A TRUE CONDENSER TUBE RESTORATION
COMPOSTILLA POWER PLANT

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INTRODUCTION

Endesa’s Compostilla Power Plant is located in Ponferrada (León), Spain, commissioned in 1964. It is a coal-fired power plant with a capacity of 1292 megawatts spread across five (5) turbines, which are a combination of Westinghouse and Mitsubishi.

The cooling water for the steam condenser is a closed loop system, coming from a cooling tower with water from a local reservoir in unit 4 and 5, and open loop in 1, 2 and 3.

The Unit G-4 condenser was started up in 1981. The unit consists of 24,740 tubes, 800 of which are in the Air Removal sections. The 800 Air Removal tubes are 1” O.D. Type 304 Stainless Steel. The main body of the condenser tubes (23,940 nos.) are made of Admiralty Brass, Alloy C44300, 1” O.D. (25.4mm) x 18 BWG (.049”/1.245mm wall thickness) x 30’3” long (9,220mm).

Within a few years, the inlet-ends of the Brass tubes began to experience inlet-end erosion. Therefore, in 1987, the power station installed plastic tube inserts (6” / 150mm long) in all 23,940 Brass tubes. Although the plastic tube inserts protected the ends of the tubes, a phenomena known as “end-step erosion” began to take place at the exit end of the insert. Over time, the end-step erosion resulted in severe wall loss and eventual failures in the area of the tube just beyond the insert.

With the plant engineers now in a precarious position regarding the G-4 condenser, considerations were given to the possible repair methods.

FAILURE MECHANISMS

Inlet end erosion is a common problem with copper based condenser tubes, caused by the kinetic force of the cooling water. Entrained 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.

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.

Another type of corrosion encountered in tube ends and at tube-to-tubesheet joints is 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 tubesheets and tube ends can also be caused by mechanical factors (e.g. improper tube expansion) and by poorly executed tube-to-tubesheet welds.

TUBE END REPAIR METHODS

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 inlet-end erosion, chloride pitting, stress corrosion cracking, ammonia grooving, etc.

This repair is not a temporary repair but a true restoration that will add years of service to the existing condenser. One U.S.A. facility located in California 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 tube shields 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.
- Stiffens tubes, reducing vibration.
- 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 allow 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 emerged as an acceptable method for protecting condenser tube ends, 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 and the effective life of this type of repair is unknown. Other problems associated with the epoxy coating of tube I.D.'s are that they:

- Do not restore structural integrity to weakened tube-to-tubesheet joints.
- Do not restore leaking tubes to service.
- Make tube end/tube joint leaks undetectable.
- Can be damaged during conventional tube plugging.
- Cannot be applied during low-load conditions.
- Can be damaged by certain types of mechanical cleaning.
- Require regular inspection and repair.
- Can create condensate contamination by abrasive grit passing through weakened or failed tubes.

RESULTS

After evaluating their options, Compostilla engineers elected to install tube end shields for the repair of the G-4 condenser. Besides the aforementioned advantages and disadvantages, Endesa also wanted to recover the mechanical rigidity of the parent tubes, which I.D. coating could not do. Plastic inserts were ruled out for the same reason, along with the fact they had caused end-step erosion. An order was then placed for 24,000 shields of 70/30 CuNi (Alloy

C71500) material. The 70/30 was chosen because of it’s compatability with the Admiralty Brass tubes, and its’ improved erosion/corrosion resistance. The shields were 12” (300mm) long with a 0.020” (0.5mm) wall thickness, flared on one end and I.D. chamfered on the opposite end.

In October 2003, during a one-week outage, plastic inserts were removed using slidehammers coupled with tapered, threaded spears. The inlet ends wire brushed and tube I.D.’s measured and recorded. Shields were then inserted into each tube end and a hydraulic mandrel inserted into the shields. The mandrel is coupled to the strain volume control hydraulic pump, which is preset to achieve full-length expansion of the shields. A “hybrid” expansion was then accomplished when the flared end of the shield at the tubesheet was expanded to a torque setting by use of a conventional tube expander. The downstream end was then expanded using a mechanical setting, therefore avoiding any possibility of over-expansion. The final step was to seat the flare of the shields so that they conform to the tube-to-tubesheet profile.

SUMMARY

In less than 7 days, Compostillas’ G-4 condenser was fully restored. In addition, approximately 900 previously plugged tubes were returned to service. The plant now has a leak-free condenser that will be able to perform reliably for the next 10-15 years. The repair was carried out at a price of $320,000. Compared to a retubing price of approximately $1.5 million (excluding the Air Removal sections), the station was able to save nearly $1.2 million, or 21%, vs. the cost of a partial retube.