

Cracked High Pressure Steam Superheater Alloy 800 Piping of A Thermal Oxidizer from a Gas Plant SRU

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ABSTRACT

A failure was reported in an alloy 800 (UNS N08800) high pressure steam superheater piping downstream of a thermal oxidizer in a Sulfur Recovery Unit of a Gas Plant. Unexpected cracking on the circumference was observed. No evidence of corrosion was found on the piping. A metallurgical failure analysis investigation established that the piping had failed due to intergranular environmental stress corrosion cracking (IGSCC), specifically Caustic Stress Corrosion Cracking (CSCC) cracking. The cracks most probably originated as a result of unexpected wet conditions and caustic carryover. It was recommended to review the water treatment program, prevent water condensation and inspect the rest of the piping for similar cracks.

Keywords: Caustic Stress Corrosion Cracking, Alloy UNS N08800, Alloy 800, HP Steam Superheater, Thermal oxidizer, SRU

INTRODUCTION

Caustic soda (sodium hydroxide) is one of the most widely used inorganic chemicals in water treatment process. Improper injection rate or concentration have led to many failures in the industry. These failures have been mostly identified as Caustic Stress Corrosion Cracking (CSCC).

Caustic Stress Corrosion Cracking (CSCC) is a form of Environment Assisted Cracking (EAC), characterized by surface-initiated cracks that occur in materials exposed to caustic environment. EAC is defined as a cracking process caused by the synergistic effects of stress, and environment on a specific material. All three factors—stress, aggressive environment, and susceptible material are necessary for EAC. The environment aggressiveness escalates with increase of caustic concentration and metal temperature, in case of CSCC.

This damage mechanism can affect many materials including carbon steel, low alloy steel, series 300 stainless steel, and Nickel base alloys. However, Nickel base alloy are recommended for high temperature services starting at 230°F (110°C), where caustic contamination is possible. Under microstructural examination, this cracking mechanism was predominantly observed as intergranular cracking.⁽¹⁻⁴⁾

Previously, Alloy 800 (UNS N08800) was tested in steam environment containing caustic soda and chlorides. The wet/dry steam environment experiment with caustic soda was carried out for 18 weeks and no cracking was reported.⁽⁵⁾ Furthermore, the chloride environment carried out for 36 weeks and no cracking was reported for the non-welded specimens.⁽⁵⁾ Another test, also in a chloride environment was performed on welded specimens which cracked intergranularly in the heat-affected zone (large-grained) after 6-13 weeks. The cracked specimens were not annealed after welding.⁽⁵⁾ However, the annealed specimens did not fail after 13 weeks.⁽⁵⁾ In susceptible corrosion resistance alloys, damage at grain-boundary can occur due to sensitized conditions.

It has been reported that Alloy 800 is susceptible to CSCC at 610°F (321°C) in sodium hydroxide concentration ($\leq 10\%$ NaOH) and 500°F (260°C) in 20% NaOH.⁽⁶⁾ Increasing caustic concentration for water treatment and/or pH control increases the probability and severity of cracking in addition as temperature increases the probability and severity of cracking rises. Moreover, various reports have indicated failures of Alloy 800 in nuclear power generation industry due to CSCC in steam system.⁽⁷⁾

BACKGROUND

In a sulfur recovery unit, a leak was observed downstream of the High Pressure (HP) Steam Superheater 8 inch horizontal piping during operation. A crack was observed from 11 O'clock to 1 O'clock position. A temporary clamp was installed for eleven (11) months. Then, the clamp was removed and the pipe was sent for failure analysis. The pipe was in-service for six (6) years. Design specifications and operating conditions of the pipe is provided in Table 1.

Table 1
Design Specifications and Operating Conditions

Material of fabrication	Alloy 800 (UNS N08800)
Size (Dia./Thickness)	8 inch Sch. 40
Service environment	High pressure-temperature steam
Length of service	6 Years
Design temperature	1050°F (566°C)
Operating temperature	595-650°F (313-343°C)
Design pressure	725 psig (5,000 KPa)
Operating pressure	625-635 psig (4,309-4,380 KPa)

This HP Steam Superheater is fed saturated steam through an 8 inch pipe. Downstream of the heater,

the superheated steam exits through an 8 inch pipe which connects to a 2 inch un-insulated pipe. The other end of this 2 inch pipe is the saturated steam that fed to furnace. This 2 inch line is connected to pressure differential pressure transmitter. The failure of the 8 inch downstream piping is located just after the 2 inch pressure balance line as shown in Figure 1. Different chemicals were injected into the system at earlier stage before reaching the HP Steam Superheater such caustic soda, neutralizing amines, oxygen scavenger and anti-scalant.

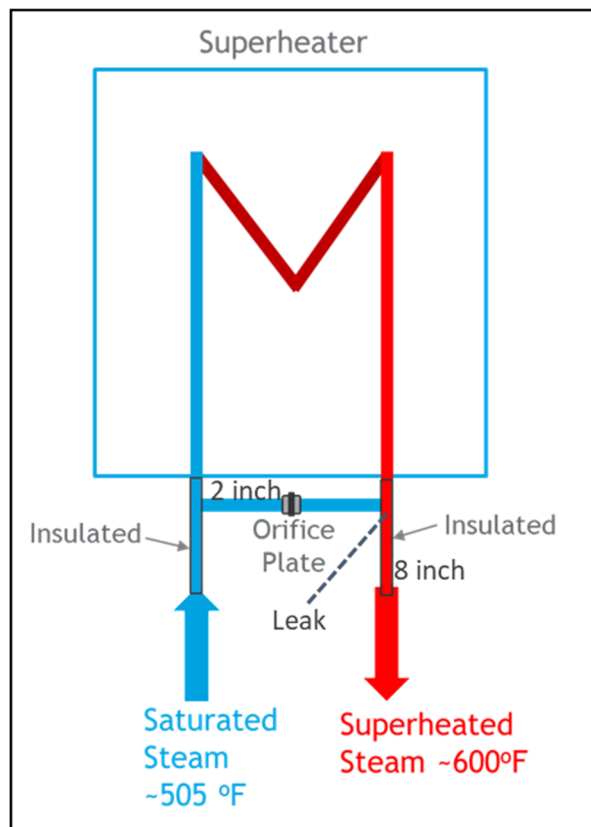


Figure 1: HP Steam Superheater diagram.

FAILURE ANALYSIS PROCEDURE

The failed pipe segment was subjected to metallurgical examination. This included different tests classified as visual, microstructural, mechanical and chemical analyses.

Visual Examination

Figures 2 and 3 show photographs of the as-received cracked pipe. The pipe was visually examined externally. There was no evidence of corrosion found on the pipe external surface. Close examination revealed nearly the entire circumference was cracked from 7 O'clock to 5 O'clock position as shown in Figure 2. The crack grown with time. Also, the pipe was found to be longitudinally welded.

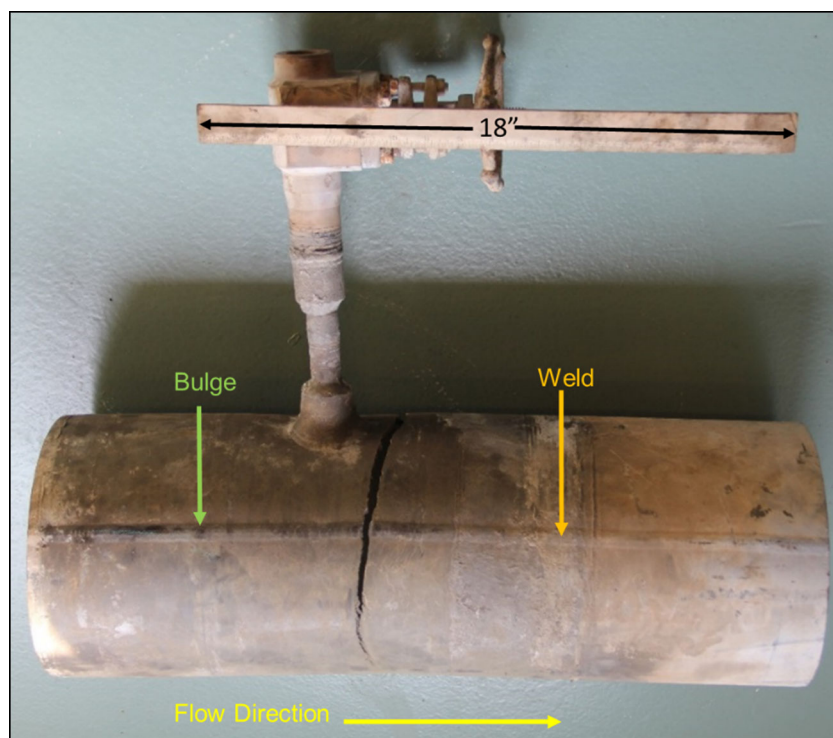


Figure 2: A general, as-received photograph of the failed pipe.



Figure 3: Close-up image of the crack.

Slight bulging to the inside was observed as shown in Figure 4. This bulge appears to be at the end of the clamp location. The sample shown in Figure 5 was cut at the crack end near the 7 o'clock position when viewing in the direction of flow. Internal visual examination showed the internal surface exhibited interconnected cracks like mud-cracking or a spider web as shown in Figure 5. Moreover, no metal loss was observed on the internal surface.