Full length ID coating of steam condenser tubes: Q&A

By Edward L. Curran, CEO, Curran International

1. What is the typical percentage loss in terms of overall heat transfer across the tube wall with a coating compared to bare metal? How does this compare typically with scaling? Are any reports available to substantiate these claims?
   EPRI reported in1993 a U of 4633 W/m2K for an acid cleaned 90/10 CuNi tube compared to 3038 for a typical fouled condition and 3742 for a coated tube. This was presented in EPRI TR-107068. Recent developments and lab studies of micron and nano sized thermally conductive pigment additives have enabled Curran Intl to increase thermal conductivity of our coating by at least 100%, however no EPRI type heat transfer resistance of coated tube vs clean tube study has been repeated. Developmental thermal conductivity lab work for these improvements was performed by US Department Of Energy Brookhaven Lab under a joint collaboration with Curran Intl. Base resin thermal conductivity was changed from 1.4 kj/h.m.C to a maximum of 3.7 kj/h.m.C. Addition of thermally conductive pigments also significantly (3x) increased values for tensile modulus, tensile strength, flex, and elongation, which will enhance long term viability of the coating.

2. What effect does the coating have on the condensate in case of a tube leak? E.g. degree of contamination?
   After full cure the coating is basically inert and will not leach any products into the cooling water or condensate.

3. Is the product suitable for operation in our own type of cooling waters? CW waters are derived from natural river waters, which are cycled 15 – 20 times. Chlorides are around 400ppm and sulphates around 1000ppm.
   Our coating has operated in all types of recirculating cooling water, sea water, brines, and high turbidity river water.

4. What is the effect of oil in the cooling water? At times there is contamination of turbine or BFPT lube oil in the CW.
   Oil has no effect on the coating and is a recommended coating for hydrocarbon service. We have hundreds of exchangers coated in the refining industry that can occasionally be contaminated from other leaking exchangers. Most notably they experience accelerated organic growth in the cooling water system, but the coated exchangers remain clean. Our coating is also applied in direct contact with crude and crude products.

5. What materials can be coated; typical tube material is brass and stainless steel.
   All materials can be and have been coated

6. What is the comparative wear/abrasion and corrosion resistance of this product vs. admiralty brass? The coating is rated at 50mg average loss per 1000cycles on a Taber CS-17 wheel.
   Our coating has been used to eliminate inlet and outlet tube end erosion. We have service history in 5 m/s high turbidity once through river water and 15 m/s gas flow. Both Services were highly erosive to the parent tube. Poorly adhered oxides are rapidly removed in erosive environments. Coating application prevents oxidation/passivation of the tube wall eliminating any further wall loss. Our coating is also filled with ceramics to

enhance abrasion resistance. Coating your tubes will prevent exposure to corrosive electrolytes providing protection against typical admiralty brass failure mechanisms of under deposit corrosion, dezincification, erosion, MIC, and ammonia.

7. What is the tolerance to mechanical damage? It is typical to find small areas of chipped coating on the inlet tube ends. These are a result of impacts of rocks, concrete or other foreign debris in the cooling water. Wood and other non metallic materials do not damage the coating.
   Our coating is a composite with tensile strength of 35MPa and tensile modulus of 900MPa.

8. What is the scaling resistance of the coating relative to brass? New CuNi tubes have a surface tension of 1200 dynes/cm2 which will increase with passivation and any fouling.
   Our coating has a surface tension of 30 dynes/cm2 and will not degrade in service. Coating application has proven to be a major contributor to elimination/reduction of scaling. We have many case studies of exchangers that were being cleaned every 6 months, now providing years without maintenance.

9. Are there any conditions under which the coating is susceptible to chemical or biological degradation?
   Certainly there are chemicals that can degrade the coating, but they are not commonly found in cooling water or if they are the concentrations are very low. HCl at 5%, sometimes used for cleaning will degrade our coating. Biological degradation will not occur. We have coated many SS condensers to protect against active MIC attack.

10. Are there any conditions that would increase the susceptibility of fouling?
    We have had a few cases were very low flow from pump failures or control valve malfunction has allowed minerals to deposit on the tube wall from vaporization of the water.

11. Can this system be interfaced with other technical repair procedures such as insert application?
    Yes, we can and have coated over metallic inserts.

12. What are the chances of experiencing internal surface corrosion? E.g. at the insert to coated tube interface (where metallic inserts are used).
    There has been much discussion regarding cracking from thermal expansion differentials at the insert to tube interface when the insert is a different metallurgy than the parent tube. We have had good results so far. We do prefer a hydraulically expanded insert vs. a rolled installation, for the additional mechanical lock. Overall we maintain that the coating will perform at least equal to an insert, and without the end step erosion, thermal expansion and possible cracking issue.

13. Is there any possibility of corrosion under the coating?
    There is a possibility if the surface preparation is inadequate or corrosive ions remain on the surface of the tube. We will be testing for all these ions during the surface preparation stage, and if found, be prepared to remediate them. EPRI study examined coated CuNi tubes that had blistered and accumulated pockets of concentrated chlorides underneath the blister and found no evidence of accelerated corrosion.

14. Is there evidence of intensified corrosion after coating, when small areas of the coating are damaged in service (due to erosion, mechanical damage, etc.)?
    It was reported in EPRI that small voids in the coating passivated normally and did not lead to accelerated corrosion cells. It has been our experience, also, that areas of mechanical damage corroded at normal rates.

15. What quality control criteria are implemented to ensure the preparatory surface cleaning is adequate prior to coating?
    We will video probe a sampling of tubes to verify cleanliness from grit blasting. Tube ends and tube sheets will be tested for soluble chlorides and sulphates. Tes-tex replica tape will be used for surface profile verification.

16. What sort of environmental conditions must be established to ensure a successful application of the coating e.g. temperature, humidity etc, ventilation, over coating times, curing times before operation?
    Sigma, our resin supplier has no specification for RH, but specifies 3c metal surface temperature above dew point. We use <85% RH as a standard. Minimum application temperature is 10c. Ventilation will be maintained throughout application and cure by means of pneumatic air movers. Cure times and over coat windows are offered by Sigma and we will provide documentation for each project.

17. What quality control criteria are implemented to establish the integrity of the coating immediately after application?
    Tube sheets will be scanned for any missed tubes. Ventilation will be maintained to remove solvents. Time and temperature will be recorded to establish overcoat window/cure timing. DFT's will be taken and recorded

18. What methods of tube inspections are possible after coating has been applied (e.g. eddy current)?
    All methods of NDT are possible after coating.

19. How is the condition of the coating assessed over time? What performance/condition monitoring is recommended once a condenser has been coated?
    The best method of condition/life assessment is a video probe examination. We provide this service globally to our clients at your regular maintenance cycles. We will write a report and provide a disc with the video probe pictures.

20. Will the application of a coating result in an increased CW flow rate for a given pressure differential between the inlet and outlet waterboxes?
    We have two case histories with Exxonmobil where they have measured CW flow from side by side coated vs. not coated exchangers. In one case the flow rate improved 80% and the other the flow rate improved 100%. As stated before the surface tension of the coating will reduce the boundary layer drag and should increase flow. It will also reduce the energy required to pump the cooling water through the CW system. I have no flow improvement data from a power plant.

21. What is the minimum wall thickness required prior to cleaning? What material loss may be expected from cleaning (worst case scenario)?
    We have tested tubes with 125micron wall and not perforated the tube. We have also coated leaking tubes to plug the hole and return the tube to service. We are able to close a 1.5mm hole. EPRI studies and our own has

shown a worst case 50 micron wall loss after 3 minutes of blast cleaning. Our typical cleaning dwell time is 15-30 seconds.

22. Will the coating increase mechanical strength of the tube, in anyway?
    This may be beneficial in some instances where degraded, thinned tubing may fail due to fluctuating CW pressure. We have no data to support an answer. However being a composite coating, it will provide mechanical strength, ie, fiberglass bonded to wood

23. Are there any limitations after coating on the use of on-line ball cleaning systems (i.e. Taprogge)? Is there any evidence of coating damage or wear from such operation? What is the recommendation regarding the operation of the on-line cleaning system once a condenser has been coated?
    The only limitation would be the abrasive coated balls could not be used. Otherwise, ball cleaning systems do not effect or wear the coating. Due to the foul release factors of the coating the ball cleaning is only used periodically to remove silt when back pressure increases.

24. What is the maximum operating temperature range of the product/s?
    125c immersion/wet 190c dry

25. What is the impact or effect of temperature fluctuations (i.e. two shifting) Can a less brittle coating system be used (i.e. not epoxy) to avoid differences and cycle effects with regards thermal expansion?
    Our composite coating is much less brittle than conventional materials. We have millions of tubes in service from 25c to 150c and have never had a thermal expansion issue. A standard test is to cycle a coating from -20c to 100c in 1hour cycles to test for TE disbondment.

26. What is the effect of over temperature events (Unit islanding, passing steam drains)?
    Our coating has passed steam condition tests up tp185c for five one week cycles. It is typical for petrochem plants to steam out the od of the tubes at 150c for 12-24 hours to remove hydrocarbons.

27. What is the average life expectancy of the coatings and in what operating conditions has this been realised?
    Please provide typical examples and “best case”). Are there any particular circumstances or conditions, which are likely to significantly reduce this? Life expectancy is 15 years. Currently, the first large scale application which was applied in 1993 is still intact and protecting the tubes. We have made significant improvements in all aspects of surface prep, materials, and application since this effort, so achieving 15 years is very realistic. This first condenser is operating in once through sea water at 20 to 30c. I cannot define any particular life limiting issues in a condenser.

28. Must the waterboxes be removed to apply the coating?
    We can apply the coating with the water box on, but it is a single tube system. If we can remove one side of the waterbox we are able to use a coating application system that can coat four tubes at a time. It is obviously out preferred method.

29. What outage period is required to clean and coat a condenser with typically 20 000 tubes, each 10 meters long and 1 inch diameter?

14 to 21 days.

30. Can plugged tubes be recovered with the coating?
Yes, we have recovered tubes with 1.5mm holes and successfully returned them to service. We have 6 years of service on our earliest recovered tubes.

31. Typically what guarantee's will be offered?
Generally, we provide a one year guarantee to cover our application. We will extend our guarantee to the point of full economic recovery by Esom.

32. Can condensers be recoated after the first application? What are the implications?
Condensers can be recoated. The existing coating tends to remain in the deep pits when the tubes are grit blasted again, which is ideal for over coating. There are no other variables/implications, you are simply starting over again with new coating.

33. What are the limitations and restraints of this technique?
I can not think of any immediate large limitations we have not already mentioned such as temperature limits, chemical exposure, and fluid velocity. Where additional mechanical support is needed, such as tubes broken off behind the tubesheet ,from SCC, hydrogen imbrittlement, or ammonia attack, we will install inserts and coat over them into the remaining tube. We coat tubes every day that go into a multitude of services.

34. What affect has dynamic loading on tube coating system. (I.e. vibration or resonance of condenser tubes) in cases such as when baffle plates are worn or where a bypass system is fitted?
We have no data on dynamic loading. It is common of our previous applications that condenser tubes exhibit atypical corrosion at the baffle plates and tube sheets. We have not seen any evidence of premature coating failure in these areas.

35. Are solvent-free coatings or solvent borne coatings your preferred coating and what are the merits of the preferred option? Where disadvantages have been identified how are these mitigated and managed?
We can and do apply solvent free and solvented coatings. We prefer the solvented coatings at this time because of many factors. The main reason is service history. We have coated millions of tubes and have enjoyed years of excellent service. Solvented coatings are easier to spray, provide a very uniform coating film inside the tube, have excellent pit filling characteristics, and have longer over coat windows. The main disadvantage of solvented coating is the solvent. We ventilate the water boxes with pneumatic air movers and exhaust it to outside the box, or the plant if needed. There is generally a slight odor within 15 meters of the coating activity but it has never registered any level of LEL. Other work has never been encumbered around the immediate application area unless it was hot work.