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Long Term Restoration to Address Condenser Tube Inlet End Erosion/Corrosion

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Abstract:

During 1982 a west coast utility unit was experiencing frequent condenser tube leaks in the inlet end of the seawater cooled condenser employing copper alloy tubes. These leaks were identified to be the result of inlet end erosion/corrosion. Based on measurements of statistically significant tube samples, high numbers of tube failures were projected for the near future. Three alternatives were evaluated to remedy the problem:

- Retube the condenser
- Install inlet end protective shields
- Epoxy coat the inlet end of the tubes

All tube samples pulled prior to 1982 had shown little or no erosion/corrosion in areas other than the inlet end after more than 14 years service. The same was also noted in other units at the station for up to 20 years service. Since the causes of the difficulties were isolated to a specific section of the condenser. It was expected that the inlet shield would be quite effective in eliminating the inlet end erosion problem without causing any harmful side effects on the tubes or tube sheet with properly maintained cathodic protection and ID tube cleanliness program.

Recently a tube specimen was removed during the 2004 maintenance outage to determine root cause failure of a leaky tube that was plugged prior to the outage. The leak was determined to be the result of through wall damage from steam impingement that had occurred near the exit end of the condenser tube. Inspection of the tube section that contained the sleeve insert confirmed that the inserts were performing as intended in 1982 projection in providing inlet end protection of the condenser tubes to allow for long-term restoration of the condenser tubes.

Background:

The seawater-cooled condenser consists of 1-inch OD, 20 BWG 90-10 CuNi tubes and Muntz metal tube sheet with zinc waste plates for cathodic protection. Tube failures were occurring at a frequency of once a week with multiple tube leaks were starting to become a trend. Based on the trend the frequency was expected to increase. In order to prevent boiler damage and leak detection expenses the installation should be done in the most expeditious manner possible. Highlights of the three alternatives evaluated are as follows:

Retubing:

- Most reliable method
- Most expensive in terms of installed cost were 6.41 times sleeve inserts and 8.33 times epoxy coating.
- Most outage time-4weeks unit had to be off line.

Epoxy:

- Least reliable for long term due to brittleness of coating and potential for pin hole leaks
- Concern regarding the use of metal and brush scrapers used to periodically clean the condenser tube ID surfaces of deposition and marine growth may damage the epoxy coating. Maintaining the cleanliness of the waterside of the condenser tubes is essential in prolonging the life of the tubes.
- Least expensive in terms of installed cost and outage cost ~30% less than installing sleeve inserts
- Least outage time-1 week unit had to be off line.

Inlet end Shields (Metal Inserts)

- Industry experience had noted improper or lack of cathodic protection (a must with seawater cooling) could result in localized pitting at the downstream transition where the shield ends ~6" into the condenser tube. An example of the failure is shown in pictures 1 and 2.
- Only slightly more expensive than epoxy coating
- Could accommodate metal and brush scrapers used to periodically clean the condenser tube ID surfaces of deposition and marine growth.
- Least outage time-1 week. With condenser half out of service could be done on line.

Inlet end Shields (Plastic Inserts)

Plastic inlet inserts were another option but industry experience was not favorable for use long-term restoration and was not considered as noted in the following findings:

- They tended to provide protection for a period of 2-10 years
- Due to the thickness at the inlet the sleeve resulted in an ID reduction of around 35% at the tube entry
- The plastic inserts are glued in versus expanded into place as the case with the metal sleeve. Plastic inserts does not insure correction of the inlet end corrosion parent tube to tube sheet integrity as is the case with metal inserts.
- Plastic liners tend to work out of the tube over time. The void around the lip of the inlet end of the insert has resulted in severe tubesheet ligament damage to tube sheets.
- The 35% reduction inhibits cleaning the tubes with any proper sized cleaning device as nothing that goes through the insert has any chance of cleaning and maintaining clean condenser tube ID surfaces. Maintaining the cleanliness of the waterside of the condenser tubes is essential in prolonging the life of the tubes.
- If a tube leak develops is very difficult to get proper seal of the plastic liner to the tube sheet to address any leaks at this interface.
- Based on the issues with plastic inlet sleeves within the U.S. Navy ship main condensers all of the plastic inserts were being removed from the ships condensers and replaced with metal shields.

Short Term versus Long Term Benefits:

All tube samples pulled prior to restoration measures have shown little or no erosion/corrosion in areas other than the inlet end after more than 14 years service. Therefore, with continued ID tube maintenance cleaning program the minimum expected service life of the tubes following shield installation should approach or exceed another 14 years. Due to the relatively low cost of the project and the resultant payback of less than 9 months with higher degree of confidence of continued service life of the tubes versus epoxy coating, the recommendation was to have CTI Industries install AL6X shields.

Twenty-Two Years Later:

During 2003 the condenser had develop a condenser leak. It was the first leak to occur in a number of years. Early 2004 another condenser leak in the same area was identified and plugged. As part of a scheduled maintenance the tube that was recently plugged was pulled to determine root cause failure analyses. The tube had failed as a result of OD through wall pitting from steam impingement near the exit end of the condenser.

As part of the metallurgy assessment of the removed tube, the tube inlet and protective shield were also examined. The concern was that as part of an environmental up grade, the cathodic protection was changed from zinc waste plates to impressed current during 2000. Of specific concern was the interface between the shield exit end and the condenser tube where the potential for galvanic corrosion has the highest potential for corrosion to occur (reference pictures 1 & 2).

There was no evidence of any erosion or corrosion at the exit end of the shield. Pictures 3 and 4 show the as found condition of the inlet tube surface below the shield and at the shield exit end after cleaning to remove tube oxides.

Conclusion:

Based on the 22 years of continued service and the findings of the metallurgy examination, the decision to install protective inlet shields to provide long-term restoration of the condenser was the correct choice. Emphasis in maintaining proper cathodic protection and maintenance cleaning program for the tube ID surfaces are essential requirements for prolonging the life of tubes. The shield's internal diameter did not deter from the ability to continue to use mechanical cleaning devices required periodically for maintenance cleaning of the condenser tubes.

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