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**Fineweld Tube** ***TECHNICAL LETTER***

# 90/10 Copper-Nickel vs. Type 316 Stainless Steel
# A Functional Comparison of Two Condenser Tube Alloys

Condenser tube material selection is one of the most important decisions faced by Electric Utility Engineering personnel. A "wrong" decision can result in premature failure of the condenser tube material which, in turn, can result in unscheduled downtime and costly maintenance. Conversely, paying too much money for one material when another less costly material satisfies all functional requirements can also be a bad decision.

Determination of the "best" material for a given application should be based on an evaluation of a material's strengths and weaknesses versus the functional requirements of the application. Typical criteria for evaluating condenser tube materials include water side corrosion resistance, condensate side corrosion resistance, heat transfer capability, compatibility with other system materials, condenser design considerations, ease of installation, in-service inspection considerations, and economics.

90/10 Copper-Nickel and Type 316 Stainless Steel are two condenser tube materials that are generally accepted for use in fresh and brackish water installations. 90/10 Copper-Nickel, with an official alloy designation of UNS C706 00, has a nominal chemical composition of 10% nickel, 1.4% iron, and 88.6% copper. Traditionally known for being a seawater condenser tube alloy, its outstanding resistance to most types of corrosion has led to its widespread use in freshwater systems at a wall thickness of 0.035" (20 BWG). UNS S316 00, more commonly referred to as Type 316 Stainless, has a nominal composition of 17% chromium, 2% molybdenum, 12% nickel, and iron as the balance. With improved resistance to corrosion from chlorides versus Type 304 Stainless, Type 316 Stainless represents a stainless steel that can be used in brackish water environments, and it is typically used at a wall thickness of 0.028" (22 BWG).

The strengths and weaknesses of each of these materials relative to the functional requirements listed above are discussed in the following paragraphs.

Heat Transfer Capability – Tube material and gauge correction factors for "new clean conditions" as listed in the Heat Exchange Institute's "Standards for Steam Surface Condensers" (Ninth Edition) are listed below. Admiralty Brass is included in this table because it is rated at 1.00 for a wall thickness of 18 BWG and is considered the standard to be used when making comparisons.

| Tube Material | Tube Wall Gauge (BWG) | | |
|---|---|---|---|
| | 22 | 20 | 18 |
| Admiralty Brass | 1.02 | 1.01 | 1.00 |
| 90/10 Copper-Nickel | 0.98 | *0.96* | 0.93 |
| Type 316 SS | *0.85* | 0.81 | 0.74 |

At the wall thicknesses which are commonly used, the 90/10 Copper-Nickel is shown to be superior. Once placed into service, the heat transfer capability of a condenser tube deteriorates from the "new & clean" condition due to the occurrence of fouling, scaling, etc. Cleanliness factors are used to adjust the "new & clean" values for in-service conditions and are based on the propensity for scaling and bio-fouling of the given material. The potential for growth of bio-fouling organisms in Type 316 SS justifies the use of a significantly higher cleanliness factor for the 90/10 Copper-Nickel. Thus, in the area of heat transfer, the 90/10 Copper-Nickel alloy has a definite advantage.

Biological Fouling is more likely to occur in recirculating cooling water systems than in once-through systems and is a primary contributing factor to crevice-related attack in susceptible alloys. Bio-fouling can also have a significant adverse effect on heat transfer capability. All copper alloys are resistant to bio-fouling. By comparison, all stainless steel alloys are susceptible to bio-fouling. Manufacturers of stainless steels recommend increased flow rates, but chlorination is usually still required.

General Corrosion Resistance – Both materials would be rated as "Excellent" because condenser tubes never fail prematurely from general corrosion. Rather, premature failure occurs because of a selective form of corrosion attack. A summary of each alloy's resistance to various forms of selective attack is provided in the table below and is discussed in the paragraphs which follow.

| Type of Corrosion Attack | 90/10 Cu-Ni | Type 316 SS |
|---|---|---|
| General Corrosion Resistance | Excellent | Excellent |
| Erosion-Corrosion Resistance | Very High | Excellent |
| Resistance to Sulfide-Related Pitting | Poor | Excellent |
| Resistance to Crevice-Related Pitting | Excellent | Fair |
| Resistance to Bio-Fouling | Very High | Poor |
| Steam Impingement Resistance | Good | Excellent |
| Resistance to Condensate (Ammonia) Attack | Very High | Excellent |
| Resistance to Stress Corrosion Cracking | Excellent | Fair |

Erosion-Corrosion Resistance – The potential for erosion-corrosion is directly related to cooling water velocity. Both materials are good, but Type 316 SS is better. 8 fps is recommended as the maximum design water velocity for 90/10 Copper-Nickel in seawater, and 10 fps max is recommended for fresh water.

Sulfide-Related Pitting Attack is the "Achilles Heel" of all copper alloys. The reader is cautioned against the use of 90/10 Copper-Nickel in cooling waters containing greater than 10 ppm sulfides.

Crevice-Related Pitting Attack has historically been the "Achilles Heel" for stainless steel alloys. The increased chromium and molybdenum content of Type 316 SS vs. Type 304 SS improves the resistance of this alloy to crevice-related pitting attack, but exposure to temperatures above $70^{o}$ F in stagnant water for any period of time should be avoided as the alloy's resistance to crevice attack decreases above this temperature.

Steam Impingement Resistance – Virtually all copper-nickel and stainless steel alloys exhibit very good resistance to this type of corrosion.

Resistance to Ammonia Attack – Both 90/10 Copper-Nickel and Type 316 SS are considered suitable materials for the air removal section of the condenser.

Resistance to Stress Corrosion Cracking – Typical environments in which stress corrosion can occur include ammonia (for copper alloys) and chlorides (for stainless steels). 90/10 Copper-Nickel is essentially immune to stress corrosion in both of these environments. By comparison, Type 316 SS has been found to be susceptible to chloride stress corrosion.

Other factors to consider when selecting a condenser tube material include the following:

Compatibility with other System Materials – Galvanic corrosion is a possibility whenever two dissimilar materials are in contact with one another as is often the case with condenser tubes and tubesheets. Traditionally, tubesheet materials have been produced from copper alloys, and 90/10 Copper-Nickel should be slightly favored when copper alloy tubesheets are being used. When cathodic protection systems are utilized, the manufacturer should be consulted if Type 316 SS is selected as the tube material since too large of a negative potential can result in hydrogen embrittlement of the tube material.

Condenser Design Considerations – The potential for mid-span collision is primarily a function of support plate spacing and the condenser tube material's modulus of elasticity. In a properly designed condenser, mid-span collision will generally be a consideration only if there is a change in tube material. Consultation with the condenser manufacturer is highly recommended if a high modulus material is being replaced with a lower modulus material.

Ease of Installation – Sound, leak-free joints can be obtained with either material when generally accepted rolling-in procedures are practiced.

Economics – The price of a condenser tube is comprised of manufacturing cost and metal value, and metal values change constantly as the "supply & demand" relationships change. However, based on the metal values in effect as this comparison is being written, Type 316 Stainless Steel and 90/10 Copper-Nickel are comparable in price at the wall thicknesses that are commonly specified for each material (i.e., 0.028" wall (22 BWG) for Type 316 SS and 0.035" wall (20 BWG) for the 90/10 Copper-Nickel). However, it is strongly recommended that quotations be obtained for both alloys before final material decisions are made.

Conclusion – Assuming normal standard operating parameters, economics and heat transfer capability favor the selection of 90/10 Copper-Nickel. Should it be the alloy of choice, the reader is cautioned to review cooling water flow rates versus the recommended design velocities for the alloy and to evaluate the cooling water for the presence of sulfides. Should Type 316 Stainless Steel be the alloy of choice, the reader is cautioned to avoid exposure to temperatures above $70^{o}$ F in stagnant waters (e.g., during half-condenser operation during tube cleaning) and to fully explore the potential pitfalls of cathodic protection.