



The Babcock & Wilcox Company

20 South Van Buren Avenue | P.O. Box 351 | Barberton, OH 44203-0351 | USA
+1 330.753.4511 | Fax +1 330.860.1886

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PSB-59 Clarification and Discussion

The following provides additional technical background regarding PSB-59, which was recently mailed to you in hard copy form. PSB-59 was publicly available on B&W's website prior to the mailing of the hard copy that you received. You received the hard copy as part of a B&W initiative investigating alternative methods of communicating and distributing plant service bulletins. However, due to the passage of time between the date the bulletin was posted on the website and the date of the mailing, B&W recognizes that this is not likely to be received as new information. We will continue to review improved methods to communicate and distribute plant service bulletins in the future, and apologize for any confusion that this may have caused.

During the late 1960s through the mid-1970s the boiler industry experienced failures in cold bent carbon steel riser and supply piping. The failures occurred in material that had been ordered hot finished, bent at a ratio less than 4:1, and put into service without further heat treatment or inspection. The failures caused alarm through the industry and led to determination of the root cause, which was creep-crack-growth in the strengthened carbon steel bends due to cold work and strain aging.

By 1972, B&W had revised its internal design standards for all carbon steel and carbon-molybdenum steel tubes with outside diameters greater than 3.5", which would be used for supplies, risers, and interconnecting piping. These revisions included the requirement that all material used for these applications be normalized rather than subcritically annealed or stress relieved, which was more stringent than the ASME code requirements. Bend ratios were limited to 4:1 or greater without heat treatment and a post bend heat treatment was required for bend ratios between 4:1 and 3:1. These standards are still in effect today.

Upon the request of Electric Power Research Institute (EPRI) members for better predictive guidance to prioritize component inspection and examinations for graphitization due to aging plants, EPRI undertook a literature review/research project. In light of field experience, members were questioning the validity of the predictive curves generated in 1993. Ultimately, EPRI published report 1019783, Graphitization in Carbon and Carbon-Molybdenum Steels, in December 2010. While the report provided fairly accurate predictions of expected life for

carbon steel materials, the data on carbon-moly failures has been limited and prediction curves for this grade could not be developed. The EPRI report offered recommendations on prioritizing inspections and sampling for plants containing carbon and carbon-molybdenum steels.

In February 2011, a plant built in the late 1960s experienced a failure in a SA-335 P1 primary superheater inlet pipe.[1] The pipe did not leak before it failed, and caused considerable interest throughout the boiler industry. The investigation was led by Structural Integrity Associates (SIA) and an Industry Notice, dated 09/2011, was issued at the conclusion of the investigation. The Industry Notice stated that the failure occurred after approximately 275,000 hours of operation and the analysis indicated the root cause was a unique form of graphitization found along the grain boundaries. No details of the bend radius, fabrication heat treatment, or manufacturer were included in the notice.

PSB-59 is based upon the findings published in the 2010 EPRI report (1019783) and the 2011 Industry Notice from SIA discussed above. It was intended to be received by plant personnel already familiar with the results and recommendations of both reports.

After the industry notifications and the development of PSB-59, further information had become available regarding the 2011 failure of the SA-335 P1 pipe. During a presentation to the National Board of Boiler and Pressure Vessel Inspectors in 2013 more details were provided. The SA-335 P1 pipe had an outside diameter of 6.25", wall thickness of 0.935" and was designed for 830F. The unit had also experienced previous non catastrophic failures on this and similar components since 1982. After determination of the root cause, the plant performed an extensive sampling plan on all SA-335 P1 in service at the first unit, a sister unit, and remaining coal-fired units for another owner. The result of the sampling found that grain boundary graphitization was confined to formed bends that did not appear to have been thermally treated after forming [1], which implies cold bending was used.

An exhaustive unit by unit analysis is not available, however, as an aid to PSB-59, within B&W designed units, carbon-molybdenum steels have been used in risers, supplies, and interconnecting piping. As previously stated, B&W has enforced specific bend ratios and heat treatment requirements on these components since 1972 based upon industry experience. These practices decrease the nucleation rate of graphite and slow its growth.

Other applications where carbon-molybdenum steel is used in utility boilers supplied by B&W include:

1. Steam cooled convection pass enclosure
2. Economizer stringer tubes
3. Primary superheater inlet banks
4. Reheater inlet banks.

The convection pass enclosures are normally smaller diameter tubing that is assembled in membrane wall panels with limited use of tight radius bends. Stringer tubes are used to support the horizontal convection pass banks of superheater surface. Normally these tubes will operate at temperatures well below where graphitization occurs.

Superheater and reheater tubes that are bent to radii less than 1.5:1 are heat treated after bending to reduce the stress created from the bending process.

Economizer, Primary and Reheater banks are typically within the boiler enclosure.

In industrial boilers supplied by B&W, which typically operate at pressures below 1850 psi and at lower temperatures, the use of carbon molybdenum material would be limited to superheater sections.

So, while the focus of the industry has shifted since the final information on the initial failure became available, owners and operators are still advised to review the EPRI and SIA recommendations for sampling and evaluation. Graphitization is a time-dependent aging phenomenon that continues to be an area of focus as the average age of the current utility boiler fleet increases with the continued operation of boilers that are 40-50 years old. B&W can assist in evaluating the specific boiler details and determining areas to target for further investigation.

Reference

1. Galanes, George W. (2013, August 29). Recent Catastrophic Failures of High Temperature/High Pressure Power Boiler Components. [NationalBoard News]. Retrieved from <http://www.nationalboard.org/NationaBoardNews.aspx?NewsPageID=518>.

Background

Babcock & Wilcox (B&W) received an Industry Notice from Structural Integrity Associates regarding a finding it made in a recent failure analysis, dealing with carbon-molybdenum steel. This Industry Notice is located on Structural Integrity's website. [Reference 1]

B&W has not used carbon-molybdenum steel for a number of years, but has previously used this alloy in tube and pipe applications, in saturated steam connections, and in other steam-containing applications. The grades of steel covered in this Industry Notice are SA209-T1, T1a, and T1b tubing, and SA335 Grade P1 piping.

Problem

The Electric Power Research Institute (EPRI) and others have studied the graphitization of carbon and carbon-molybdenum steels for many years. Drawing on studies which have spanned more than 50 years, EPRI released the findings of a study in September 2011 that graphitization occurs in carbon and carbon-molybdenum base metal, welds and

weld heat-affected zones. The study concluded that carbon steel weld regions may be considered at risk of graphitization and failure where they have been in service approximately 10 years or more at 850F (454C), and at temperatures as low as 750F (399C) with longer service time.

The EPRI study reports that data on carbon-molybdenum steel is lacking to allow for quantitative predictions of life for that alloy. However, the report indicates that, as a preliminary guide, both welds and base metal may be subject to graphitization with a service life of approximately 10 years at 850F (454C), and at temperatures as low as 800F (427C) with longer service life, similar to carbon steels.

The failed pipe in Structural Integrity Associate's root cause analysis showed a form of graphitization in which patches of graphite formed within grain boundaries of a preferential orientation which then linked together to form areas of weakness along aligned grain boundaries. The result was a significant loss of material toughness and ductility compared to that which would be expected for the type of material.

Action Required

The conditions described in the Structural Integrity Associates Industry Notice and the EPRI report could expose plant personnel to sudden and catastrophic boiler failures, **RESULTING IN PERSONAL INJURY AND DEATH**. While reliable nondestructive evaluation (NDE) methods are not yet available, B&W recommends that owners and operators of steam generation plants give the graphitization problem described in the Industry Notice their immediate attention and undertake the actions recommended. B&W also recommends that, until reliable NDE methods are developed, plant owners and operators should begin removing samples of the carbon-molybdenum materials SA209 and SA335 P1 at each outage. The samples should be removed, preferably at bends and weldments, starting with those materials largest in diameter, longest in service, and operating at the highest temperatures.

B&W Support

Contact B&W Field Engineering Services through your local district office for assistance in your investigation and to answer any questions.

Reference

1. "Industry Notice – Graphitization," Structural Integrity Associates, Inc., <http://www.structint.com>, September 2011.

Babcock & Wilcox
20 S. Van Buren Avenue
Barberton, Ohio 44203 USA
Phone: 330.753.4511
Fax: 330.860.1886

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