HAVE YOU CONSIDERED STAINLESS STEEL CONDENSER TUBES?

Many advantages are to be realized by use of stainless steel tubes, not the least of which is their excellent corrosion resistance.

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Today, over 60 million ft. of stainless steel tubing has been purchased for use in steam surface condensers in the electric utility industry. Every passing year has seen more of it purchased for this application. Currently, about one-half of this industry's requirements for replacement tubes and new installations is being met with stainless steel. A large part of the growth in this field certainly must be attributed to a favorable cost and reliability relationship.

Need for reliability

Some potential users of stainless steel steam surface condenser tubes have questioned the reliability of stainless steel in this application. Unjustified concern about stress corrosion cracking causing massive failures has in some instances caused those persons to shy away. This form of corrosion of stainless steel tubes in steam surface condensers has not occurred, and the likelihood of its future occurrence appears to be remote.

Consider for a moment the sequence of events resulting from condenser tube leakage in the new high pressure steam systems utilizing once-through boilers. Return condensate, having become corrosive from contamination by the cooling water, could eventually cause a boiler tube failure. Such a failure would represent a serious threat to the safety of persons in that area. As a result, the reliability of the condenser tubes plays an important role in preventing such hazards from occurring.

The following will examine all of the factors influencing the selection of the condenser tube material in the order most frequently discussed with those not familiar with stainless steel. Certain operating considerations and precautions that should be observed to insure the continued reliability of stainless steel condenser tubes will also be presented.

The material cost factor

Initial applications of stainless steel steam surface condenser tubes were in severe corrosive environments where the increased reliability of stainless steel was desired. The cost of the material, in those instances, was not the prime consideration. Today, the potential user finds, much to his surprise, that he can obtain this increased reliability at no cost penalty.

The current market finds that the cost of a welded, cold drawn and annealed stainless steel condenser tube is priced to be competitive with a copper based alloy tube. This situation has largely resulted from the increased volume of stainless steel condenser tube production, coupled with refinements in manufacturing techniques.

Stainless steel has a justifiable reputation for poor heat transfer when the material's inherent heat transfer ability is the sole consideration. It was for this reason, as well as material costs, that stainless surface condenser tubes are produced with a lighter or thinner tube wall than copper based alloy tubes.

Source of resistance to heat transfer

An analysis of the overall or total heat transfer in a steam surface condenser, shows that the tube resistance to heat transfer composes about 2% of the total resistance under severe fouling conditions. The primary resistances to heat transfer are caused by films and fouling on the tube surfaces.

In as much as stainless steel condenser tubes normally have less steam and waterside fouling, many installations have unofficially reported equivalent heat transfer performance with stainless steel tubes of 0.028 in. wall when compared to previously used copper based alloy tubes of 0.049 in. wall. These results have also been attributed to the lack of a corrosion product buildup on the stainless steel tubes.

These reports are currently being investigated because potential users can be faced with a calculated long term cost penalty for stainless steel based on heat transfer factors used in engineering design. The important condenser tube factors used in the calculation of the overall heat transfer coefficient are the material and gauge factor and the cleanliness factor. The former is a ratio based on 18 BWG admiralty which is established by the Heat Exchange Institute for new tubes. This factor has been revised once for 22 BWG stainless steel from 0.69 to 0.79 and based on present service data, the possibility exists for another favorable increase.

The effect of service exposure on the clean tubes is considered in the cleanliness factor, which is usually taken as 0.85 for design purposes with copper based alloys in normal waters. Actual cleanliness factors can be much less because of fouling and corrosion product buildup. A 0.9 design cleanliness factor for stainless steel tubes is not uncommon because stainless steel tubes have been found to retain more of their original heat transfer rate than copper based alloy tubes. Actual cleanliness factors have been higher than 0.9 and in some cases, have exceeded the clean tube heat transfer rate based on the 0.79 material and gauge factor. Tests have shown that the heat transfer rate of a 22 BWG stainless steel tube can exceed that of an 18 BWG admiralty tube after service exposure because the stainless steel tube had a higher actual cleanliness factor.

Installation and compatibility

Due to the differences in mechanical properties between stainless steel and non-ferrous materials, those unfamiliar with stainless steel may question the relative ease of installation of stainless steel tubes compared to non-ferrous tubes.

Expansion into the tube sheet usually represents the primary concern. However, experience has shown that stainless steel tubes can be easily rolled into the tube sheet using conventional equipment and techniques. Maintaining a 5% reduction in wall thinning with a torque controlled tube expander during rolling results in leak-free joints. Flaring the rolled tube ends when desired is also accomplished employing standard tools. The flared diameter should not exceed 125% of the original diameter.

In the past, there has been some concern regarding the installation costs of stainless steel tubes. Contract condenser tube installers may have a tendency to estimate higher installation costs for stainless steel tubes because of their unfamiliarity with the material. However, a recent large installation of stainless steel tubes was completed in less time than that required for a sister unit having admiralty brass tubes in the main bank and stainless steel tubes in the air removal and steam impingement areas.

Galvanic and crevice corrosion between the stainless steel tubes and the tube sheet was originally considered as a potential problem. To date, stainless steel tubes have been installed in tube sheets manufactured of all the commonly used materials with no evidence of any steam or waterside compatibility problems.

Galvanic corrosion problems never materialized because the most frequently used alloy-surface area combinations always follow safe design practices for combating this form of corrosion. Crevice corrosion just does not appear to be a factor in these environments.

Corrosion resistance

The excellent corrosion resistance of stainless steel formed the basis for the introduction of this material into the steam surface condenser tube application. Stainless steel tubes were originally selected to solve specific corrosion problems encountered with copper based alloys. Time has shown them to be resistant to ammonia attack, impingement erosion-corrosion, and general or overall corrosion. Such problems as copper pickup in the boiler water, ammonia stress corrosion cracking, and tube wall thinning caused by corrosion or erosion-corrosion have been successfully eliminated by stainless steel tubes. Examination of tubes which have been in service show that an indefinite service life can be expected if proper maintenance programs are followed.

The only corrosion problem ever experienced with stainless steel tubes has been chloride pitting corrosion. This form of corrosion can result in pinhole tube wall penetrations. Service experience has shown this to be a minor problem more likely to occur in coastal installations where the cooling water has a high chloride content.

The most commonly used stainless steels for steam surface condenser tubes are types 304 and 316. Resistance to chloride pitting corrosion is greater with type 316 and this alloy is usually selected when the chloride content of the cooling water exceeds 1,000 ppm. Although not immune to pitting, the use of type 316 over type 304 in medium to low chloride content waters will afford a greater margin of safety at an additional initial cost.

Whatever pitting corrosion has occurred in stainless steel condenser tubes has resulted from chloride plus certain types of deposits from the cooling water. Waterside deposits which are uniform, dense and tightly adherent can act as protective barriers. Water conditions which lead to the formation of a deposit which is either soft, porous and loose, or spotty in nature with a high chloride content can result in pitting corrosion. These deposits can sometimes occur in stainless steel tubes unknowingly because there may be no significant change in heat transfer to warn of their formation.

It should be noted that local chloride concentrations in the deposit on the tube surface can be much higher than the bulk concentration in the water. These high local chloride concentrations are primarily responsible for the pitting corrosion which as been observed. Allowing the evaporation of high chloride waters during downtimes should be avoided since this practice will result in high local chloride concentrations.

Formation and removal of deposits

The formation of troublesome deposits is often unpredictable because they appear to be organic in origin. The hard and relatively inert surface of stainless steel will provide a foundation for these types of deposits whenever the proper water conditions exist for their formation. This same surface makes adhesion by other deposits more difficult. For the same reasons, a stainless steel surface is easy to clean, and the resultant cleanliness enhances its corrosion resistance.

It follows that prevention or continued removal of deposits in stainless steel tubes is an effective method of preventing tube failures due to pitting corrosion. Besides indirectly promoting safety by cleaning, more efficient heat transfer and increased reliability are also obtained. The use of a continuous condenser tube cleaning system appears to offer the ultimate in achieving these goals. The installation cost of such a system can often be justified by savings in fuel and maintenance costs.

There are currently available two such systems each of which were originally used in Europe. The first installation used in the U.S.A. was the Amertap system. *This device recirculates sponge-rubber balls of a slightly larger diameter than the I. D. of the tube through the condenser tubes with the cooling water. Recently introduced in the U. S. A. was the M. A. N. cleaning system, which utilizes a reversal of the water flow to move a nylon brush from its inlet tube cage to its outlet tube cage. There appears to be a trend in the new large generating stations having stainless steel condenser tubes to use or make provisions for the eventual use of a condenser tube cleaning system to improve efficiency and insure reliability.

Summary

In summary, corrosion has not been a problem in the vast majority of stainless steel condenser tube installations. Prevention or continued removal of water deposits is an effective corrosion control method in those few instances where pitting corrosion has occurred.

The objective of the foregoing discussion was to show why stainless steel tubes should be considered for steam surface condensers. This point by point review of the essential requirements for a condenser tube alloy illustrates that many preconceived opinions that prevented the consideration of stainless steel tubes are no longer valid. In fact, an evaluation of these important factors shows there are many advantages to be realized by the use of stainless steel tubes, not the least of which is reliability.

*Amertap Corp., 15 Park Row, New York, N. Y. 10038
*American M.A.N. Corp., 500 Fifth Ave., New York, N.Y. 10036

Literature cited

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Q. Between the two materials for surface condensers—stainless steel and Admiralty—you indicated that from experience chloride attack has not been as serious as people have said. I believe a good number of installations have Admiralty for the surface condenser tube materials. I am interested if he has data or others have with experience of ammonia leaking into the cooling water system.
Long: Are you referring to ammonia stress corrosion cracking of Admiralty?
Q. Yes.
Long: This is one of the reasons why the use of stainless steel tubes in steam surface condensers has grown so rapidly. Stainless steel tubes are used extensively in the air removal section of main condensers where there have been corrosion problems with Admiralty tubes due to ammonia. Not all of the stainless steel tube footage which I have mentioned goes into a condenser which is completely tubed with stainless steel, although more and more of the new, large surface condensers are being completely tubed with stainless steel. For the most part today, the air removal sections are being tubed with stainless steel, and there have been no problems with steam side attack, as far as either stress corrosion cracking or crevice corrosion is concerned.
Q. I was under the impression that a good number of the users had Admiralty metal in the surface condensers.
Long: Extensive use of stainless steel tubes has only occurred in the past 10 years. Presently, stainless steel accounts for over half of the electric utilities condenser tube requirements and as a result, there would be a number of surface condensers which have Admiralty tubes.
Q. The main comment was that the Admiralty would be attacked by ammonia and I am wondering if this has been borne out by experience.
Long: Yes, I have seen examples of it, and I am sure that others here have also.
F.W.S. Jones, Canadian Industries, Ltd: I would like to comment that we have had experience with this kind of attack. Not on a surface condenser, but in the coolers on an air compression service. We replaced 14 Admiralty brass bundles in our Texaco plant in Canada due to this cause.
Q. You have not mentioned anything about chloride stress cracking. I wonder if you know what are the temperature limits that are tolerable? Can you take 150 degree water and not be concerned with chloride attack?
Long: I would like to limit my first comments to steam surface condensers. As far as this application is concerned, there has been no evidence of chloride stress corrosion cracking. I feel that this is basically due to the relatively low temperature operation of a surface condenser. The only stresses you would be concerned with would be at the rolled joint, and we have not seen any stress corrosion in any of these installations. As far as general comments on this subject, I think there is little agreement on what the "magic" temperature is for stress corrosion to occur. I have observed from my own experience that at atmospheric pressure, a temperature of 180 F is a point at which you become concerned. I remember an experience a few years ago with a fabricator who made heater tubes for anodizing tanks. We received a frantic call from him stating that his customer was having a problem which, it was later determined, was due to chloride stress corrosion cracking. I forwarded this information to the fabricator and he would not believe it. He had been making these assemblies for almost 30 years and had never experienced any trouble due to this cause. An examination of the records showed that the vast majority of the installations were designed to operate in the 140 - 160 F. level. Checking the plant, we found that there had been instances where the temperature had gone beyond that point.