

Case Study – Suspected SAC in Recovery Boiler Screen Tubes Revealed a Manufacturing Defect

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ABSTRACT

A longitudinal crack in the swaged section of a screen tube was discovered in the black liquor recovery boiler at a paper mill. An adjacent tube to the failure contained an “indication” of a crack when X-rayed. The mill originally suspected stress assisted corrosion (SAC). These tubes were examined in the lab, and neither appeared to be damaged due to operation. Further investigation determined that the failure originated from a manufacturing flaw at the external tube surface in the swaged section. The examination indicated that the condition was likely isolated and not indicative of the general condition of other tubes with similar service.

The mill planned to remove all of the screen elevation swaged tubes from the boiler during the next outage. These tubes were examined using phased array ultrasonic testing (PAUT) for SAC and no indications were detected. As a follow up, two additional tubes from the inspection were also metallurgically examined and there was no evidence of the manufacturing defect. This was confirmed to be an isolated incident.

Key words: black liquor recovery boiler, swage, screen tube, phased array ultrasonic inspection, manufacturing defect, stress assisted corrosion, corrosion fatigue.

INTRODUCTION

Stress assisted corrosion (SAC) is a common damage mechanism in black liquor recovery boilers. In 2004, it was reported to affect up to 50% of recovery boilers.¹ This mechanism is taken seriously because a leak can allow water to enter into the furnace and react with the molten smelt that can lead to an explosion.² SAC is sometimes considered a specialized case of corrosion fatigue (CF), and the two mechanisms are similar. SAC and CF are typically long-term, slow growing cracking mechanisms that require multiple start/stop cycles to propagate to failure, typically brought on after years and years of operation. It is commonly found in areas with residual stresses such as weld attachments (e.g., buckstays and D-rings), elbows along the extrados, rolled tube ends, and bends. The residual stresses along with water chemistry upsets help initiate corrosion and subsequent cracking. More specifically, the differences in stress levels creates a galvanic cell, where the higher stress area is anodic to the surrounding metal, meaning the stressed area preferentially corrodes.³

Carbon steel tubes depend on a protective magnetite (iron oxide) layer to prevent corrosion from occurring. When this film is disrupted, whether chemically or mechanically, it can allow initiation of cracks or pits.⁴ The initiating pits are sometimes the result of a hydrochloric acid chemical cleaning that was not fully rinsed. Once the cracks are of sufficient size, startups and shutdown of the boiler can continue to propagate the cracks via standard corrosion fatigue. The primary drivers of SAC are pH and oxygen levels.

Cracking is typically bulbous, necklaced, longitudinal, and straight through the tube wall. There are often multiple, deep pits present on the internal surface as well that are characteristic initiation points for CF or SAC. Figure 1 shows some pictures of typical SAC damage in boiler tubes. If CF or SAC is present in a tube, it is likely to be present in other similar tubes. Determination of CF or SAC warrants additional inspection to assess the extent of damage and determine if larger scale tube replacements are necessary.

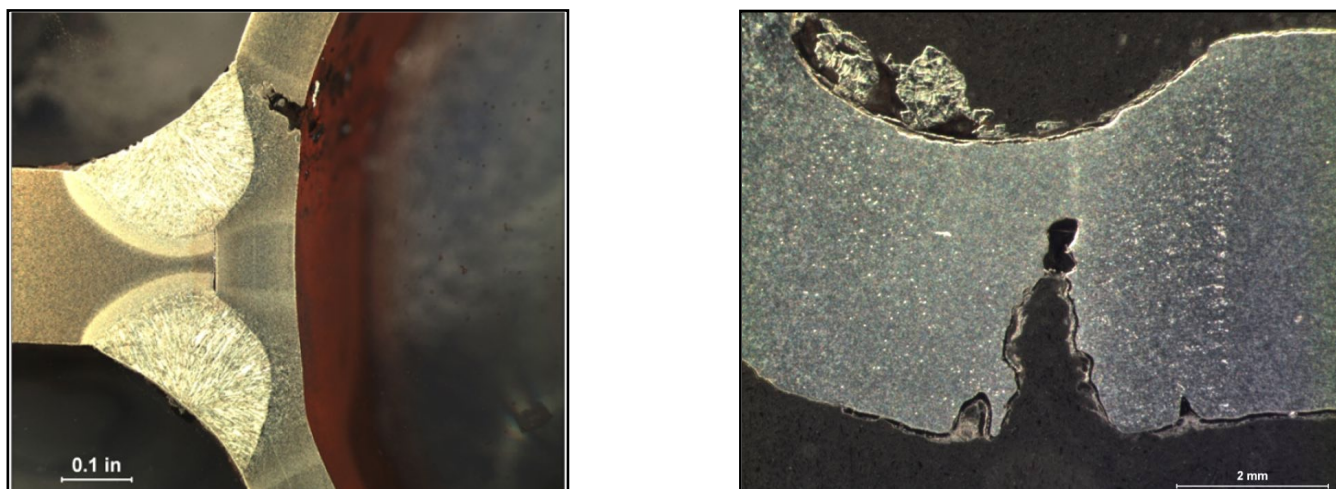


Figure 1: Typical SAC in boiler tubes.

In this paper, a case study will be discussed regarding a paper mill that suspected SAC damage in the screen tubes for one of the recovery boilers. The recovery boiler was placed in service in 1987 (32 years old at the time of failure) and is run continuously. It operates at a pressure of about 1350 psig and a temperature of approximately 580°F. The screen tubes were original to the boiler and specified as SA-210 Grade A-1, seamless, medium carbon steel. The tubes were swaged from 2-1/2 inches to 2 inches in diameter in the area of the failure. They operate in a flue gas environment at a temperature range of 900 - 1200°F.

FIRST LAB EXAMINATION

After one of the mill's spring outages, two rear wall screen tubes were received from the boiler for analysis (Figure 2). One tube contained a visible longitudinal crack in the swaged section on the cold side (Tube 129), and the other tube contained a crack-like indication in the same area when X-rayed (Tube 126). A metallurgical examination was performed on the tubes to determine the failure mechanism(s).

Visual Examination

The crack was straight, non-branching, through-wall over most of its length, and extended from the butt weld at the small diameter end to the swaged transition on the larger diameter end of the tube (Figure 3). No cracking was observed in the swaged area of Tube 126, and the only anomaly observed was a discolored area on the hot side of the swaged area (Figure 4). Tube 126 was split open and cleaned, revealing a defect in the internal tube surface. No internal or external corrosion was noted.

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Figure 2: Screen tubes received for analysis. Bracket indicates crack location.

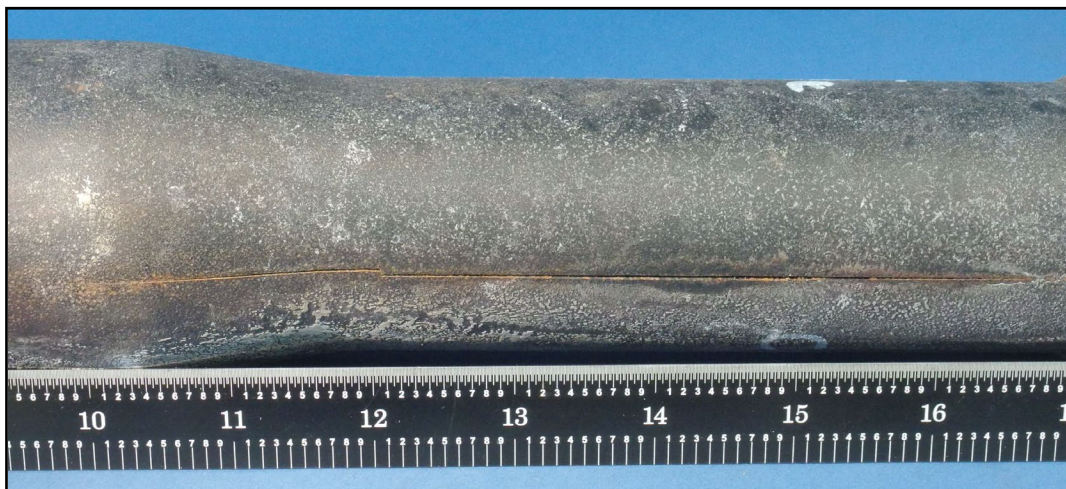


Figure 3: Closer view of the crack in Tube 129.

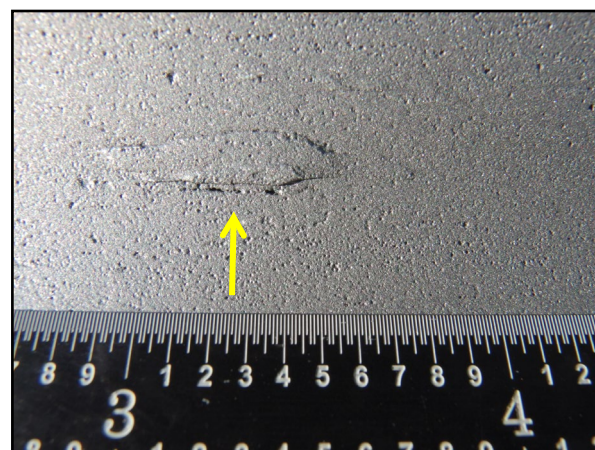
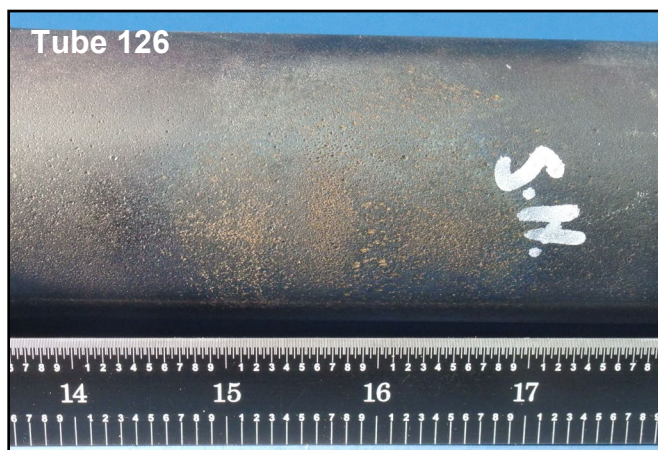


Figure 4: Swaged Area of Tube 126 where an X-ray indication was noted (left – external surface, right – internal cleaned surface).