Recommended practice for prevention, detection, and correction of deaerator cracking

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Following the catastrophic rupture of a deaerator in a paper mill in 1984 and the subsequent discovery of serious cracking in many other vessels, the National Association of Corrosion Engineers (NACE) formed a task group to study the causes of deaerator cracking. In April 1990, NACE issued Standard RP0590-90, "Recommended Practice for Prevention, Detection, and Correction of Deaerator Cracking." It provides historical information about deaerator cracking and failures and describes methods for finding cracks, repairing them, and performing preventive maintenance. This article summarizes the findings of the NACE Recommended Practice and discusses deaerator inspection, repair, and operating practice.

Deaerator configuration

Deaerators control waterside corrosion and deposition in steam power plants by removing oxygen and other dissolved gases from boiler feedwater. The feedwater is sprayed into the deaerator, where it is heated by a countercurrent stream of steam. The heating effect of the steam strips dissolved gases out of the feedwater. Deaerators generally consist of a heater, in which the heating and deaeration takes place, and a feedwater storage tank. The most common deaerator configuration has the heater as a horizontal cylindrical vessel with domed heads at each end of the cylinder. This heater sits atop a larger water storage tank of the same general shape. **Figure 1** illustrates a typical deaerator.

Deaerators can fail to operate properly because of design problems, mechanical failure, or improper operation. The most frequent mechanical problems are improper tray alignment and plugged or broken water spray nozzles. The most frequent operational problem is failure to maintain pressure differentials because of inadequate control of water and steam temperatures. Problems also arise when water entering a steam-filled line or deaerator vessel causes "water hammer," pressure fluctuations that exert large cyclic hoop stresses on the vessel wall.

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Nature of deaerator cracking

Deaerator cracking is predominantly a form of environmentally assisted cracking that is best described as corrosion fatigue. The cracks start at welds or at other regions of high stress on the inside of the vessel and propagate outward. Residual tensile stresses from welding promote the initiation and growth of cracks. Water hammer and temperature differentials increase the stresses propagating these cracks. Finally, corrosion from the steam or water environment contributes to the cracking process.

Most frequently, cracks in deaerators run across welds, but cracks running along the edge of the weld are also common. Cracking alongside the welds joining the domed head of a deaerator to the cylindrical portion of the shell has caused catastrophic failure in several vessels. In horizontal deaerator vessels, most cracks are found below the water line between the 4 o'clock and the 8 o'clock positions.

Cracking has also been found at the steam/water interface and in the steam zone, particularly at locations where attachments are welded to the outside of the vessel. The cracks initiate from corrosion pits, surface defects in welds, or other stress concentrations. They generally propagate perpendicularly into the wall, although in some cases, limited branching has been observed.

Cracks are generally filled with rust and have blunt tips and wide mouths. Since they are driven by the stress field, they propagate transgranularly (across the crystal grains of metal) rather than intergranularly (between the metal grains). In the few instances where transgranular cracking has been observed in branched cracks, it has not propagated significantly.

Data collected by NACE show that of more than 700 vessels inspected, 30-40% were cracked and required repair. The NACE committee concluded that water hammer was a principal cause of the vessel cracking problem. Cracking did not correlate with operating pressure, manufacturer, size, age, materials, or water treatment.

Inspection methods

Deaerator inspection methods should be sensitive enough to detect cracks that could threaten the integrity of the vessel. However, tests should not be so sensitive as to confuse the steam plant supervisor with irrelevant information about defects that have existed unchanged since the vessel was fabricated or defects that do not affect vessel integrity. A deaerator inspection should always begin with a complete and thorough visual examination. All internal welds should be inspected (girth welds, seam welds, and attachment welds). The interior of the vessel should also be inspected at locations where there are external attachment welds.

The NACE report concludes that the best method of detecting cracks in deaerators is by wet fluorescent magnetic particle testing (WFMT). Sometimes this testing may need to be supplemented by ultrasonic or radiographic examination.

NACE has established a classification scheme for reporting inspection results.

- Category I: no relevant discontinuities* detected (as defined by ASME Code, Section VIII, Division I criteria)
- Category II: discontinuities detected but weld repairs not required
- Category III: discontinuities detected and weld repairs required.

Information about the rates at which cracks grow—or whether old cracks recur or new cracks initiate after repairs—is very limited. NACE recommends that the time interval between deaerator inspections should be based on the severity of problems found during prior inspections and on the severity of operating conditions. Vessels whose welds have been repaired should be reinspected soon (e.g., after one year). If prior inspections did not reveal any relevant discontinuities, the reinspection can be delayed (e.g., for five years).

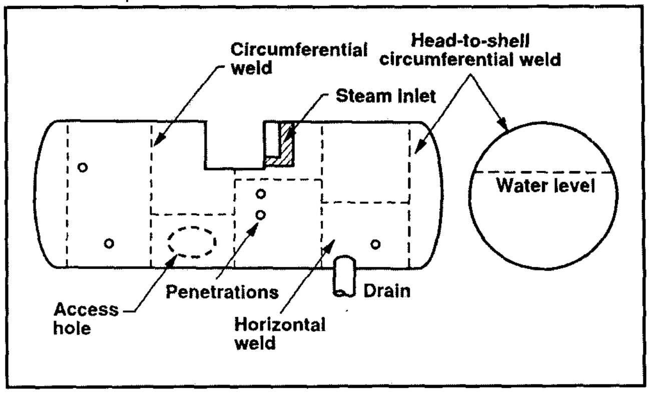
When a deaerator vessel is being inspected, it is prudent to also inspect the associated auxiliary equipment. This includes inlet spray valves, condensate vent baffles, tray sections, steam inlet piping, regulating and safety valves, and pressure and temperature gauges.

Repair

Cracks should be removed by grinding. After grinding, the affected area should be re-examined by WFMT to assure that all cracks have been removed. Air arc gouging is not recommended, since the local thermal stresses it produces may drive cracks further into the vessel wall. If the depth of grinding to remove cracks violates the minimum required wall thickness calculated according to the ASME boiler and pressure vessel code, weld repair will be required.

Repair welding must use procedures qualified in accordance with the National Board Inspection Code. If repair is not required, the grinding cavity should be contoured with a 3:1 taper in accordance with the requirements of the National Board Inspection Code. Filler electrodes should have a tensile strength comparable with that of the parent metal. Both preheat and post-weld heat treatment may be applied to reduce the tensile stresses introduced by repair welding. When the weld repair is completed, the absence of shrinkage cracks should be verified by WFMT. Spot radiographic examination may be considered to evaluate the quality of repair welds. Defects that do not affect the integrity of the deaerator need not be repaired.

1. Deaerator configuration. Most cracks are found on the head-to-shell circumferential weld, below the water line between the 4 o'clock and the 8 o'clock positions.



Operation and water chemistry

Water hammer is the principal cause of deaerator cracking, although other operating conditions can increase the thermal and mechanical stresses that drive the cracks. Corrosion also can weaken the deaerator. The risk of deaerator cracking can be minimized by observing the following operating practices:

- To minimize thermal stresses and water hammer during startup, the vessel should be warmed up at no more than 100°F per hour, especially when the operating temperature is high or when superheated steam is used.
- To minimize the temperature and pressure fluctuations associated with startup and with changing steam load, the deaerator steam supply must have adequate pressure and pipe size. Pressure-reducing valves should be installed and the deaerator load carefully monitored.
- In addition to controlling water hammer during startup and during load fluctuations, precautions must also be taken with condensate handling. Back pressure must be maintained on the high-temperature condensate line, and the returning condensate must be cooled either by the direct injection of cool makeup water or by using a makeup heat exchanger. It is sometimes necessary to increase the size of the high-temperature condensate line to eliminate water hammer. To prevent corrosion, the pH of the boiler water should be kept in the range 8.5 to 10.5, and the performance of the deaerator should be monitored to verify that the dissolved-oxygen content of the deaerated water remains low.

To maintain the performance of the deaerator, the following items should be checked once or twice per shift: steam pressures, water temperatures, pH, and the concentrations of dissolved oxygen and oxygen-scavenging chemicals. Safety equipment such as vents and level controls should be checked monthly.□

*"Relevant discontinuities" is an inspection term used to describe flaws that may or may not affect the structural integrity of a pipe or vessel.