

**I.P. FEEDWATER HEATER RESTORATION
DETROIT EDISON, ST CLAIR STATION
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**Nidal H. El-Takach
Detroit Edison
2000 2nd Ave, Detroit, MI 48226**

**Kevin Shugrue
CTI Industries
283 Indian River Rd, Orange, CT 06477**

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I.P. Feedwater Heater Restoration

Abstract

In August of 2006, Detroit Edison contacted CTI Industries of Orange, CT about the possibility of restoring failed tubes at St. Clair Station's, Unit 7, #5 IP Feedwater Heater. Stress Corrosion Cracking (SCC), throughout the desuperheating section of the 6+ year old YUBA heater, resulted not only in the loss of the #5 IP heater, but also forced the #6 HP heater to be taken out of service due to an isolation problem between the heat exchangers, and to also eliminate the damage caused by the hot drain from # 6 to 4 after a long isolation. With both IP and HP heaters in the Unit 7 train taken out of service for a long period of time, more than 100MW unit was derated from the heat loss penalty suffered. This then became a top priority to address.

Independent Eddy Current Testing indicated the SCC was confined to the desuperheating section of the heater, an area extending from the tubesheet to a depth of approximately 12 feet in. Testing revealed no damage indication at the inlet side of the FWH. With a new unit months away from delivery, sleeving all the outlet tube ends to a depth extending beyond the desuperheating section was the only possible alternative to restore the heat-rate.

Detroit Edison contacted CTI to discuss options. Detroit Edison elected to use Seamless-Alloy 800, to best combat the SCC. A decision was reached to size the inserts 13' long, which would extend beyond the target area by one foot. The inserts would be expanded hydraulically, full-length, then mechanically expanded at the first inch (tubesheet) and last inch (discharge end), to completely shield the problem area.

In weeks, not months CTI returned almost 900 tubes back to normal service, resulting in both heaters being back on-line, restoring the heat-rate to pre-failure levels. This is not a temporary band-aid fix, but rather a life extension restoration. By restoring the heater, engineering would have enough time to buy a new FWH to be installed during the coming periodic outage using TP 439 as tube material.

This paper will discuss the failure mechanism, examination, probable cause, and corrective measures to extend the service life of the heater.

Outline

Introduction

Feedwater heaters are expected to last between 25-30 years of service under normal operating conditions. The St Clair Power Plant is a supercritical, 500 MW, coal fired base load unit which was placed into service in 1969. The SSCP# 5 FWH is a fairly new heat exchanger with a full access channel design manufactured by Yuba. For years DTE Energy has been trying to eliminate the copper deposit on the turbines blades by retubing condensers and replacing original heaters that failed with SS instead of 90/10 copper-nickel or admiralty.

The # 5 FWH is a 3 zone, IP heater with a 12' long desuperheating zone designed and fabricated by Yuba. The inlet temperature is 723 F and operating pressure is 177 psia. Prior to May 2006, the # 5 FWH was operating with no tube leaks and no plugged tubes.

Description of performance/failure and Root Cause Analysis

The intermediate pressure (IP) FWH # 5 was put into service in 1999 with 304N Stainless Steel selected as the tube material of choice. The heater had its first tube failure on July 9, 2006 and had suffered several repetitious failures over a 10 day period before being removed from service after numerous attempts to restore the heater.

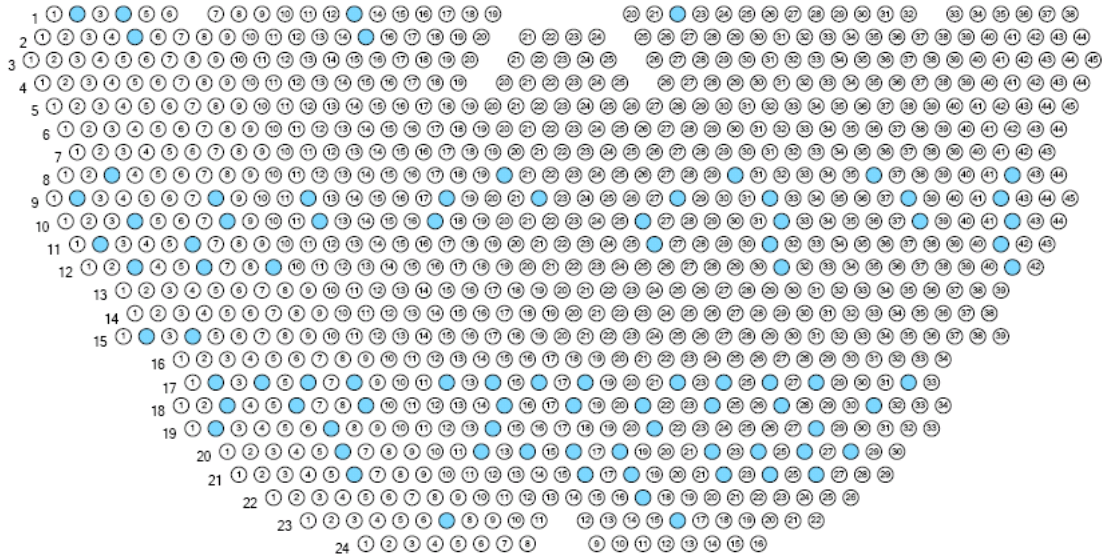
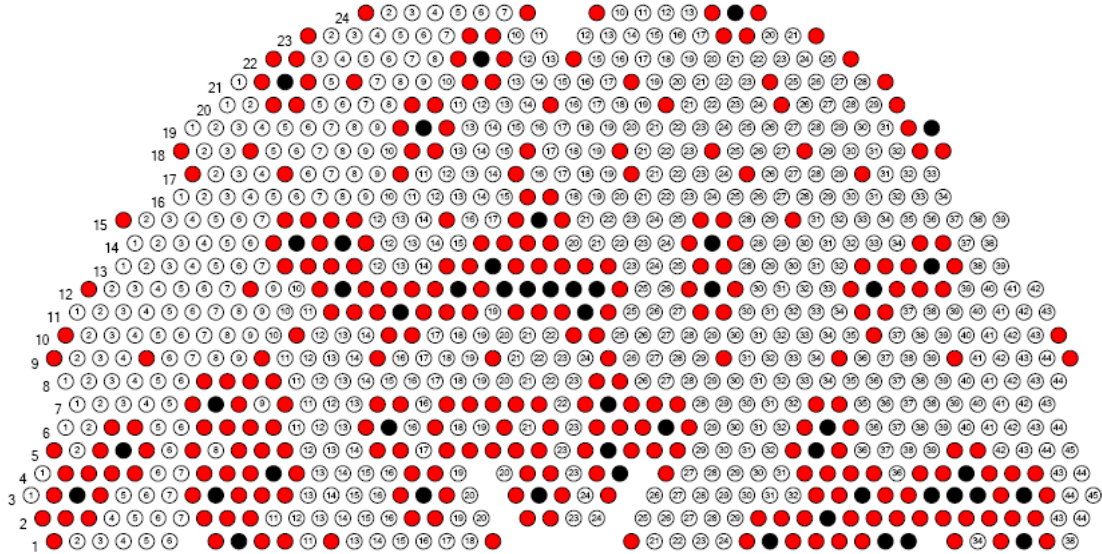
Metallurgical testing identified the FWH #5 failure mode as OD initiated, chloride induced, transgranular stress corrosion cracking. Cracks were independent of tube support locations and welds. An eddy current examination was performed on 20 percent of the tubes. All of the tubes tested had multiple indications throughout the desuperheating zone, all of which showed wall loss of 80 percent or greater indicating failures would occur under normal operating pressures.

This was confirmed as over 100 tubes were plugged within the 10 day period. Borescope pictures showed a through wall cracking that spread throughout the entire length of the desuperheating zone. Further eddy current testing was performed on 100% of the tubes, inlet and outlet tube ends. The more detailed exam revealed that all tubes at the inlet side had no sign of defect while the outlet side tube ends showed 80-100% wall loss on 278 tubes.

See Fig 1

Detroit Edison St. Clair Unit 7 LP FWH 5 Results

Top Section T



Bottom Section B

Database : St_Clair_U7_LP_FWH_5

Character	Extent	Total	% of Total	Character	Extent	Total	% of Total	Character	Extent	Total	% of Total
② Default Tube		1377	77.01	● DENT	0	0.00		Total number of tube locations		1788	
● 20% to 39% Wall Loss	0	0.00		● NDD	85	4.75					
● 40% to 59% Wall Loss	0	0.00		● OBSTRUCTED	0	0.00					
● 60% to 79% Wall Loss	0	0.00		● PLUG	48	2.68					
● 80% to 100% Wall Loss	278	15.55		▲ RESTRICTED	0	0.00					

Theoretical: Failure Mechanisms

A tube sample was then removed and sent to the metallurgical lab for analysis which it revealed that the failure mechanism is due to Stress Corrosion Cracking. Additional tube testing was also completed outside of the desuperheating zone. Initial results indicated no cracking in this region. The tubes were subjected to a boiling magnesium chloride test and were found to be highly susceptible to stress corrosion cracking. Deposits of chromium, copper, and zinc oxides were also found on the OD of the tubes, particularly in the desuperheating zone.

. (See fig 2&3)



Fig.2 (up-close)

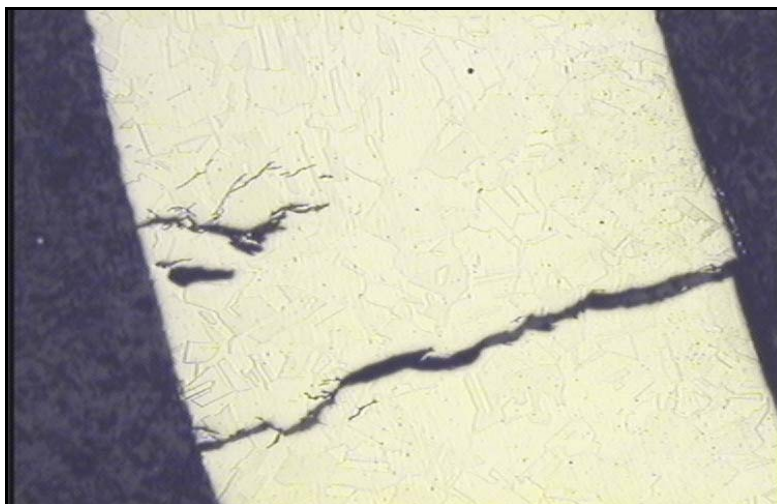


Fig 3 (50X micro)

Problem-Stress Corrosion Cracking (SCC)

SCC requires stress, a susceptible material, and a specific environment to exist. Eliminating just one of these three requirements eliminates the potential for SCC to become a failure mechanism. Susceptible materials include austenitic stainless steel, especially those containing nickel, and copper based tube materials.

A stress can include residual stresses or service stresses. A residual stress could occur from a manufacturing process or during installation. A service stress is caused by an expansion stress, hoop stress, or bending stress. Examples of a service stress include but are not limited to excessive thermal cycles, excessive valving in or out, pressure swings, and temperature swings.

A susceptible environment carries temperatures greater than 150 degrees Fahrenheit and shows a presence of oxygen. For feedwater heaters this would be in the form of dissolved oxygen in the feedwater as a result of air inleakage through the surface condenser. For stainless steel materials, this includes the presence of concentrated chlorides. For copper based materials this includes the presence of ammonia. The chlorides and ammonia allow the susceptible material to corrode and thus deposit within the FW cycle.

Chlorides enter the FW system when there are condenser tube failures or problems with the demineralizer. Chlorides can also carryover as steam from the boiler drum, or enter into the steam through attemperation introducing the chlorides directly to the turbine and thus the shell side of the FWH string.

Ammonia is used to control PH in the FW cycle. Under normal operating conditions levels are within EPRI guidelines. However, excursions have occurred. Sources are feed water treatment with ammonia, hydrazine which thermally breaks down while going through the boiler, and release from the polisher as contaminants from condenser leakage are removed.

Analysis

The environmental conditions were met. The susceptible material in this case was austenitic stainless steel compounded by the fact that nickel was included. Chlorides identified during the previous start up indicate that the chloride levels were great enough even if only by excursion, to allow this mechanism to exist. High chloride levels are attributed to the large number of tube leaks on both the MU and TBFP Condensers, which are both at end of life. The dissolved oxygen levels were elevated as indicated by the surface condenser in-leakage tests.

Since the turbine blade failure in 2001, unit 7 was exposed to high level of air in leakage from the damaged condenser tubes. Consequently, the low pressure FWH's receive limited protection from corrosion, especially when the dissolved oxygen levels are high. When dissolved oxygen levels are normal, the HP-FWH's are protected better than the LP FWH's by hydrazine because of the elevated temperature and the residence time in the FW System. However, when dissolved oxygen levels are high, the HP-FWH's also receive limited protection, and corrosion damage from dissolved oxygen will be greater.

Corrosion

It is normal for some corrosion to exist in the feedwater heater. However, this occurs gradually over the expected life of the FWH. Ammonia and chlorides act to allow corrosion to exist in the FW cycle, as indicated in the SCC section. The other requirement for corrosion is air in-leakage. Ammonia and chlorides exist within all FWH systems. Furthermore, it is not possible to operate with some air in leakage at the condenser, but it is possible to minimize the dissolved oxygen in the FWH train. If ammonia and chlorides as well as air in-leakage are kept within EPRI recommendations, a heater should reach its expected life before this failure mode becomes apparent.

Once corrosion of the FW materials has occurred, the corrosion products that are formed (primarily copper oxides and iron oxides) can be released or eroded away into the FW flow, and then transported to other areas in the cycle with the likely hood of deposition occurring. For example, deposition can occur within the feedwater heater tubes, within the boiler tubes, and on the turbine blades. Since 2001, there have been many chloride excursions due to condenser tube failures or problems with the demineralizer.

Solution

A root cause analysis was performed accompanied by a unit health assessment. Many options were discussed, from operating the unit with no HP heaters, expediting a new heater, or installing long tube inserts. Shorter inserts had proven their effectiveness in condenser and previous FWH repairs. The health assessment performed by the engineers also included cost risk assessment and ROR. Since the damage was not localized in one area where damages can be isolated and addressed individually, all focus was directed toward the possibility of installing inserts since its effectiveness was proven in other applications.

Selecting the proper alloy is also a critical step in the sleeving process. Incoloy 800 was determined by DTE to be the material of choice because of its resistance to SCC. The full access to the tubesheet allowed the installation of the inserts and tooling to go smoothly. When dealing with inserts over eight feet long

it's important to size the inserts to account for friction for the ID fit, for expansion characteristics, and the tooling required to fit inside the $\frac{3}{4}$ " x .035" tubes can be delicate to handle.



Fig. 4- Full Access Channel and tooling

The tubes should be prepped by wire brushing the tube I.D.'s to a depth equal to the length of the insert. The inserts are loaded and expanded hydraulically using custom made hydraulic pumps. The pump/mandrel combination is the most effective way to expand the thin-walled inserts into the parent tubes. Pressure and volume controlled expansion of the inserts creates a metal-to-metal seat without the risk of over expanding the parent tube. No explosives, no welding, no risk.

The next step is to mechanically expand the insert at the tubesheet. Roller expansion at the tubesheet results in a leak-free bond while also reinforcing the original tube-to-tubesheet integrity. The final expansion process is to mechanically expand the insert at the final inch, the discharge end. Deep-end expansion is vital to the success of the process, not only does the deep roll eliminate a transition-step, it also provides a seal.

The deep end expansion, in conjunction with the roll at the tubesheet totally isolates any problem area <leaks>, and also protects against any further damage. During the air leak test, few tubes were found to be leaking after the expansion and roll. The sealing process was repeated in order to seal these tubes where it was successful. A few tubes on the periphery were not accessible for inserts due to an inner surface ring for a gasket seal and were plugged.

Conclusion

The sleeving method was very cost effective since it only took 10 days from start to finish. The FWH was returned to service and Detroit Edison recovered the 100MW that was missing. The #5 heater at St Clair Power plant has been performing **leak free** since 09-2006. The sleeving technique implemented has proved its effectiveness; the unit has cycled numerous times due to condenser or boiler tube failures with no heater problems.

The installation of the inserts was a successful method to fully recover a FWH and this technique is very useful when the failure mechanism is localized.

CASE HISTORY
NO. U9592
SEPTEMBER 2006

- CLIENT:** Detroit Edison
St. Clair Generating Station
East China, Michigan
- UNIT:** Unit 7, No. 5 LP Feedwater Heater
894 304N Stainless Steel U-Tubes
3/4" O.D. x .035" Avg. Wall x 47' long
- PROBLEM:** Chloride induced Stress Corrosion Cracking (SCC) occurring in the outlet tube ends throughout the entire desuperheating zone to a depth of 12 feet from the tubesheet.
- SOLUTION:** Installation of 894 thin-walled CTI Shield/Seals constructed from Seamless Alloy 800. The 13' long Shield/Seals were expanded by hybrid expansion, hydraulically expanding the inserts full length, then mechanical expansion at the tubesheet, and discharge end. This application allowed the return of both the #5 LP Heater and the #4 HP Heater, which had to be shut-down also, resulting in an immediate heat rate increase.