Olin

Fineweld Tube ***TECHNICAL LETTER***

Alloy 194 vs. Alloy 122 in Air Conditioning/Refrigeration Applications

Connection tube is one of the most important elements in a refrigeration/air conditioning system. It serves to transmit fluids between major system components – compressor, condenser, and evaporator. Typical applications of connection tube include headers, manifolds, and liquid and suction lines. The tube is generally larger in diameter than the heat transfer surface tubing used in the condenser and evaporator. Large rooftop units, for example, may use tube as large as 3 in. (76 mm) in diameter.

Copper is the conventional connection tube material. Alloy 122, a phosphorus deoxidized grade, is most commonly specified. It has generally been considered to be invulnerable to material substitution because its combination of joinability, field repairability, fabricability, strength, and corrosion resistance could not be matched by other metals.

Alloy 194, an iron-modified phosphorus deoxidized copper, however, represents a viable alternative to Alloy 122. Alloy 194's high strength, resistance to softening during brazing, and improved corrosion resistance permit tube wall reductions of nearly one-third and subsequent cost savings. The following discussion indicates how Alloy 194 can provide equal or better performance to Alloy 122 with regard to mechanical properties, corrosion resistance, and fabrication/installation, while reducing overall cost. Unlike in condenser and evaporator coils, heat transfer is not an important consideration in connection tube applications; therefore, comparative heat transfer data is not included in this discussion.

Mechanical Properties

Connection tube must be strong enough to withstand operating pressures over a range of temperatures. It must also resist fatigue failure due to vibration and cyclic loading.

As shown in Table 1, Alloy 194 has superior yield, tensile, and fatigue strength when compared to Alloy 122. Composition and other physical properties are also included for reference purposes.

The superior strength of Alloy 194 is the key to its cost advantage. Its higher strength allows tube wall reductions of approximately one third without decreasing the burst pressure of the tube.

Table 1. Selected properties of Alloys 194 & 122.

Composition, %	**Alloy 194**	**Alloy 122**
Copper	97.0-97.8	99.90 min
Iron	2.1-2.6	--
Zinc	0.05-0.20	--
Phosphorus	0.015-0.15	0.015-0.040
Room Temperature Properties		
Density, *lb/in*^{3}	0.317	0.323
Specific gravity	8.78	8.94
Thermal expansion coefficient, *10*$^{-6}$*/F*	9.0	9.8
Modulus of elasticity, *10*^{6} *psi*	17.5	17.0
Tensile strength, min., *10*^{3} *psi*		
Hard temper	***60***	*36*
Soft temper	***45***	*30*
Yield strength, min., *10*^{3} *psi*		
Hard temper	***52***	*29*
Soft temper	***18***	*6*
Elongation in 2 in., *%*		
Hard temper	5	8
Soft temper	30	45
Fatigue strength, 10^8 cycles, *10*^{3} *psi*	***16-20***	*11-14*

Burst pressure is calculated using Barlow's formula, which is $P = (2St)/D$ where

P = burst pressure (psi),
S = minimum soft temper tensile strength (psi),
t = wall thickness (inches), and
D = outside diameter (inches).

Using this formula, the burst pressures for some common Alloy 122 connection tube sizes (Type L) are compared with those of Alloy 194 tubes at wall thickness reductions of approximately one-third. The results are shown in Table 2. Based on comparable burst pressure strength and higher fatigue strength, the mechanical properties of reduced-wall Alloy 194 tubes are equal to or better than those of Alloy 122 tubes.

Table 2. Burst pressures are similar when the wall thickness of Alloy 194 tube is one third less than that of Alloy 122 tube (Type L).

Standard "Size", ***in.***	**Outside Diameter,** ***in.***	**Wall Thickness,** ***in.***		**Burst Pressure,** ***10^3 psi***	
		Alloy 194	**Alloy 122**	**Alloy 194**	**Alloy 122**
1/2	0.625	0.027	0.040	3.888	3.840
5/8	0.750	0.028	0.042	3.360	3.360
3/4	0.875	0.030	0.045	3.086	3.086
1	1.125	0.033	0.050	2.640	2.667
1 1/2	1.625	0.040	0.060	2.215	2.215

Corrosion Resistance

Corrosion resistance is an important requirement for connection tube. The results of a variety of tests indicate that Alloy 194's resistance to corrosion is superior to that of Alloy 122.

In a test designed to measure the steady state corrosion rate of Alloy 194 and Alloy 122 in a saltwater environment at various fluid velocities, the data show that Alloy 194 is more corrosion resistant than Alloy 122 and is much less sensitive to increases in fluid velocity (Fig. 1). These test conditions are more extreme than the expected service conditions for connection tube; however, they are useful for showing the relative corrosion resistance of the two alloys.

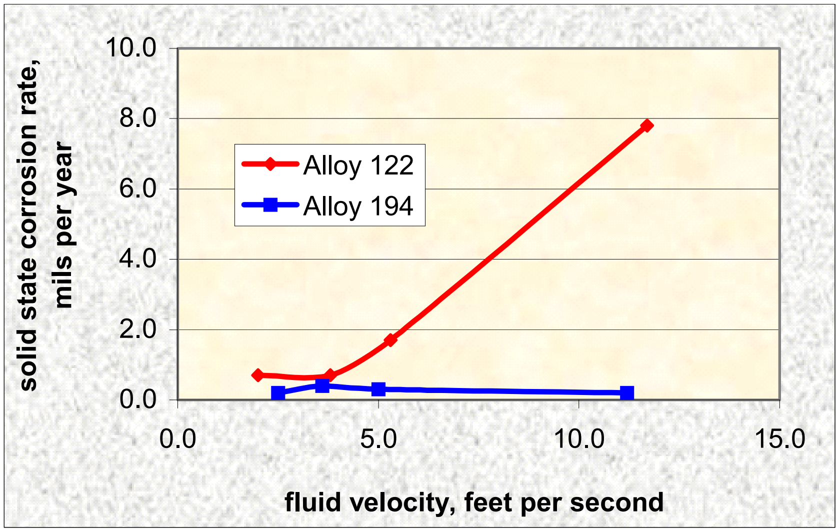

Figure 1. Steady state corrosion rates of Alloy 194 and Alloy 122 in recirculating 3.4 percent NaCl solution at 40° C and 4.7 ppm dissolved O_2.

Fabrication/Installation

Connection tube materials must be suitable for joining (e.g. brazing or soldering) and fabrication (e.g. bending, spinning, drilling, extruding, piercing, or swaging). As discussed in the following paragraphs, Alloy 194 is equal to or better than Alloy 122.

Joining

The ability to braze and the retention of strength after brazing are important considerations in headers and manifolds where multiple brazing operations may result in prolonged exposure to high temperatures.

Alloy 194 is readily brazeable to itself, copper, and other materials such as steel and brass using the same techniques and filler metals conventionally used for copper.

Regarding strength after brazing, Alloy 194 is superior to Alloy 122. The microstructure of Alloy 194 contains finely dispersed iron and iron phosphide precipitate which inhibit grain growth during brazing operations. As shown below in Table 3, Alloy 194 is much stronger than Alloy 122 after brazing and does not experience measurable grain growth.

These characteristics mean that brazed Alloy 194 components will have higher strength in areas adjacent to the joint. There will also be a greater tolerance for variations in the brazing operation with no major concern for grain growth. These features lend further support for the use of reduced-wall Alloy 194 tube.

Table 3. Strength of Alloy 194 and Alloy 122 tube after brazing.

Tube Material	Brazing Temperature, ° *C*	Strength, *10^3 psi*		Grain Size, *mm*
		Tensile	Yield	
Alloy 194	500	50.0	25.0	0.010
	800	41.0	16.0	0.010
Alloy 122	500	33.5	7.0	0.022
	800	31.0	5.0	0.035

Note: Results based on 1 hour exposure at temperature.

Fabrication

Reduced-wall Alloy 194 tubes can be readily bent, without wrinkling, when appropriate ball mandrels are used to handle the larger inside diameter. With very tight radii, the use of a wiper die may be helpful in making a smooth bend. Based on past experience, only minor modifications to equipment tooled for working copper are needed when switching to reduced-wall Alloy 194.

Conclusion

In the past, Alloy 122 has often been the only material considered for connection tube in air conditioning/refrigeration applications. However, Alloy 194 tube should also be considered. Alloy 194 has higher strength, better resistance to softening during brazing, and better corrosion resistance when compared to Alloy 122. As a result, Alloy 194 tube with reduced wall thickness can deliver equal or better performance to Alloy 122 tube at a lower per piece cost.