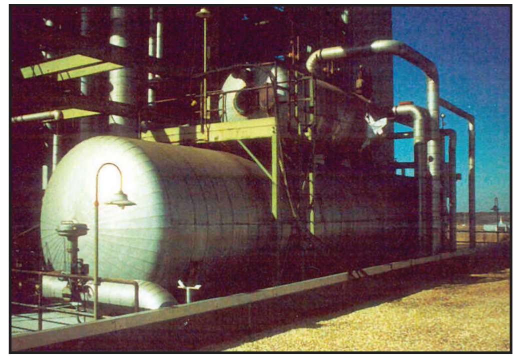
Deaerator Unit Examination

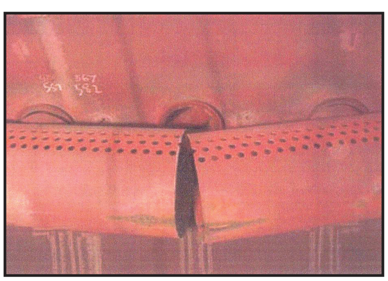
THIELSCH ENGINEERING

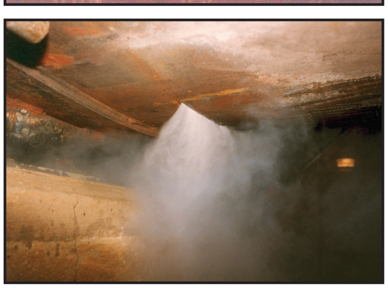
Background



In 1971, a rupture occurred in a deaerator heater installed in a power plant. In 1979, the head of a deaerator storage tank separated suddenly around the shell circumference alongside the girth weld. Two additional deaerator heaters ruptured in 1983 in the United States, with catastrophic consequences to personnel working at the respective plants. In 1998, another catastrophic rupture occurred in a deaerator located in Belgium. The rupture caused severe damage to the plant facility. This was followed in 1999 by another catastrophic rupture of a deaerator located in the Dominican Republic.

Because of the ruptures of the deaerator heaters and deaerator storage tanks that have occurred, and the discovery of cracking in a significant number of other deaerator heaters and deaerator storage tanks, the National Board of Boiler and Pressure Vessel Inspectors have expressed serious concerns about the integrity of this type of equipment. As a result of the catastrophic failures, a number of insurance underwriters, trade associations, and publications have been recommending the inspection of deaerator heaters and deaerator storage tanks.





Failure Causes and Considerations

Cracking in deaerator heaters and/or deaerator storage tanks is typically the result of mechanical fatigue or mechanical shock conditions. The mechanical fatigue is the result of cyclic stresses created by such operating conditions as full load rejection, temperature/pressure fluctuations, and water hammer.

Full load rejection occurs when the turbine trips and turbine extraction steam is lost. This may cause flooding of the downcomers, resulting in water being blown upward against the heater trays. Trays may become dislodged and in some cases, bent or broken beyond repair.

Moreover, when a unit trips, the pressure is reduced inside the deaerator heater and storage tank, resulting in steam flashing. This produces a water hammer effect, which will result in mechanical shock loading of the deaerator heater and storage tank, the pipe connections and the structural supports. These shock conditions may introduce stresses of as much as 30,000 psi. Flow induced vibrations or water hammer may also occur in the piping connected to these vessels.

Severe stresses in the deaerator can occur from temperature/pressure fluctuations resulting from either an influx of cold water or a unit trip. Large influxes of cold water entering the deaerator can cause a sudden drop in deaerator pressure and a subsequent flashing of water in the storage tank. Again, the result is movement and distortion of internal components in the deaerator heater as well as mechanical shock loading of the deaerator storage tank.

Water hammer may also occur when high-temperature condensate comes in contact with cooler make-up water. The result is damage to deaerator internals, seams and supports. Necessary precautions include cooling the returning condensate either through the direct injection of cool make-up water or through a make-up heat exchanger.

In some instances, where the cracks have been widened by slight corrosion, failures have been attributed to corrosion fatigue, even though mechanical fatigue or shock represents the actual primary cause. Nevertheless, magnetite (Fe_3O_4) generally is formed in the fatigue cracks. Thus, magnetite formation is considered a contributor to the cracking of deaerators and deaerator storage tanks.

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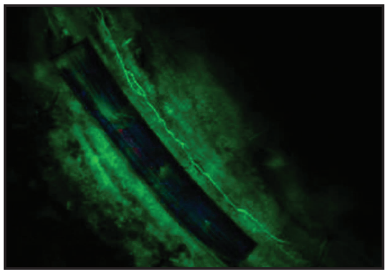

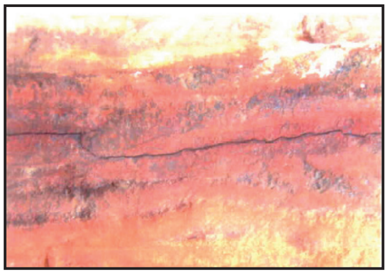

Magnetite formation, in conjunction with deep oxygen pitting, will not result in cracking or fissuring. Even where shells have developed pits of depths of 30% to 50% of the wall thickness with magnetite deposits in the pits, cracking has not occurred. In a few instances, caustic stress corrosion cracking has been apparent. These types of cracking, however, generally appear to represent exceptional cases.

Temperature cycling can also cause or contribute to cracking alongside or across welds with high residual stress levels. However, cycles involving 100°F temperature variations generally would require a million cycles for crack initiation to occur. A 200°F temperature differential would require approximately 100,000 cycles, whereas a 400°F to 500°F temperature differential in each cycle would require approximately 10,000 cycles for cracking to occur.

Cracking in deaerator vessels has also been attributed to caustic stress corrosion. This cause, however, represents an exceptional case as the presence of caustic or alkaline water is required. Caustic invasion of a feedwater system typically occurs when a breach of the piping is made because of operator error. The feedwater may also become alkaline due to additive water treatment chemicals. The attemperator deaerator heater water supply is de-ionized water, treated with hydrazine. The pH of the water supply is such that caustic stress corrosion is generally precluded under normal operations.

Water or steam erosion of the shell has also caused a number of failures of deaerator heaters and storage tanks. While erosion conditions have resulted in cracks extending through the shell, ruptures have not occurred. When erosion is the principal cause of failure, cracks have not been found to develop until the wall thickness has been reduced to less than 10% of the original shell thickness.

Qualifications and Expertise

Thielsch Engineering has collectively inspected over 1,000 deaerator heaters and storage tanks to date. We have gained significant experience and expertise that enables us to determine what causes cracking in deaerators, how these cracks affect the operating integrity of the vessels, and what can and should be done to assure the safe, continued operation of these vessels.

Thielsch Engineering was involved in the examinations of the two catastrophic ruptures of deaerators which occurred in 1983. In 1984 a third deaerator ruptured, one of the head sections suddenly separated from a deaerator, without resulting in catastrophic consequences. We performed the follow-up inspections. No other company has this experience with the conditions that cause, or may not cause, failures in deaerators.

Since 1983, when the industry first became concerned with potentially catastrophic failures in deaerator heaters and deaerator storage tanks, we have performed over 500 inspections of deaerator heaters and deaerator storage tanks. This has included a number of metallurgical examinations detailing cracking conditions. This includes cracks, which occur during fabrication, as well as progressive transverse and/or longitudinal cracks that develop gradually during service. We are familiar with all the conditions that can result in deaerator failures involving conditions that can be catastrophic, as well as conditions that may result in leaks.

We have also evaluated a number of deaerators with through-wall leaks as a result of cracking which developed after periods of 15 to 25 years. New through-wall cracks occurred, often within periods of only one to two years, due to improper repair welding. There have been many cases where repair welding was entirely unnecessary, because the conditions of cracking were not of a significance to affect the integrity of the deaerators involved. When repair welds were made, more critical or severe conditions of cracking developed within one to two years at the repair weld locations.

In general, where we have performed deaerator repairs, we have prepared a detailed repair welding procedure specifically applied for each of the particular vessels involved. Our experienced personnel supervise the entire repair to ensure that the deaerator is restored to an adequate level of integrity. We also provide our own welding personnel when necessary.

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