System Design, Specifications, Operation, and In Deaerators

Robert J. Beckwith
Joseph O. Sawtell
Harold A. Stokes
Strati Yorgiadist*

April 1988

Category: Operations

Summary: The following article is a part of National Board Classic Series and it was published in BULLETIN. (7 printed pages)

Deaerator cracking can be controlled by periodic inspection and repair of operating units.

Introduction

Catastrophic failure of deaerator pressure vessel welds has included incidents that resulted in plant failures originated as cracks caused by residual, thermal, static, and dynamic stresses, with growth by corrosion fatigue. Weld deformities and hardened material in the heat-affected zone of welds failed. In some instances shell cracking has resulted in small leaks; in others, complete failure. The life-taking and life-threatening failures reported in 1982 and 1983, technical advisories and guidelines outlining the necessity of internal weld inspection and recommending methods for inspection and statements of this type were issued by TAPPI, the National Association of Corrosion Engineers (N

Board of Boiler and Pressure Vessel Inspectors. TAPPI and NACE formed advisory groups to add The TAPPI group is an ad hoc committee of the Steam and Power Committee. NACE established Deaerator Cracking, to study and compile information on the subject. The summary of the TAPPI presented here.

**Pressure vessel weld cracks**

A large number of deaerators have now been inspected. Cracking has been more prevalent than for 30 - 50 percent of all industrial deaerators that have been inspected. Cracks have appeared in circumferential weld seams of both the heater and storage vessels. Circumferential seams are susceptible to longitudinal seams, with the highest incidence occurring in the 'T' junction of the two seams. Cracks randomly at different service nozzle welds affected by thermal expansion and thermal shock.

Cracks are thought to be caused by residual stresses imposed during manufacture, along with then stress loads imposed during uneven deaerator operation. New evidence suggests that some crack area of pits caused by corrosion. Once cracks begin, they are stressed open during periods of operation to collect on newly fractured surfaces, which causes corrosion fatigue. The slightly hardened heat is where most cracks occur. Therein lies the whole problem corrosion and weld discontinuities follow corrosion fatigue along the heat-affected zone of the welded joint.

**Inspection and repair**

Inspection and repair is the tool for the control of the growth of cracks. All deaerators, including those ASME constructed and those designated as non-ASME constructed, should be periodically inspected. Inspection supervision, should be conducted by a certified ASNT SNT-TC-1A Level II inspector. put into service, it should be inspected within one to two years. After that, the following frequency suggested at the NACE 1986 conference:

- Repaired cracks, 1 year or less
- Nonrepaired cracks, 1 - 2 years
- No cracks/no repairs, 3 - 5 years

Repaired vessels, at the same operating conditions, tend to recrack faster than the original vessel. It should be more frequent after repairs.

<table>
<thead>
<tr>
<th>Type of examination</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot</td>
<td>One X-ray shot in every 50 ft of weld, at a circumferential and longitudinal junction.</td>
</tr>
<tr>
<td>Postal</td>
<td>Two X-ray shots in every 50 ft of weld, one at a circumferential and longitudinal Junction and one at random.</td>
</tr>
<tr>
<td>100%</td>
<td>One X-ray shot per ft of weld seam.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The tank in which these estimates are based is 8 ft in diameter and 20 ft long. The total of weld in three circumferential welds, and two longitudinal welds.</th>
</tr>
</thead>
</table>

**Table 1. Example of estimated costs for x-ray examination.**

A major part of any inspection program is planning and preparation. The downtime for inspection by reducing unforeseen delays. Preparation should include several important steps. First, a data file each deaerator, including system design drawings, tank modification records, histories of inspections or sketches showing areas of cracks and repairs, and ASME Manufacturer's Data Reports. Second,
should be conducted with the owner, the insurance inspector (an authorized inspector who holds a Commission), and qualified inspection and repair team representatives. A schedule for each task, including the cool time, should be prepared.

The inspection of internal tank and weld seams should include circumferential, longitudinal, nozzl by residual and operating stresses. The actual nondestructive examination should be in accordance and NACE guidelines and must be conducted from inside the vessels. Each weld should be prepared for the following steps:

1. Clean the weld to the base metal (brush, wipe down, etc.).
2. Inspect visually, especially at the intersections of circumferential and longitudinal seams.
3. Test by the wet fluorescent magnetic particle (WFMP) procedure over the entire weld, in "wet" with WFMP.
4. If cracks are found, grind approximately 20 percent of each weld having cracks flush to the weld with WFMP.
5. If cracks are found after retesting with WFMP, they must be ground out. Cracks then should be classified as:
   (a) Class I, in which the depth of the crack does not exceed the corrosion allowance,
   (b) Class II, in which the depth of the crack exceeds the corrosion allowance but not the minimum design thickness, or
   (c) Class III, in which the depth of the crack exceeds the minimum design thickness.
6. It is mandatory to repair Class II cracks. Repairs must conform to the original design, and be acceptable to the authorized (insurance company) inspector. The repair paperwork should be kept in the records of the vessel.
7. Summarize the inspection and repair results in the data file for each deaerator.

New units-construction improvement

The deaerator specification is the most important tool available to improve the construction reducing stress and corrosion causes of cracking. The areas of concern are weld joints and attachments:

- Quality of the weld
- Residual stresses of manufacture
- Thermal shock or stress
- Dynamic loads imposed by operation
- Corrosion.

The quality of welds

An important means of reducing corrosion and stress in weld seams is to ensure that the original weld quality is by X-ray examination. While the cost of X-ray examination will vary from one manufacturer to another, the inspection may add a little to the cost of the deaerator for varying degrees of X-ray examination is shown in Table I. Based on the relatively small cost, partial X-ray examinations should be specified as a minimum for new deaerators.
Residual stresses of manufacture

Cuts of parent metal at weld junctions should be smooth with no torch cuts allowed.

Removal of residual stresses of manufacture is recommended through post-weld heat treatment (PWHT) at 1100-1200°F for a time based on plate thickness as recommended by the ASME Code. If internal to the point of reducing their corrosion resistance, they should be removed. It will be necessary to reheat vessel to do this when the head is welded to the vessel, a local PWHT which extends 360° I of the vessel must be applied to this last circumferential weld.

Thermal stress and shock loads

Internal components must not impart stress loads to the pressure vessel as a result of differences in temperature. Temperature should be uniform over the entire vessel. Cold spots should be avoided. Avoid nozzle by temperature cycles. Sleeves are an alternative. The deaerator should be specified to accommodate moments imposed by piping on all connections.

Dynamic loads of operation

The major forces imposed on a deaerator are caused by pressure changes in a short, limited time. A pressure-reducing valve should be used between the heating vessel and the storage vessel, designed to avoid additional stress on nozzles.

Specify the manholes be reinforced to distribute load at the shell weld area. Reinforce relief valve valve thrust load at the weld no matter which direction the valve is mounted.

Consider a third fixed center support for long, small-diameter vessels to reduce thermal expansion in the longitudinal direction. This support will also support the load of the centrally mounted heating vessel shell.

Deaerator pressure vessels should have the same design pressure as the header pressure of the steam to prevent over-pressure during the steam pressure reducing valve failure in the open position.

Corrosion

Corrosion must be eliminated to the greatest possible extent. Specify a minimum of 1/16-in. corrosion full vacuum to eliminate vacuum breakers, which allow oxygen to be drawn into vessels during steaming. Specify that spray devices be in a vertical position and that they be mounted on a flat surface to prevent internal corrosion during shipment and storage.

Internal tray packing and piping devices should be securely fastened so as not to become dislodged by expansion of piping between tanks should be covered by baffles to prevent tray and internal damage during preheating.

Primer paint should be required on the exterior of vessels. Nozzles should be factory sealed with a corrosion inhibitor.

System design

The deaerator system should be designed to maintain a constant operating pressure and temperature through all operating ranges. Several design suggestions should be considered.

First, install a pressure-reducing valve in the steam line that feeds the deaerator, with its sensing line itself. The pressure-reducing valve should be near the deaerator (Fig. 1).
Second, condensates and makeup water should be blended before the deaerator heater. This blend header just ahead of the deaerator or in a feedwater mixing tank between the demineralizers and de eliminates the temperature differential between separate makeup water and condensate connection feedwater mixing tank has the added advantage of making temperature changes more gradual whe vary. The choice should be evaluated based on the relative flows of hot condensate and makeup w history of condensate flow interruptions.

Third, reduce stress on piping connections. Piping design should ensure that actual forces and mor specified. Steam supply piping should be sloped for condensate to drain to the deaerator.

Fourth, oxygen scavenger should be added in the downcomer between the heater and the storage v

**Operation**

Before operators are assigned to any power plant system, they must understand the intended opera is as true for the deaerator as it is for any other part of the power plant. The deaerator should alway by the system designer.

Under normal operating conditions, the deaerator heats water as expected and removes oxygen to concentration. In the past, because they have worked so well, deaerators have received little attent removal was less efficient than required, the quantity of oxygen scavenger was simply increased to temperature fluctuations have been considered as normal operating conditions. With the incre system design, a corresponding attention to improved operation must follow. The operator should monitor all operating data. When any condition fluctuates beyond acceptable limits, especially ten causes should be found and corrected. Even though abnormal operation of the deaerator may not r immediate danger as a low drum level or a safety valve blowing the long-term effect, if not correc catastrophic.

Some abnormal conditions that should be avoided through close operator attention include (a) rest especially with cold feedwater, (b) operation above maximum capacity, (c) operation below minin operating with blended water temperature too high, (e) any significant pressure or temperature flux and (g) high oxygen in the boiler feedwater from the deaerator.

**Conclusion**

Deaerator cracking has been found to be widespread, and it has the potential for causing catastropl can be controlled, however, by periodic inspection and repair of operating units. Good engineering specification and design of new deaerators and in the systems in which they operate can eliminate
could cause cracks to begin and grow. Proper operation of the deaerator is a continuing requirement for failure.

---

Copyright © 1987 Tappi Journal. Reprinted with permission from Tappi Journal, July 1987, pp. 4-5. The text has been edited for clarity and space requirements.

*R.J. Beckwith, project engineer, Great Lakes Water Inc., Wales, WI; J.Q. Sawtell, senior power specialist, Schuchart & Assoc., Portland, OR; H.A. Stokes, power staff engineer, CRS Sirrine, Greenville, SC; S. Yorgiadis, partner, Sheppard T. Powell Assoc., Baltimore, MD.

The law of the jurisdiction where the vessel is located may require more frequent inspections.

The repairs should be completed according to the requirements of the National Board Inspection Code, Chapter III Repairs and Alteration. To assure the total integrity, an organization holding a National Board Authorization and the "R" symbol stamp should be used.

For clarification, the ASME Code, Section VIII, Division 1 did address a condition of "partial radiography" and now Section VIII, Division 1 addresses only spot or full radiography.

Editor's note: The following article is reprinted from the April 1988 National Board Inspectors' Classic Series-S 92 System Design Bulletin. Some ASME Boiler and Pressure Vessel Code requirements may have changed due to advances in material technology and/or actual experience. The reader is cautioned to refer to the latest edition and addenda of the ASME Boiler and Pressure Vessel Code for current requirements.

You can request your favorite "classic" BULLETIN article or General Meeting presentation by sending an email with subject information to ContactUs@nationalboard.org. For more information, please contact us.