

Evaluation of Corrosion Pitting in a 317L Stainless Steel Surface Condenser Tube Bundle

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ABSTRACT

Despite more than 15 years of operational reliability, a 317L (UNS S31703) stainless steel steam surface condenser at a power plant in the Northeastern United States was revealed to have a significant waterside pitting corrosion problem. The pitting was identified during Eddy Current testing and verified by removing sample tubes. The severe pitting in the tubes was primarily focused at the seam weld region. Possible causative factors for the pitting attack were identified. Metallography and electrochemical testing confirmed non-optimal corrosion resistance along the original laser seam welds, as compared to the base metal. Modifications to the cooling water chemistry were instigated to reduce the severity of the pitting attack in an effort to extend the service life of the condenser bundle. Re-tubing options with alternative stainless steel alloys are also discussed.

Key words: Pitting, Seam Weld Corrosion, Steam Condenser, 317L (UNS S31703), Stainless Steel, Cooling Water

INTRODUCTION

The power plant is a natural gas-fired, combined cycle plant with three combustion turbines and a single steam turbine. A large stainless steel surface condenser is used to condense steam off of the turbine, and provide high purity steam condensate return to the boiler system. The steam condenser was put into service approximately 15 years ago. This plant takes makeup water for its open recirculating cooling tower water system from a river location that is inland from an ocean coastal area. When the plant was built, the tubing material selected for the main steam condenser was 317L (UNS S31703). This was likely done to assure additional corrosion resistance due to the expected higher chloride content of the cooling

water. The higher chloride content in the cooling water can develop during tidal incursion of seawater into the river, and/or drought or seasonal variation, which can impact the relative salinity of the make-up water to the cooling tower system.

This is a medium dispatch power generation plant, operating approximately 16 hours per day. The cooling water flow circulation and water treatment have been maintained at all times, even when the plant is not generating power. There has never been a report of a condenser leak, but it has been known for years that there is some pitting in the condenser tubes. However, the extent and location of the pitting damage were not thoroughly investigated until recently.

Description of Tubing

The condenser tubing is typical 1.000" x 0.028" (25.4 mm x 0.711 mm) ASTM A249 welded 317L (UNS S31703) material with 5604 tubes in the condenser. The alloy test results are listed in Table 1.

Table 1
Alloy analysis and corresponding PREN Value for the 317L (UNS S31703) tubing

Element	Sample (wt.%)	Min (wt.%)	Max (wt.%)
Carbon	0.03		
Manganese	1.66		
Silicon	0.42		
Phosphorus	0.35		
Sulfur	0.005		
Chromium	18.37	18	20
Nickel	13.48	11	15
Molybdenum	3.09	3	4
Nitrogen	0.06		
Iron	Balance	Rem	Rem
PREN	29.5	28.9	34

Note: PREN = % Cr + 3.3 (% Mo) + 16 (N)

The most recent Eddy Current testing of all the tubes was conducted in two phases, with tube samples removed following the first round of testing. By the end of two rounds of testing, the plant had plugged tubes due to severe pitting indications (greater than 80% penetration), that impacted a total of less than 5% of the total tubes in the condenser.

Tube Sample Evaluation

Tube samples received in the Laboratory were split longitudinally to allow visual inspection of the Internal Diameter (ID) surfaces. Pitting was clearly visible in or along the edges of the tube seam weld and along the seam weld Heat-Affected Zone (HAZ), Figures 1-3. Concentrated chlorides (2.3 wt.% Cl) were confirmed to be present in the pitted area, via Scanning Electron Microscope – Energy Dispersive X-ray Analysis (SEM-EDXA), see Table 2.

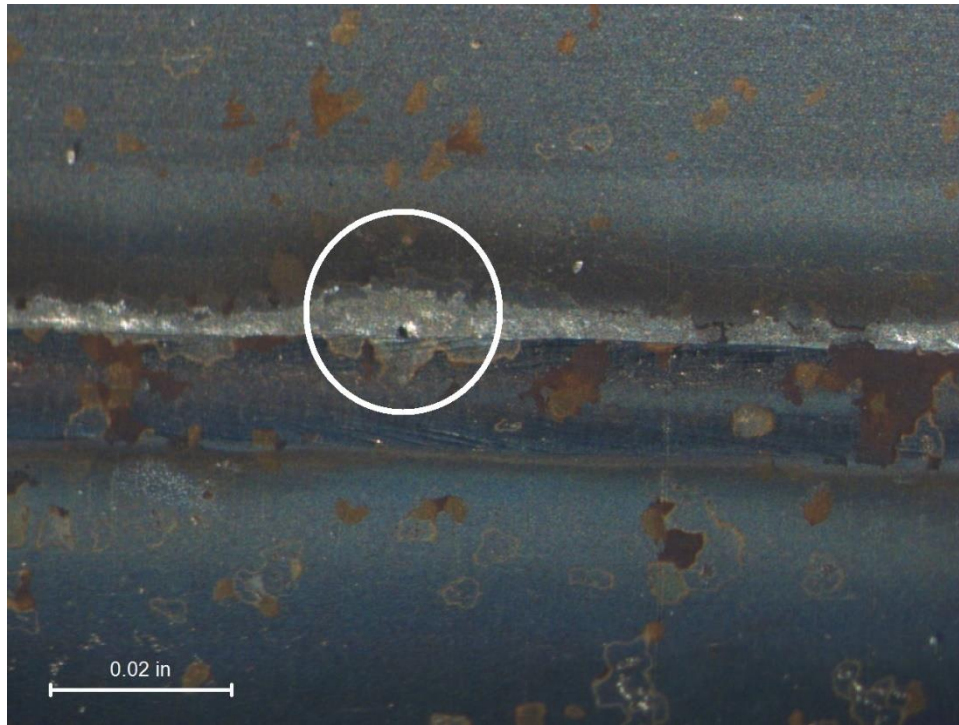


Figure 1: Macro photograph of the internal waterside surface of an as-received tube after splitting it open, in an area that showed pitting along the seam weld HAZ.



Figure 2: Macro view of visible pitting along the seam weld in an area without any significant deposit present. The location of the tube seam weld and the associated corrosion products (rust) are visible.

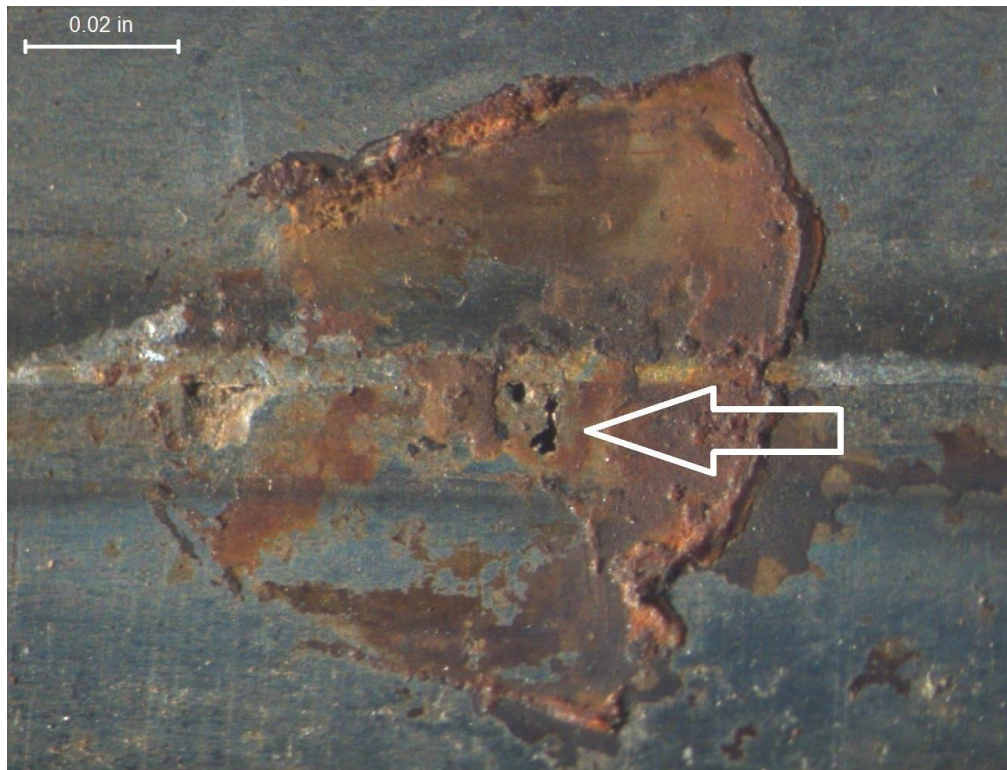


Figure 3: Close-up view of pitting (arrow) along the center and edges of the seam weld.

Table 2
SEM-EDXA analysis of the corrosion products in a pitted area

	Elements Present (%)													
Composition	Fe	Cr	Si	Al	Ca	P	Mn	Ni	Na	S	Cl	Mg	K	Ti
Weight Percent	38.1	15.6	7.6	7.3	6.2	5.7	4.5	4.3	2.7	2.3	2.3	2.2	1.1	0.2

A cross section photomicrograph (Figure 4) shows the growth of the pit into the tube wall along the edge of the weld microstructure. This cross-section photomicrograph also tells us several things about the tube manufacturing. The narrow and uniform width of the weld is indicative of this being a laser weld, as opposed to a Tungsten Inert Gas (TIG) weld. The striping in the weld is a result of segregation, and the weld was not subject to a thorough post-weld anneal.