Moly does the Job

This article is the latest in a series of case histories where the application of moly has helped companies to solve technical problems which have occurred. Nicole Kinsman of Technical Marketing Resources (Consultants to IMOA) is the author and she will continue to write similar articles for future issues of this Newsletter.

Edward Blessman of Trent Tube, East Troy, Wisconsin, contributed the information in this article and IMOA would like to thank him for his assistance.

Summary

Many aging US power plants have copper alloy condensers that are suffering from erosion or corrosion. Leaking tubes have to be plugged. This requires plant shut down and leads to reduced heat transfer and lower efficiency. Many power plants have solved the problem permanently by replacing the tube bundles with 4 to 6% molybdenum- containing stainless steels. The better thermal performance of stainless steel re-tubed units, and the lack of unscheduled outages due to leaking condenser tubes, more than compensate for the initial design and installation cost of the new tubing.

The Process

A critical part of any power plant is its condenser. It cools the steam from the turbine and condenses it to water that is recycled back to the boiler. The amount of power that is generated is correlated to the temperature difference between the steam temperatures at the inlet and outlet of the turbine. To minimize the condensate temperature, the condenser must maximize the heat transfer between the cooling water and the steam. Good thermal conductivity and large surface area of the tubing are the most important parameters for optimal heat transfer.

The Corrosion

Copper alloys have excellent thermal conductivity and, therefore, have been used traditionally as condenser tubing material. However, brass and copper-nickel alloys are susceptible to erosion, sulfur pitting corrosion, and both ammonia grooving and cracking from the steam side.

A leak in a condenser tube can lead to the contamination of the high purity boiler water. This contaminated water can damage the boiler and the turbines. For this reason a leaking condenser tube has to be plugged quickly and this may require an unscheduled shut down of the plant.

Another limitation of copper alloys is the copper contamination of the effluent water and the condensate. Environmental regulations strictly limit the release of copper into lakes and rivers. Often the only way to comply with these regulations is to eliminate all copper-containing

(Continued overleaf)

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alloys from the heat exchanger tubing. Copper in the condensate can also deposit in the boiler or the turbine and cause damage to the equipment.

The Solution

Stainless steel condenser tubing solves all of these problems. There have been more than 35 million meters (almost 115 million feet) of stainless steel (all grades) condenser tubing installed in the US in the last five years (an average condenser may use 100,000 meters, a large nuclear power plant condenser can use up to 1 million meters). Over 3.5 million meters (11.5 million feet) were high performance 4 to 6% molybdenum stainless steels. Traditionally the 6% Mo high performance austenitic grades were the most common, but in recent years an increasing number of plants have specified the 4% Mo super ferritic grades because of cost advantages. Six major plants have re-tubed with high performance ferritics in the last two years, and many more are in the planning stages for the next few years.

The ferritic stainless steels are especially well suited for re-tubing of copper alloy condensers due to their unique combination of properties. Copper tubing typically has a heavy wall thickness [0.049 inch (1.25 mm)] to compensate for its relatively low strength, low modulus of elasticity and its susceptibility to erosion. The better mechanical properties of high performance ferritic stainless steels allow the use of the same condenser designs with walls as thin as 0.028 inches (0.7 mm). The good heat transfer of the ferritics ensures that the thermal performance of the condenser remains high. Long-term thermal performance is enhanced compared to copper alloys, because the very smooth surface of stainless steel tubing minimizes fouling and remains cleaner.

The high performance stainless steels are also resistant to erosion. When plant design will permit, it is advantageous to increase the cooling water flow velocity. The higher velocity increases heat transfer and improves the clean liness of the condenser.Higher flow rates are among the most economical methods to improve condenser performance.
Stainless steels easily tolerate velocities of 5 m/sec (16.4 feet/sec) without erosion.

Most of the units re-tubed with high performance ferritics and austenitics are cooled by brackish or sea-water. These grades were chosen because of their high chloride resistance. There are also many fresh water-cooled units that could be re-tubed with standard austenitic stainless steels such as Type 304 or 316. However, their plant owners selected high performance ferritics instead. This "over-design" ensures reliability in case of upset conditions or future changes in the water chemistry, and helps to insure against forced outages because of condenser leaks.

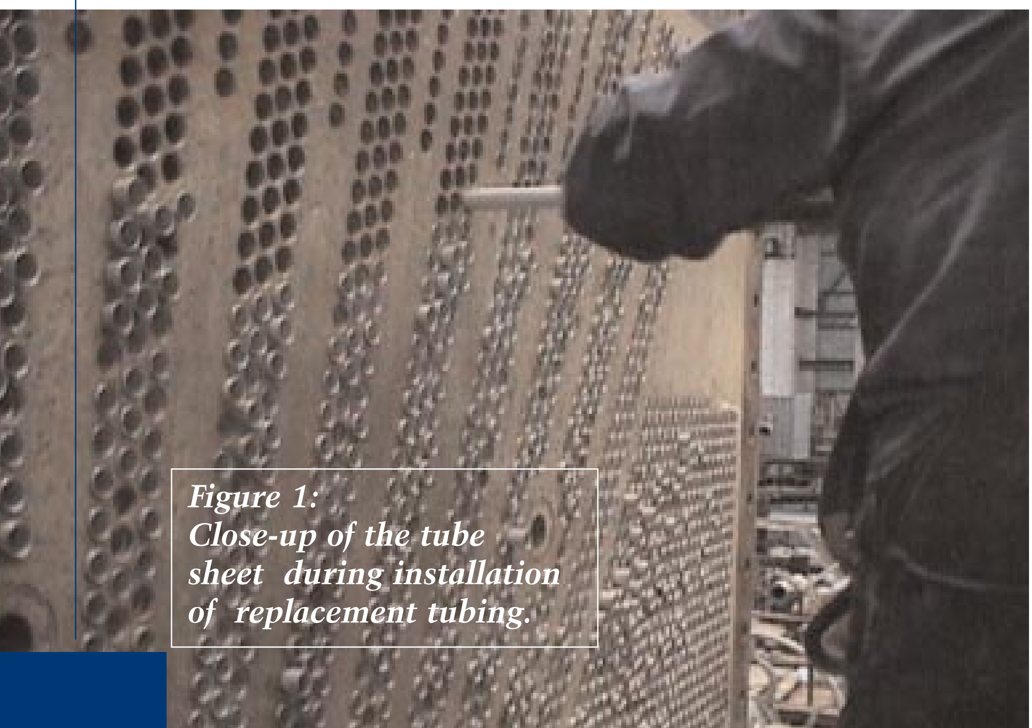

Figure 1: Close-up of the tube sheet during installation of replacement tubing.

The Cost Savings

The reasons driving power plants to upgrade condensers are improved reliability and profitability, and compliance with environmental regulations.

The trend toward high Mo stainless steels has accelerated with the transition toward an open electricity market in the US. Power plants now compete for business, and if their costs are low enough, they can sell all of the power that they can generate.

The most efficient power plants can generate power for less than $20 per MWhr. On the spot market, at times of peak demand, for example on a hot summer afternoon when air conditioners are running, power prices can be over $500 per MWhr. If a plant is off–line during a time of peak demand, it loses the opportunity to sell surplus power and it is forced to buy replacement power. For example, if a 300 MW plant shuts down for 10 hours to plug leaking tubes, it loses 3,000 MWhr of generation capacity. This power costs as little as $60,000 to generate, but, it may cost as much as $1,500,000 to purchase the replacement power from another plant.

Many older plants have a significant number of plugged condenser tubes. The leaks often stem from old ‘accidents’ and upsets. This reduction in heat transfer surface area may have a small effect on plant profitability during a time of low demand. However, any loss of heat transfer will hurt generating capacity most during hot weather, when the cooling water is warmer and does not have the same cooling capacity. Unfortunately, this is exactly when demand for power and its price are the highest.

Table 1: Typical Composition of High Performance Stainless Steels in Weight Percent

		UNS No.	Cr	Mo	Ni
Ferritics	SEA-CURE®	S44660	27	4	2
	AL 29-4C®	S44735	29	4	0
	FS 10®	S44800	29	4	2
Austenitics	AL-6XN®	N08367	21	6.5	24
	254 SMO®	S31254	20	6	18

Table 2: Typical Properties of High Performance Stainless Steels

		UNS	Thermal Conductivity [Btu/ft hr °F (W/M °C)]	Modulus [10^6 psi (GPa)]	Yield Strength [ksi (MPa)]
Ferritics	SEA-CURE®	S44660	9.5 (15.9)	31 (213)	75 (517)
	AL 29-4C®	S44735	9.5 (15.9)	31 (213)	80 (552)
	FS 10®	S44800	9.5 (15.9)	31 (213)	85 (586)
Austenitics	AL-6XN®	N08367	7.5 (13)	28 (193)	55 (379)
	254 SMO®	S31254	7.9 (13.7)	29 (200)	50 (345)

The 4% Mo ferritic and the 6% Mo austenitic high performance stainless steels are playing a significant role in improving the availability, reliability, capacity and economics of power plants in the US.

Readers with similar experiences, where moly has assisted in solving problems, are invited to contact the Secretariat.

Congratulations to our Consultants, Technical Marketing Resources of Pittsburgh! The firm has been hired by the Johnson Space Centre to assist in the selection of materials (stainless steel) and surface finish for the tools and enclosures to hold the Mars rock and soil samples which will be brought to Earth as part of the Mars Surveyor 2005 project.