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NRG Energy's Dunkirk station is located on Lake Erie, 55 miles southwest of Buffalo, in Dunkirk, New York. The 600-megawatt plant consists of four coal-fired units, including two 100-megawatt units that have been running since 1950, and two 200-megawatt units that went into service in 1959 and 1960.

Abstract:

Extending the Life of the Unit #4 Condenser at NRG - Dunkirk

NRG – Dunkirk Power Station was experiencing issues with the rapidly deteriorating tubes within their U-4 condenser. An eddy current analysis performed by APS indicated that the majority of the tubes were experiencing excessive wall loss (as much as 80%) within the last 15 feet of the outlet section of the tubes. The Dunkirk Station U-4 condenser has (15,028) ¾" OD X 18 BWG x 30' long admiralty brass tubes. APS removed tube samples were removed from the condenser for analysis which confirmed the eddy current results.

Problem:

Initially, NRG considered installing modular condenser or retubing the existing condenser. However, due to budget constraints, the costs for both of these options were more than they NRG had allocated for the condenser repair. Additionally, a partial retubing was also not a viable option due to the excessive number of tubes with severe ID erosion. There were also some discussions with respect to how much longer NRG had planned to keep Dunkirk – 4 in operation. Regardless, NRG realized that a repair of some sort had to be undertaken in order to keep the tubes in service until a permanent repair could be implemented or the unit is retired.

Solution:

American Power Services and Curran International were consulted on extending the life of the Dunkirk Unit 4 condenser due to the following issues.

1. Condenser leak rate had affected unit reliability and tube leak had progressively gotten worse and increased significantly over the last 18 months.

2. The outage maintenance schedule was no more than two weeks.

3. Maintenance budget for retubing was nonexistent due to overall plant economics

4. The plan was to operate the unit for another three years and possibly longer.

5. Under current operating conditions condenser efficiency was lacking.

6. The majority of tubes had indications of > 80% wall loss and may not tolerate grit blasting or scabs of scale might be filling in an existing through wall leak.

7. Eddy Current report had indicated a significant wall loss, (80%) specifically in the last six feet of tube moving towards the outlet water box. Erosion was generalized over the entire tube sheet.

Again, the overall objective or the proposed repair was to keep the condenser operating with a certain degree of reliability while maintaining the thermal efficiency for an estimated 2 to 3 year duration.

To evaluate any further tube damage the grit blasting in real time activity it was recommended to perform with the hot well full of condensate so if there was significant discovery leaks during the cleaning phase the coating project could be canceled. This would insure that the project would as a minimum not do any harm.

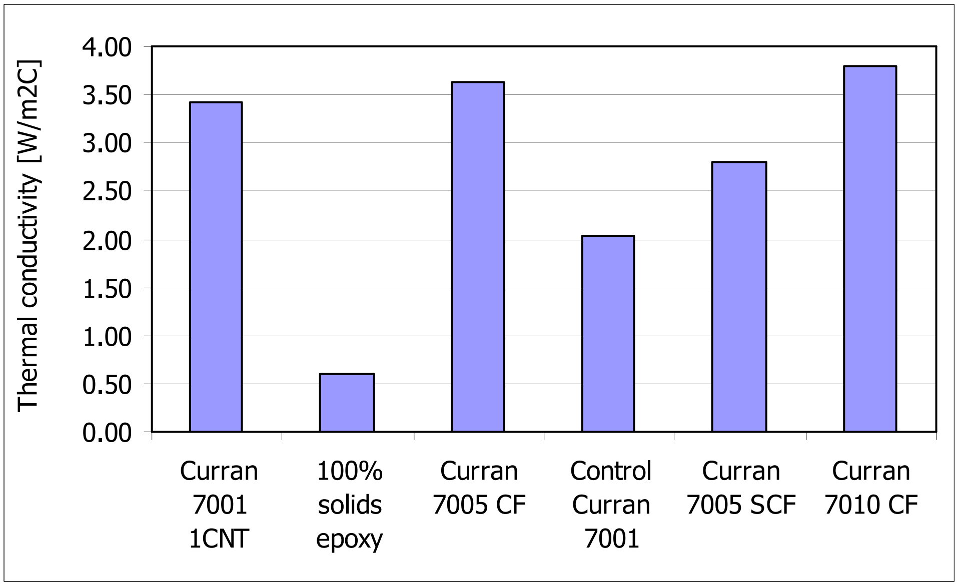
After consultation with APS and Curran International the decision was made to coat the ID of all tubes. APS and Curran also informed NRG that by utilizing a spray application any portion of the tube could be coated to prevent any further erosion/corrosion from degrading the tube wall further as well as to minimize any excessive loss of thermal heat transfer. Although initial discussions revolved around coating the entire tube length, after analysis of the condenser, it was determined the best approach would be to coat fifteen feet of tube from the center to the outlet boxes to protect the most degraded section of tubes and prevent any possible negative impact on the heat rate. It was determined this could be completed within the allotted schedule while reducing the overall cost of the project.

Thermal Conductivity:

Initially NRG had some concerns regarding the impact of the coating on the overall thermal conductivity on the condenser which is not uncommon. If fact, polymer tube linings have always suffered from an initial perception of heat transfer penalties due to their lower thermal conductivities vis-à-vis metallurgy. However, quantitative data and strong long term case history have demonstrated just the opposite. Decades of service history have shown that tube coatings can enhance heat transfer and overall performance to a significant degree. While the thermal conductivity of the coating is much less than the parent tube, this factor is mitigated by inherent properties of the coating. There have been four major studies performed on coated condenser tubes. Two by universities and two by commercial vendors. In each case the impact to overall thermal conductivity was minimal or minor, details the results from one University that compared the 75 micron coating to a 150 micron layer of scale. Another University study determined that when relating the coating to the actual tube wall, that when new and not oxidized or scaled, is 2% of the overall HTR equation the coated tube wall resistance increased to just 2.38% of the total HTR which again is minimal.

Another factor covers normal design considerations. Generally, HEI and TEMA design condensers to operate 85% capacity, or with 15 % of the tubes plugged without effecting turbine performance. Fouling factors are also built into the equation to add additional performance hedging into the design. Applying the coating either totally eliminates the subsequent fouling or greatly reduces the accumulation of typical micro-/macro-fouling, mitigating the initial design consideration.

The second major factor is the boundary layer-drag reduction. Fully 70 percent of total heat transfer resistance (HTR) across a heat exchanger tube is the slow-moving fluid coming into contact with the tube wall. Tube wall friction reduces this flow and creates an insulating barrier of low velocity fluid. Polymer coatings reduce the surface tension at the tube wall substantially, to 30 - 40 dynes per cm2 compared to metallurgy (1200 dynes/cm2) in a non-oxidized or new condition. Tube wall oxidation or scaling would increase this friction by multiples. Reducing friction reduces the boundary layer drag and substantially opens up the flow profile. Two separate studies show flow rate improvements of 80 to 100 percent with polymer coatings compared to new uncoated tubes in the same fluid train. This increase in flow and low surface energy of the coating contributes to the improved overall thermal efficiency of the heat exchanger in fluid service. This increased flow at the tube wall also inhibits nucleation site for micro and macro scaling deposition to begin. An added benefit and energy saving is the reduction of energy needed to power circulation pumps.



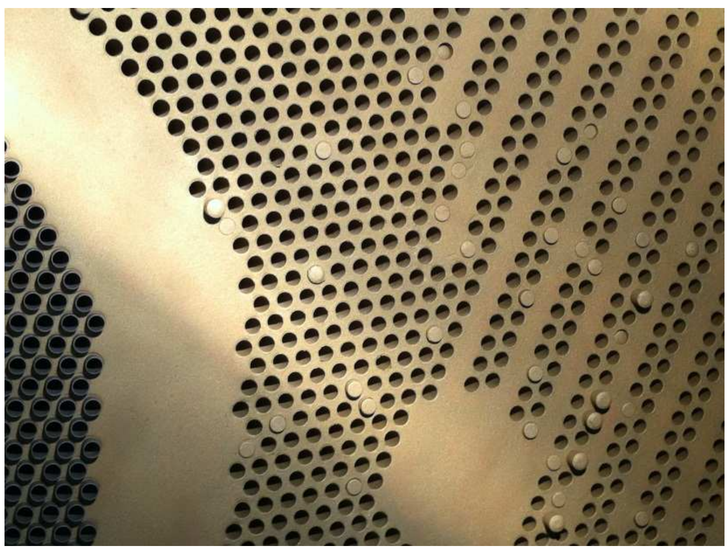
Project Details:

After arrival at site and equipment setup a cursory drying of the condenser and tubes is performed with oil and water free compressed air at 125 psi. During this initial dry activity it was discovered that over 600 tubes were completely obstructed by shells, mud, wood, and condenser tube cleaning scrapers that were left from previous cleanings. It was noted by the plant that they were aware of the plugged tubes and had tried to clear them 2 years ago, but were unsuccessful at doing so. By extensive manual rodding 200 tubes were cleared and returned to service. The remaining 400 plus were permanently plugged with brass tapered plugs.

Note the blue circle in the middle of the plugged tubes has a corroded scraper within it. This scraper was removed, but the obstruction within the tube could not be cleared.

Grit blasting was then performed on all tubes in order to remove any remaining deposits that could interfere with the adherence of the epoxy coating.

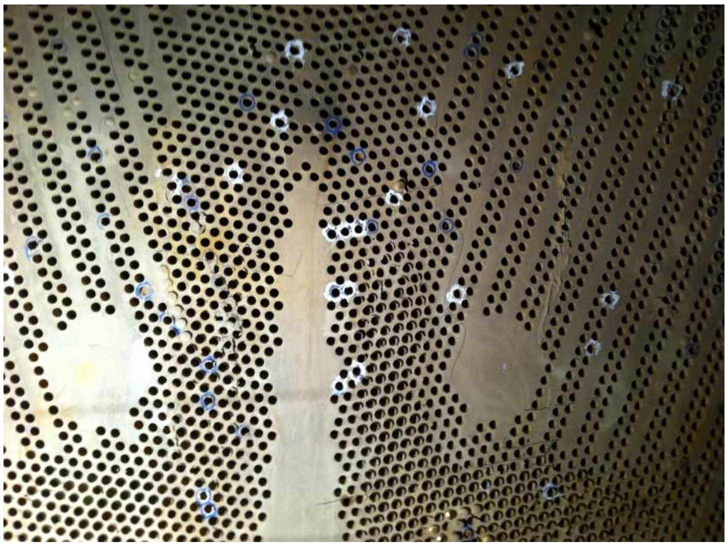
Grit blasting in progress.



Grit blasted tubes and tubesheet.

It had been determined by previous sample tubes provided by the plant and then on site fiber optic examination that 20 second dwell time on each tube was able to achieve a 100% clean tube with complete removal of all scale and oxides. A 1- 1.5 mil anchor profile was also obtained to increase the surface area for the Curran Condenser Tube Coating to mechanically bond to. Prior testing by micrometer measurements on submitted tube segments for possible wall loss from grit had not shown any metal loss after 2 minutes of grit blasting confirming prior EPRI results. Grit blasting operators where instructed and equipped to install tapered plugs in any tube leaks developed during the grit blasting activity. In all, only 20 tubes where plugged out of 15,000 during the grit blasting activity. Once the grit blasting was complete, a thorough examination of the tubesheet was performed to verify no leaking tubes prior to draining the hotwell in preparation for coating.

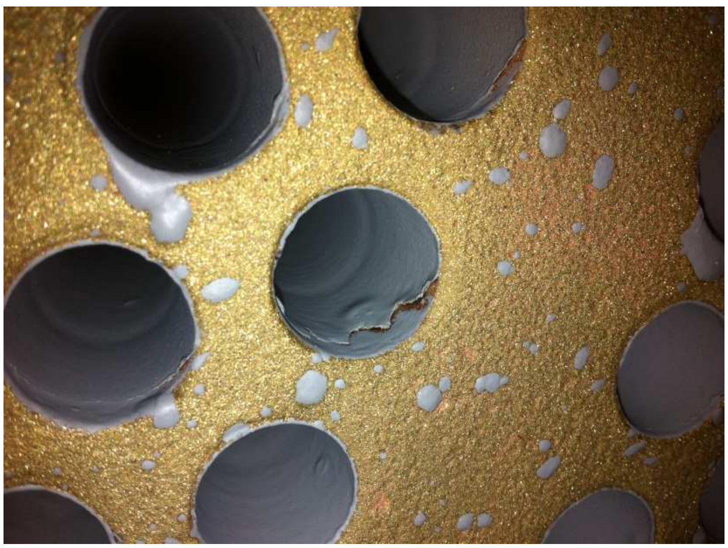
The pictures below represent a series taken within the Unit 4 condenser as part of the tube ID coating project performed onsite at the Dunkirk power station. The outlet half of the tube (15′) was sandblasted to an SSPC SP-5 white metal blast and a Phenolic Epoxy was spray applied in a single coat to achieve a 1-2 mil DFT.



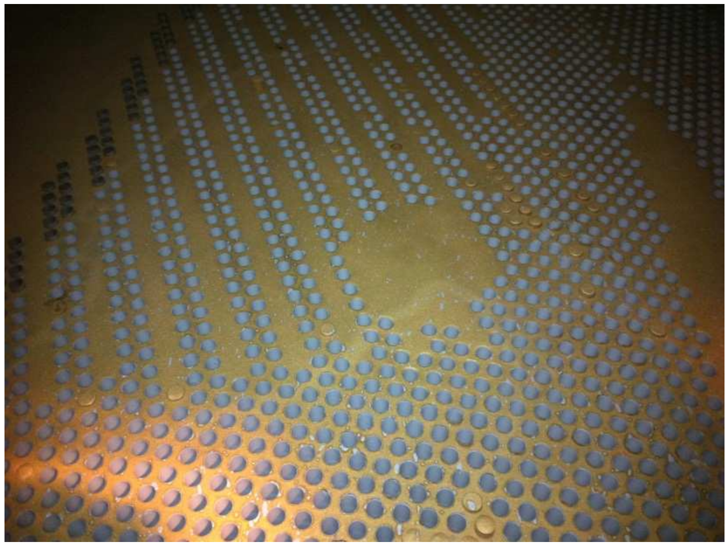
The picture above represents the condenser tubes after drying out each tube with compressed air and then rodding out the obstructed ones. The blue circles are present in the tubes that were obstructed and we were not able to clear with either compressed air, or by running a fiberglass rod down the tube. The white circles represent the tubes that were obstructed, but we were able to clear with the fiberglass rod.

Coating was then performed utilizing Curran Internationals patented condenser tube spraying machines. Each machine can spray three tubes at a time at six feet per second. Coating hoses where propelled outside of the outlet end of the tube and then pulled through the complete tube terminating the spray after fifteen feet. Each tube received a 2-3 mil layer of Curran Condenser Tube Coating.

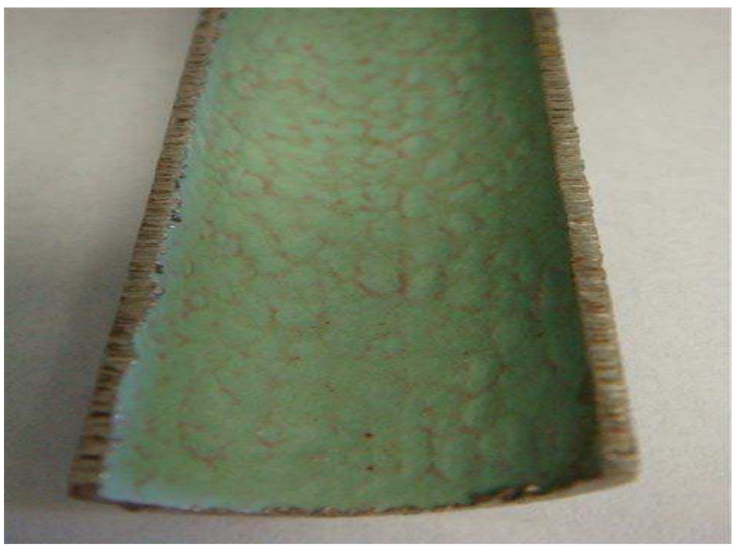
Tube coating in progress.



Note eroded tube ends. Eroded tube ends had an additional spray coat applied to them from the outlet end to encapsulate the tube end within the tubesheet.

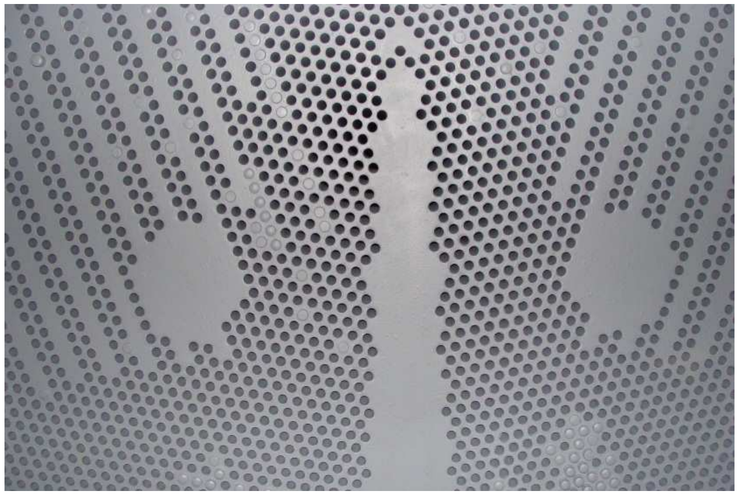


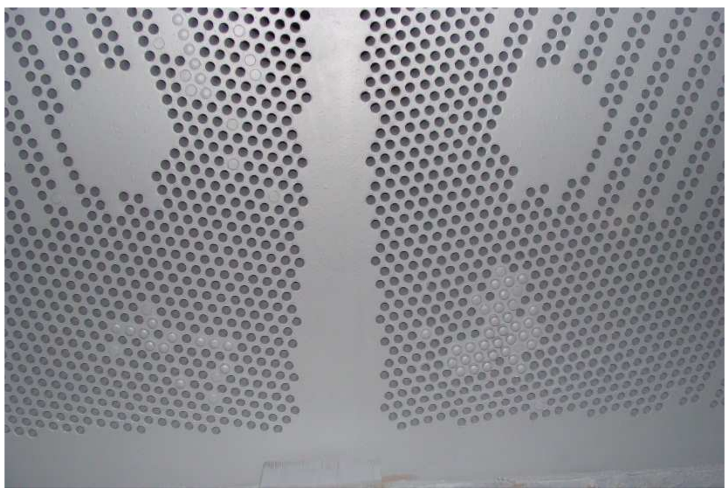
Tube coating completed.

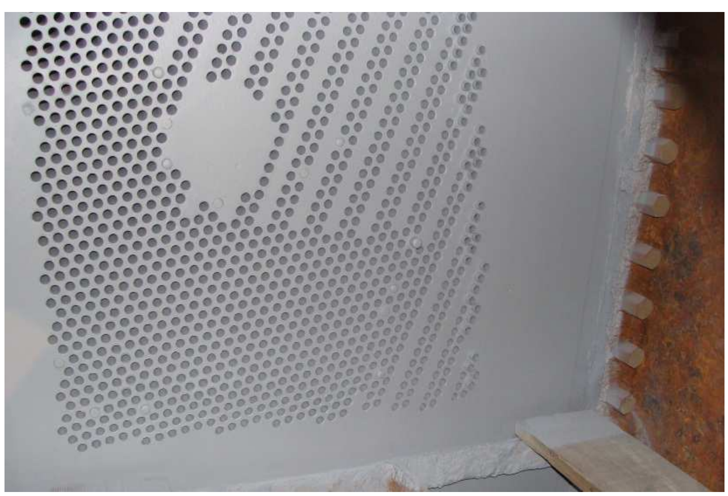


Shown above is a cutaway of a tube with the ID coated.

A single coat of the Phenolic Epoxy was spray applied to the outlet tubesheet to achieve a 4-6 mil DFT.







Above are pictures of the outlet tubesheet with a single coat of Phenolic Epoxy applied to tie in the tube coating with the tubesheet.

Conclusion:

Since the EPRI study originating in 1990, we have coated over 50 condensers in power plant configurations. It has shown to be an excellent procedure to extend the life of aged condenser tube or mitigate corrosion in copper nickel or stainless tubes at a fraction of the cost of new modular condensers or retubing of an existing condenser. It has also been successful in returning leaking tubes to service. Annually over 4 million tubes are coated utilizing data and procedures matured from the original EPRI program. There are now several condensers with 10+ years of service and still performing. Current technology improvements for condenser tubes include increased thermal conductivity, 100% solids epoxies, high temperature epoxies (365f), and application of partial length, segmented lengths of full length coating.

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