Prior to about 1983, deaerator (DAs) vessels were considered low-risk equipment and were inspected and tested infrequently. The first reported DA failure was in Germany during 1971, and three more failures occurred in North America during 1983, including a catastrophic explosion of a deaerator at a pulp and paper mill in Pine Hill, Alabama (Figure 1). Since that time, an important damage mechanism in deaerators has been recognized as corrosion fatigue cracking. The following provides a brief overview and history of corrosion fatigue damage in deaerators, and attempts to answer new questions about the damage mechanism. While corrosion fatigue is probably the most important and insidious problem with DAs, other damage mechanisms, such as flow-accelerated corrosion (FAC), have been increasingly recognized as significant risks and costly problems. Other deaerator damage mechanisms will be covered in a future Conduit article.

The DA cracking problem was first addressed during the 1980s, when a NACE task group was formed to conduct an organized, in-depth study into the cause of the high incidence of cracking. The task group’s products in succeeding years included many technical papers, and culminated in the development of NACE Standard RP0590, “Recommended Practice for Prevention, Detection and Corrosion of Deaerator Cracking.” Since the NACE Standard was first published in 1990, it has been revised three times, and today remains one of the most important resources on deaerator vessel design and fabrication practice, as well as inspections that are needed to ensure the safe operation of the equipment.

Corrosion fatigue is defined as a cracking mechanism in a material under the joint action of corrosion and cyclic tensile stresses (Figure 2). The mechanism should not be confused with stress corrosion cracking, wherein cracking of materials can occur in a susceptible corrosion environment under static tensile stresses. Cyclic stresses in corrosion fatigue are usually from the operation or service of the equipment. The presence of a residual stress, such as residual tensile stress from welding, further increases the susceptibility to cracking by this mechanism. The corrosion factor in this damage mechanism can vary from only slight corrosion (essentially no material loss), to very severe, where material thinning also contributes to increased stresses. Because corrosion is a factor, the corrosion fatigue cracking mechanism usually takes a long time to manifest to failure.

Figure 1. Photograph shows an example of the catastrophic damage that can occur with Corrosion Fatigue.

(Continued on page 2)
When looking back on the problem of DA corrosion fatigue, an important question arises: if deaerators have been in use since the 1920s, why did it take until the 1980s for the cracking problem to be recognized? The answer is probably that in the early years, DA vessels were of riveted construction, and were of robust design – plenty of thickness, ample design factor and corrosion allowance. Thus, stresses were relatively low.

Secondly, welded DA vessels began to replace riveted construction largely in the 1940s and 1950s. Significant advances in welding methods, quality control and means of nondestructive testing also occurred during this period, and in 1951 the ASME design safety factor for pressure vessels was decreased from 5.0 to 4.0. It appears that most of these earlier welded vessels, leading into the 1960s, continued to be of robust design, because both material and labor were relatively cheap in the early periods. However, during the industrial expansion of the 1960s and 1970s, with ever-increasing demand for more electrical power, the cost of equipment became more significant, and designers and fabricators of DA vessels were forced to conserve on material and labor. Vessels produced during this later period were likely of lower fabrication quality, with lower minimum wall thickness. Further, the low design thickness of deaerator vessels did not require post-weld heat treatment (PWHT) under ASME design rules. The consequence of “lean” engineering and fabrication practice during the 1960s and 1970s was that vessels were more susceptible to corrosion fatigue than ever before, and by the mid-1980s, up to 50% of deaerators inspected were found to be cracked.

Since the introduction and implementation of the NACE practices twenty-five years ago, the incidence of deaerator cracking appears to be significantly decreased. Additionally, the importance of modifying certain in-service operation practices to reduce operation stresses was recognized, such as minimizing water/steam hammer, and cyclic fluctuations. Thus, better operation helped to reduce the incidence of cracking. A final caution: though the incidence of cracking is lower today, the adverse consequences of a vessel failure are very high – the possibility of injury and loss of life and loss due to downtime – the periodic nondestructive testing and inspection of in-service DA vessels remains a critical practice.

A newer challenge today is to reduce problems of DA vessel thinning due to the FAC damage mechanism. This problem occurs due to high velocity flows of liquid and mixed-liquid/gas phases during deaerator operation. The occurrence of FAC affects only carbon steel material and is largely a problem associated with design. Yet, the use of carbon steel with only small amounts of chromium will vastly decrease susceptibility of FAC. The subject of FAC of deaerators will be covered in a future Conduit article.

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By: Oscar Quintero  
Senior Engineer

With oil and gas exploration activities increasing every year, the need for companies to build facilities to store, transport, refine, and distribute oil and gas in various countries has steadily increased over the last few years. Countries, such as Mexico, have opened up their exploration and refining activities which will only increase the need to build even more facilities. As the need for companies to outsource component manufacturing to several countries across the globe increases due to increasing demand (while keeping production costs low), quality issues can arise when a quality program is not implemented at the manufacturing facility.

Many countries, such as Mexico, Russia, Turkey, Argentina, among others, have different regulations for oil and gas exploration and facility construction. For the purpose of this article, only Mexican regulations will be considered. Some of Mexico’s governing specifications are very similar to API and ASME. In most cases, they have a set of stricter guidelines than API and ASME.

Such is the case for the weld repair section in ball and gate valves. NRF 211 is the specification related to gate and ball valves used in transportation lines of hydrocarbons. NRF-211 Section 8.3.4 states:

“The repair of defects must be documented in a procedure which specifies heat treatment, non-destructive testing and its corresponding report. The weld repairs from the manufacturer must be limited to 30% of the length of the weld for partial penetration welds and 20% of the length of the weld of full penetration welds. The heat treatment of the weld repairs must be performed according to the corresponding material specification. Weld repairs in forged materials and plates must be performed by agreement. The weld repairs in castings must be performed according to the corresponding material specification.”

On the other hand, ASME B16.34 “Valves – Flanged, Threaded, and Welding End”, does not provide any requirements for weld repairs or non-destructive examination unless a special class valve is used (Section 8). Special class valves require a non-destructive examination on the cast, forged, rolled, wrought or fabricated material, and if a weld repair is performed. Such weld repairs are governed by the ASME Boiler and Pressure Vessel Code Section VIII, Division 1.

NRF-211 requires that the weld repairs must be documented during the fabrication process along with any non-destructive testing performed and any post-weld heat treatment that was done when repairing defects. If the weld repairs were not documented, or if any of the documentation is missing, the certifying and validating units that review the documentation related to the facility may not pass the valves for service. This is where the macro-etch technique comes into play. The macro-etching technique can be used in two different ways:

- Without grinding
- With grinding (recommended)

Preparing the surface by grinding will yield better results. When conducting a visual inspection of a valve, look for suspect areas of weld repair such as pores, uneven surfaces, grinding marks, and different surface colors and texture (Figure 1).

After identifying the suspect area, prepare the surface by grinding up to 300 grit. Some might refer to this technique as a “non-destructive technique”, but technically, it IS a destructive technique. As some material is removed, although small. If the technique is done by an experienced operator, you will produce good results by removing less than 5 mils off of your sample area. The results are only as good as the surface preparation. An improperly prepared surface will still yield results, but if artifacts are introduced during surface preparation, such

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artifacts might prevent a proper assessment and could even yield to misinterpreted results.

If the surface was prepared for macro-etch testing, you can also perform remote metallography (other trade names: in-place metallography, in situ metallography or remote replication) to assess the condition of the weld repair or metal component. Whether it is used to evaluate the metal due to high temperature exposure or evaluate a weld repair, it allows an examination of the component without it being removed.

You can also evaluate the microstructure by using an acetate tape to make a replica, then evaluating the replica by using a portable microscope.

Hardness testing can also be performed on the prepared area using a portable hardness tester. This can aid in determining if a proper heat treatment was done after a weld repair.

Macro-etch testing and remote metallography can assist you in identifying if a valve was weld repaired and assess the condition of the weld repair. A valve can be weld repaired properly and be fit for service, but if the documentation supporting the weld repair and its subsequent non-destructive testing reports are incomplete or missing, the regulations in some countries might consider this a nonconforming valve and will not accept it, even if it is deemed fully functional by any of the US codes that might be applicable, such as ASME B16.34.

Figure 1. Photographs shows features such as pores, uneven surfaces, grinding marks, different surface colors and textures which can be considered suspect areas. Notice weld repair after etching (bottom image).
Preventing Failures in Steam Generating Equipment

M&M Engineering Associates, Inc. presents their 4th Annual (Fall Edition)

September 15-16, 2015
Leander, Texas
(see next page for details)

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- Water Touched Boiler Tube Damage Mechanisms
- Steam Touched Boiler Tube Failure Mechanisms
- Introduction to Nondestructive Testing & Inspection Contracting
- High Energy Piping: Damage Mechanisms and Corrections

Day 2

- Introduction to Failure Analysis
- Failure Investigation Principles for Combustion Turbines
- Basic Steam Turbine Failures
- Condenser and Cooling Water Failures
- Damage Mechanisms in Deaerators
- Water and Steam Chemistry-Influenced Failures in the Steam Cycle
- Discussion and Wrap Up

* (sessions are subject to change)

The registration fee for this two day event is $750 (continental breakfast and lunch are included). The registration deadline is August 14, 2015. For details, and to register online, visit:


Or contact Lalena Kelly by phone or email for further information:
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