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Testing and Installing Repair Sleeves will Improve Reliability, Performance and Extend Condenser Life.

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Abstract:
Condenser tubes that have tube defects or leaks identified by eddy current testing can be repaired and kept in service. Tubes that are plugged because of past tube leaks can be unplugged, cleaned and restored back into service using a repair sleeve sized and installed to **seal** the tube defect area only.

Sleeving projects have helped correct the following Condenser, CCW, oil cooler, hydrogen cooler and feedwater heater tube failure problems: Ammonia Grooving, Stress Corrosion Cracking, (SSC); Microbiological Induced Corrosion, (MIC); tube OD induced vibration, high velocity turbulence resulting in inlet end tube erosion; erosion-corrosion; H2S and Sulfuric Acid Attack; low pH and presence of sulfur compounds with dissolved protective patinas; polluted, stagnant waters create hydrogen sulfide generated from decomposition of marine organisms; general corrosion and copper transport, as copper dissolves the tube wall gradually thins and the copper is carried to the feedwater heaters, the boiler tubes and to the HP turbine blades. Biological fouling, scaling, steam or drips/drain flow induced vibration, other water chemistry problems. Stainless Steel tube failures such as chloride stress corrosion cracking, pitting, crevice corrosion, flow induced vibration, biological fouling and other water chemistry problems.

Tubes that have more than one location along the length of the tube with defects or failures (multiple tube failures) can be repaired with more than one repair sleeve or the repair sleeve can be sized to seal all major defects with one longer sleeve. Repair sleeves can be installed and sealed anywhere along the full length of the tube.

This paper will describe several sleeving projects completed successfully in both Nuclear and Fossil Power Plants. Sleeves that restored tubes back into service and reinforced tube defects that were likely to fail between outages. Installing a repair sleeve over defects likely to fail during operation has proven to significantly reduce forced outages due to tube failures. Repair sleeves installed over severe defects and leaks (50-100% of tube wall defects), have improved condenser and heat exchanger reliability. The sleeves improved condenser and heat exchanger

performance by restoring tubes to service, providing more surface area for improved heat transfer. The increased number of tubes in service will also reduce cooling water pressure drop, reduce tube side velocity and the rate of inlet end tube erosion. The largest benefit is the savings in capital and maintenance dollars by postponing costly retubing projects for years.

Condenser tube leaks mix the source cooling water (river, lake, ocean, cooling tower) which are harsh, aggressive, and contaminated with the clean, pure steam and condensate. Any small leak from the cooling water into the steam and condensate will be harmful to the power cycle components (pumps, piping, feedwater heaters, boilers, steam generators, turbines, etc. Condenser tube and plug leaks contribute to some of the most serious chemistry problems in the plant.

It has been proven that tube joints between a sleeve to parent tube (metal to metal contact) will not stop or prevent tube leaks or provide a leak free seal. Metal sleeves hydraulically expanded into parent tubes will not provide a leak free seal on their own unless it is at a tube sheet where the forces of hydraulic or roller expansion exist.

In order to achieve a leak free seal with a condenser repair sleeve, the sleeve to tube interface must contain a sealant. A sealant applied to the sleeve OD will prevent any differential water/steam pressure to pass between the sleeve OD and the parent tube ID (between the cooling water and the steam/condensate system).

Through several years of R&D and testing a high temperature sealant located in the annulus between the parent tube and the sleeve OD can provide a seal stronger than the yield pressure of the sleeve or the parent tube. The use of a high temperature (400 degree) sealant has proven to be the best in providing a 100% leak free seal repair that will last in low pressure applications.

Condenser sleeve: This 7/8” OD X .049” wall parent tube with a hole, sealed with a ¾” OD X .035 wall sleeve. A Hydro Test starting at 100 psi to 4,000 psi provided 100% leak free seal. At 4,500 psi the sleeve material yielded and bursed the .035” wall sleeve through the parent tube hole. The hydro tests held for days between 100 to 4000 psi without a drip before building pressure to burst.

APS’s R&D for high temperature and high pressure (up to 1000 degrees F & 1000 psi) requires a braze joint between the sleeve OD and parent tube ID in order to provide a leak free seal. APS's new technology to locate sleeves along the length of the tube, locate and hydraulically expand the sleeve to the parent tube centered over the defect area and the use of an internal tube plasma ID tube heater to braze the sleeve to the parent tube have all been developed in the last few years in order to expedite the sleeve installations while providing a 100% leak free seal. The following picture shows a high temperature, high pressure stainless steel sleeve ready for installation containing a stainless to stainless brazing ribbon and flux to provide the sleeve to parent tube leak free seal.

Feedwater heater sleeve: This 5/8" OD X .083" wall parent tube with a through wall hole was sealed with a .430" OD X .035" wall sleeve. A Hydro Test started at 500 psi to 10,000 psi provided 100% leak free seal. A hydraulic mechanical strength test to pull the parent tube and sleeve stretched and then broke the sleeve in two. The brazed joint remained as a leak free seal. The brazed joint was tested by mechanically pulling the parent tube away from the sleeve as shown above. The strength of the brazed joints was not effected.

The following Case Studies are Sleeving Projects successfully completed to restored failed tubes and tubes with severe defects back to service for low pressure and high pressure applications:

Case #1: Ammonia Grooving and Severe Inlet Erosion of a 16,318 tube condenser originally containing 550 plugged tubes:

This 350 MW coal fired mid-west power station condenser was experiencing an increase in the frequency of tube failures. A sample eddy current test completed in 2001 identified nearly all of the tube damage was at one tube sheet. A tube sample was pulled verify the eddy current test results and verify the root causes of tube failure. Inlet erosion and OD metal loss from ammonia grooving was documented on nearly all Inlet erosion reduced the wall of the tube three inches from the face of the tube sheet to 30% of the tube wall and at the same time ammonia grooving on the back side of the tube sheet eroded the OD of the parent tube. There was also ID erosion in 1/4th of the outlet tubes in one water box. The remainder of the tubes were in excellent condition with very few tube defects.

Hydraulically Expanding 6" long sleeves to seal leaking tubes at the inlet and outlet tube sheets.

The plant decided to extend the life of this condenser tubes for at least 2 years by installing 20,000+, SB-111, Alloy 706, 90/10 Cu/Ni .910" OD X .028"AW 6' long inserts from the tube sheet face 6 inches down the length of the tubes. The length of the sleeve (insert) would prevent additional inlet erosion and allow the damaged tube behind the tube sheet to be repaired at the same time. The outage time to complete the cleaning and installation of over 20,000 sleeves was 10 days working (2) 12 hour shifts.

1" long collars were also used between the insert and the eroded parent tube ID at the tube sheet to strengthen the tube joints and help prevent cracking of the very thin parent tubes with severe inlet erosion. All (550) tubes previously plugged were opened, eddy current tested, cleaned eight inches down the length of the tubes and then 6" long inserts some with collars were installed, hydraulically expanded 6", hard rolled at the tube sheet and the far end of the sleeve was feathered into the parent tube to prevent the development of condensate erosion at the end of the sleeve. The product "Loctite" was used between the insert and the parent tube on the 7,000 inserts installed in the tube outlets to prevent the possibility of an insert coming lose. The sleeve installation took 216 elapsed time hours, 9 days working (2) 12 hour shifts, (1 day early).

20,000 6” X .910 OD X .035” wall 90/10 Cu/Ni tube sleeves installed in 9 days.

The project included removing 1,100 tube plugs (550 tubes) and install (16,318) 6” long sleeves to prevent continued inlet erosion and reinforce the tube OD metal loss ammonia grooving damage also at the tube inlet water. (4,000) 6” long sleeves were also installed in the outlet water box tubes having the highest ID erosion (50 to 70% IDML). The tube ID’s were cleaned and 20,000 sleeves were installed in (18) 12 hour shifts or 9 days. After the installation a standing hydro revealed only 8 tube leaks remained. 542 out of the 550 previously plugged tubes were back in service (98.5%). The $2 million + retubing project was postponed and the condenser ran reliably with an improved thermal performance for 6 years before it was retubed in 2007.

Case #2: Fast track job! 7 days before the end of the outage a standing hydro test revealed numerous tube leaks. Tube plugs were removed and 100% of the tubes were eddy current test. (173) full length liners were installed during the last five days of a planned outage. The unit went on line as originally scheduled with no tube plugs.

Case #2 continued:

A 550 ton per day waste to energy plant with a 15 MW turbine generator set found some bad news seven days before the unit was to be put back in service. The plant found out they had a large number of tube leaks and took the following actions.

1. On Thursday, with seven days left in the spring 2010 outage, a condenser shell hydro revealed hundreds of tube leaks. No major problems were expected because the 20 year old condenser had been running smoothly and had only 1% of the tubes plugged; 21 tubes (42 tube plugs). There was no time to plan and install partial length sleeves, so full length liners were located in stock.

2. On Friday, with six days left before the end of the outage, two eddy current testing crews mobilized to the Florida Garbage burning plant and 800 full

length tube liners were shipped “Hot Shot” from stock in Ohio to the Florida garbage burning plant for delivery on Saturday.

3. On Saturday, with five days before the end of the outage, 42 tube plugs were removed and a 100%eddy current test of 2,078 tubes in the condenser was completed in (3) 12 hour shifts, Sunday at 12:00 noon. The first eddy current test of the condenser tubes was conducted and revealed 173 tubes (8.3%) of the tubes had leaks or defects of 60% or greater primarily from ID tube erosion.

4. On Sunday afternoon, all 2078 tubes were cleaned and prepped for full length liners. Starting Sunday second shift, new liners was installed in each of the 173 tubes with holes and defects 60% wall loss or greater. Each liner was hydraulically expanded to the ID of the existing 173 tubes with leaks or severe damage. After the hydraulic expansion, each liner was trimmed to the tube sheet face, were roller expanded into the tube/tube sheet on both ends and were flared to match the inlet of each parent tube.

5. All tubes in the condenser were tested with a standing hydro revealing no tube leaks with no tube plugs on Tuesday by 2:00 PM. The unit was back in service as originally planned by Tuesday at midnight, five days after learning of the problem. The result included improved reliability, efficiency and an improved condenser tube life.

Case #3: A Nuclear Plant LP Feedwater Heater with ¾” OD X .035 wall X 41’ 2” long SL 304 Stainless Steel tubes contained scattered stress corrosion cracking. (682) 304 Stainless Steel Repair Sleeves were installed in different depths throughout the bundle to provide reliable service with no tube plugs.

1. Eddy current test 100% of the ¾” X .035 wall 304 stainless steel tubes and record all defects in each tube within 1” of the defect location. A sleeving plan was developed to optimize the repair sleeve installation.
2. The eddy current test report was review to identify exact tube defect locations and then develop a comprehensive sleeving plan and color coded tube sheet map depicting the tubes to be sleeved as well as the location of each sleeve within each tube to be sleeved.