CONDENSER AND HEAT EXCHANGER TUBE RESTORATION
NRG – INDIAN RIVER POWER PLANT

BY:
PETER TALLMAN
CTI INDUSTRIES, INC.

AND

JIM SMITH
NRG

PREPARED FOR PRESENTATION AT:

ASME POWER 2004
BALTIMORE, MARYLAND
MARCH 30 – APRIL 1, 2004

CONDENSER AND HEAT EXCHANGER TUBE RESTORATION

Introduction

It is common experience that many failures of condenser tubes in the electric utility industry occur within the first six inches of the bundle. Frequently encountered forms of such tube end damage are erosion, impingement attack, stress corrosion cracking and pitting/crevice corrosion. The damage variously manifests itself as tube thinning, grooving, localized pitting and cracking, all of which can ultimately lead to leakage and tube failure.

In the past, the accepted solution for repairing this highly localized tube damage has been full retubing, even though usually more than 95% of the tube bundle length remains largely unaffected. However, this is a radical solution, which is very costly and time consuming. Today, with the emergence of deregulation of electric utilities, a proven, cost-effective alternative to retubing must be strongly considered by plant engineers.

Historically, the most familiar stratagem for protecting damaged tube ends against further erosion or erosion-corrosion, and thus extend condenser tube life, is the use of plastic inserts. These inserts or tube protectors are only partly effective because they are not pressure tight and therefore unsuited for restoring leaking tubes to service. Also, plastic inserts can cause end step erosion and tend to become dislodged over time, especially during cleaning and back-flushing operations.

With the objective of dealing with these shortcomings, a new restoration technique was developed in the mid-1970's. It makes use of thin-walled metallic inserts, variously referred to as I.D. tube shields, or sleeves, which are expanded into the existing tube ends, adding years of additional service to the exchanger.

The characteristics and capabilities of metallic tube inserts are described below. Also, briefly covered for sake of completeness are tube restoration/protection methods that make use of non-metallic materials.

Common Tube Failure Mechanisms

Inlet end erosion is a common problem with copper alloy condenser tubes, caused by the kinetic force of the cooling water, particularly if it contains entrained abrasive solids. Changes in flow direction, eddying and air bubbles combine to create highly turbulent conditions at tube inlets, resulting in impairment of protective passive films on the tube I.D. About six inches into the tube, turbulent flow conditions change to laminar flow, and fluid erosivity is sharply reduced. Other factors that can contribute to high turbulence are unfavorable design configurations of the waterbox and inlet piping.

With fluids containing corrosive constituents, tube wastage can be greatly exacerbated. This so-called erosion-corrosion is a synergistic phenomenon wherein the combined action of erosion and chemical attack are greater than their separate effects. Corrosive process fluids most commonly cause erosion-corrosion. However, it can also occur with waters, as for example with brasses exposed to sulfide and/or ammonia treated cooling waters.

Stress Corrosion Cracking (SCC) is another fairly common failure mode in condenser tubing. It is caused by the combined action of tensile & compressive stresses and corrosion. SCC frequently occurs in the rolled area immediately beyond the tubesheet, especially with overrolling, and is metal-environment specific. Well-known forms are ammonia SCC of copper base alloys, chloride SCC of austenitic stainless steels and alkali SCC (caustic embrittlement) of carbon and alloy steels. These failure mechanisms can occur in the **outlet** tube ends, as well as the inlets.

Other types of corrosion encountered in tube ends and at tube-to-tubesheet joints are pitting attack and crevice corrosion. Crevice corrosion is a virulent form of deep local penetration, experienced most often with austenitic (Cr-Ni) stainless steels exposed to chlorides. Both SCC and crevice corrosion are greatly accelerated at elevated temperatures. Damage at this critical location of the inlet tubesheet and tube ends can also be caused by mechanical factors (e.g. improper tube expansion) and by poorly executed tube-to-tubesheet welds.

I.D. Tube Shields

Metallic thin-walled inserts or “shields” were introduced in 1976. This restoration process protects, restores and seals the damaged tube ends. The shields are manufactured to specific dimensions while retaining ductility required for expansion. A thin-walled construction, I.D. chamfer of the outlet end and metal-to-metal expansion greatly reduces the chance of end step erosion, a common occurrence with other tube inserts.

As in the case of the condenser tubing, selecting the proper shield alloy is critical. Material can be selected from a range of different alloys, depending on existing tube material and their failure mechanism. Choices of shield material range from copper alloys, conventional stainless steel, superaustenitic stainless steels and nickel-base alloys. This allows the plant to select an alloy to combat a specific failure mechanism such as chloride pitting, stress corrosion cracking, ammonia grooving, etc.

The installation process is carried out in-situ beginning with wire brushing tube I.D.’s allowing for a pressure tight seal to hold the shield in place. After the tubes are blown clear with compressed air, I.D. measurements are taken to determine expansion requirements. Shields are then inserted into each tube end. A hydroswage mandrel is inserted into the shields. The mandrel is coupled to the strain volume control hydroswage pump, which is preset to achieve full-length expansion of the shields. A hybrid expansion is then accomplished by roller expanding the shields at the tubesheet to torque controlled settings. The final step is to flare the shields so that they conform to the tubesheet profile.

This repair is not a temporary repair but a true restoration that will add years of service to the existing condenser. One West Coast facility states that “the first condenser which was sleeved was intended to be a short-term five (5) year fix. These same tubes are still in service twenty (20) years later with no problems.”

Besides condensers, shields have been installed in high-pressure heat exchangers (4200 psi) and high temperature service (1200°F). In some cases, though not typical, shields have been able to “bridge” tubes that have been completely severed.

Tube restoration by means of metallic inserts is a cost-effective repair method offering the following favorable features and capabilities:

- Restore and protect the damaged tube ends.
- Restore tube-to-tubesheet joint strength.
- Provide pressure tightness.
- Return plugged, leaking tubes to service.
- Enable the tubes to maintain mechanical cleaning capabilities.
- Minimizes end-step erosion possibility.
- Installation during low-load conditions.
- Have no ill effects on heat transfer.
- Reduce outage time.
- Extend bundle life.

Because of the thin-wall construction and the expansion of the shield, tube openings are reduced by only a fraction compared to considerably thicker plastic inserts.

Plastic Inserts

Flanged or flared plastic inserts or tube protectors were originally developed for the specific purpose of alleviating inlet end erosion. They are typically four to eight inches long, and furnished in a range of conventional thermoplastics or fluoroplastics. Installation is either by press fit or by cementing in with an adhesive.

Plastic inserts are furnished in pre-set standard diameters based on new tube dimensions, which makes them an inexpensive commodity. However, they do not provide for tube wall loss or irregular wear of the tube I.D. Even though the downstream end of the insert is tapered, end-step erosion takes place in the tubes immediately beyond the inserts. This is caused by the turbulence of the circulating water exiting the insert and entering the parent tube I.D. Therefore, although the inlet end erosion has subsided, a new problem has been created.

Another drawback in the design of the plastic insert is the reduced I.D. at the flanged area. Depending on the insert O.D., the thickness of the insert can range from 0.042 in. to 0.130 in. This could mean a reduction of the original tube I.D. of over 30%, severely restricting the amount of circulating water entering the tube.

Other problems associated with plastic inserts are that they:

- Do not restore structural integrity to weakened tube-to-tubesheet joints
- Do not restore plugged/leaking tubes to service
- Do not fit properly in eroded tubes
- Prevent proper mechanical tube cleaning
- Frequently become loose or dislodged
- Promote crevice corrosion
- Cannot be installed into **outlet** tube ends

Epoxy Coatings

Application of epoxy coatings has recently emerged as a suitable method for restoring eroded/corroded I.D. surfaces of condenser tubes, as an extension of its application on tubesheets and waterboxes. Coating systems applied are phenolics, epoxy phenolics and fluoropolymers. Coating performance and life is critically dependent on meticulous surface preparation and coating application, particularly on pitted surfaces, and requires specially developed devices.

Unfortunately, the quality assurance necessary to ensure proper surface preparation of the tube I.D.'s remains suspect. Because this is still considered "new technology", the effective life of this type of repair is still unknown.

Other problems associated with epoxy coatings are that they:

- Do not restore structural integrity to weakened tube-to-tubesheet joints.
- Do not restore plugged/leaking tubes to service.
- Cannot be applied during low-load conditions.
- Can be damaged by certain types of mechanical cleaning
- Can create condensate contamination by abrasive grit passing through weakened or failed tubes.

NRG – Indian River Power Station

Indian River Power Station, located near Millsboro, Delaware, consists of four coal-fired units with a combined capacity of more than 750 megawatts. Unit 1 went in to service in 1957 and has a capacity of 90 megawatts. Unit 2 followed in 1958 and also has a capacity of 90 megawatts. Unit 3 came on line in 1970 adding 165 MW. Unit 4 started up in 1980, adding 424 MW to plant capacity.

Units 1 and 2 have Westinghouse condensers. Unit 3 has a DeLaval condenser. The closed cycle system for units 1 and 2 is cooled by three Yuba closed cycle heat exchangers. The 1, 2 and 3 condensers (and coolers) are all single pass, with 70/30 CuNi, 18 BWG tubes. Unit 1 and 2 condenser have 7,796 tubes – 7/8" O.D. x 28 ft. in length. Unit 3 condenser has 8,984 tubes – 7/8" O.D. x 34 ft. in length.

In the mid-70's, plastic inserts were tried at the inlet ends of the unit 3 condenser tubes. This was done due to forced outages caused by inlet end erosion. Initially this stopped salt leaks due to erosion, but soon, failures appeared downstream of the inserts because of the turbulence at the exit end (interface with the tube). The inlet end erosion had simply moved 6 inches downstream, to the ends of the inserts creating "end-step corrosion".

In 1993, Unit 3 condenser tube inlets received a down-tube coating, 6 to 9 inches. This effectively stopped tube-end erosion, but required regular inspection and repair, and ruled out shooting the tubes with scrapers.

In 2001, after a regular brush cleaning ´C` closed cycle cooler was hydrostatically tested and showed several leaks. It was decided to try tube end shields and the unit was returned to service. The following year ´B` cooler also had shields installed with positive results.

In the fall of 2002, after a standard brush cleaning of the unit 2 condenser, inspection indicated severe inlet end erosion. It was decided to install shields in the unit 2 condenser. The air removal sections were repaired first. The perimeter tubes await an outage to complete the installation.

In spring 2003, unit 3 condenser was partially retubed. The upper half received new 70/30 CuNi tubes. The tubes in the bottom half were in good condition except for the inlet ends. It was decided to install shields in the lower half of the condenser, saving the cost of a full retube.

In late spring 2003, after cleaning unit 1 condenser; the same inlet end erosion was noted. Unit 1 had been experiencing sporadic salt leaks. In this case the B-side of the condenser (B waterbox) had tube shields installed on the inlets. ´A` side awaits an outage for completion.

- Cost to sleeve the tubes in 1B waterbox: $17,562.00
- Cost of a full retube of unit 1 in 1985: $450,000.00
- Projected savings vs. retube: $415,000.00 (94%)

All condenser and heat exchanger shields were manufactured in 70/30 CuNi material with a 0.020" wall thickness in lengths from 6-8 inches. In some instances, collars were installed with the shields due to the severity of inlet end erosion. The installation was performed via mechanical expansion for the first and last inch of shields.

In late fall of 2003, ´A` closed cycle cooler was sleeved.

- Cost to sleeve the cooler: $13,370.00
- Cost to fully retube the ´A` cooler: ~$162,000.00
- Savings vs. retube $148,630.00 (92%)

In each case, tube sleeving:

- Saved the present cost of a full retube
- Ensured reliability of the system
- Allowed the plant to defer full retube costs for hopefully 10 years or beyond