Material Selection for Utility

Materials Selection for Cooling Water

Table A-15 of Appendix A contains a materials selection for aerated freshwater systems. As indicated in Note 27 of Appendix A and mentioned previously, in freshwater systems admiralty brass (UNS C44300) should be limited to a pH of 7.2 maximum from ammonia and copper-nickel alloys and should not be used in waters containing more sulfides than 0.007 mg/L. The process inlet side temperature for admiralty (UNS C44300) usually is limited to about 177°C (350°F) for cooling service. Aluminum bronze or copper-nickel alloys often are used when the process inlet temperature is 177°C to 232°C (350°F to 450°F). In addition, codes such as ASME Section VIII have temperature limitations for these materials. Aluminum bronze alloys have a somewhat higher tolerance for hydrogen sulfide than copper-nickel alloys. It is best to check with the materials supplier to determine which material is best suited to the specific conditions in the cooler.

The materials selection in Table A-15 also is satisfactory for seawater except that pump cases and impellers should be a suitable duplex SS or nickel-aluminum bronze alloy (properly heat treated). Neoprene- lined water boxes should be considered. For piping, fiber-reinforced plastic (up to 1,035 Wag [150 psig] operating pressure) and neoprene-lined steel also should be considered. Titanium (UNS R50400) and 6 MOSS tubes should be considered where low maintenance is required or the cost can be justified by life expectancy.

Steam and Condensate

Pure dry steam is not corrosive to carbon steel up to about 540°C (1,000"F). Above this temperature the oxidation rate in air and steam increases rapidly. Normally, a minimum alloy content of 1-1/4 Cr-1/2 Mo is used above 455°C (850°F) to avoid graphitization. Oxidation of 1-1/4 Cr-1/2 Mo is not a problem until about 590°C (1,100"F). From 590°C to 650°C (1,100"F to 1,200"F), 2-114 Cr-1 Mo is satisfactory, although 18 Cr- 8 Ni SS has been used above 590°C (1,100"F). Stress corrosion cracking of 18 Cr-8 Ni SS has occurred in crevices, e.g., connections welded to elbows for thermowelds have failed with solids carry-over in the steam. For this reason 2- 114 Cr-1 Mo alloy is preferred in the 590°C to 650°C (1,100"F to 1 ,200"F) range except in large-diameter, high-pressure systems where alloy T91 (vanadium modified 9 Cr-1 Mo steel) sometimes is more economical because of significantly higher strength. When austenitic stainless steels are used above 540°C (l,OOO"F), the " H grades (heat treated to a coarse grain size and limited to 0.04% carbon minimum) should be specified. In addition, solution annealing should be specified after cold-forming operations to avoid loss of creep ductility, as well as the loss in strength due to fine grains from recrystallization. Cold forming also can be detrimental to carbon steel heater tubes. For example, very small defects on the outside of cold bends in boiler tubes have propagated to failure in creep at temperatures as low as 320°C (600°F). Problems with steam can occur in let-down valves due to erosion-corrosion. To prevent attack, hard facing, e.g., Stellite 6TM(U NS R30006 commonly is used when the pressure drop exceeds 1,035 kPa to 1,380 kPa [150 psi to 200 psi]). In addition, 1-114 Cr - 112 Mo or 2-114 Cr - 1 Mo is used for 4 diameters downstream.

This limit can be raised to 3,450 kPa (500 psi) for clean, dry steam. Erosion-corrosion also occurs in wet steam. Resistance to wet steam is enhanced by increasing both the metal hardness and chromium content. The product pvx (25)exceeding 2.14 x lo3 in metric units (1 x 105 in English units) has been used as an approximation to estimate if carbon steel would be satisfactory in wet steam. More recently, computer programs based on the effect of a significant number of parameters and operating experience have been developed to estimate the erosion-corrosion rate in wet steam. The effect of small amounts of copper in steel on erosion resistance is controversial. Some tests indicate

a benefit while others show no effect on wet steam erosion resistance. Huijbretgs used the equation

R = 0.61 + 2.43 Cr + 1.64 Cu + 0.3 Mo

to estimate the relative resistance of carbon steel to erosion-corrosion.26 He reported that no failures occurred when R was greater than 1.0. Usually either 1-114 Cr-112 Mo or 2-114 Cr-

1 Mo is used for lines containing wet steam or feedwater when erosion-corrosion is anticipated. The 2-114 Cr-1 Mo alloy has shown no attack when pvx exceeds 2.14 x lo3 in metric units (1 x 18 in English units). The pH of the water also is a factor; increasing the pH from 8 to 9 can decrease the erosion-corrosion loss by a factor from 2 to 10. To maximize erosion-corrosion resistance, the pH of boiler feedwater should be controlled to a 9.3 minimum.

Boiler feedwater (BFW) also can cause erosion-corrosion in carbon steel pumps when the temperature exceeds approximately 100°C (200°F). Impellers of 12 Cr are normally used above 100°C to 120°C (200°F to 250°F) in BFW pumps to avoid erosion-corrosion. Carbon steel cases have been used above 120°C (250”F), but *5* Cr-1/2 Mo or 12 Cr are preferred. BFW is treated primarily to prevent corrosion from condensate rather than from steam. BFW deaerators work either by a combination of thermal and mechanical means to drive off oxygen or chemically by adding oxygen scavengers, such as catalyzed sodium sulfite or hydrazine. Hydrazine is preferred for high pressure (> 6.89 MPag [l,OOO psig]) boilers. Some of the hydrazine (N2H4) breaks down to form ammonia (NH,). The ammonia, together with carbon dioxide from the decomposition of carbonates and bicarbonates, causes a corrosion problem on copper base alloys in the air removal section of surface condensers. Although published data indicated that admiralty brass (UNS C44300) is satisfactory if the ammonia content does not exceed 10 ppm, admiralty brass (UNS C44300) tubes failed in an ammonia plant surface condenser designed to hold ammonia to 10 ppm maximum. The copper alloy that has the best resistance to the ammonia and carbon dioxide found in the air removal section of surface condensers is 70 Cu-30 Ni (UNS C71500). Serious corrosion fatigue cracking has been reported in a large number of deaerator vessels. Cracks often are so tight and filled with scale that they can penetrate throughwall before they are detected. Therefore, wet fluorescent magnetic particle examination (the only way they can be found) is required to avoid catastrophic failure. Most users are now specifying at least 10% radiography and postweld heat treatment for new vessels. New units also are designed to minimize localized stress and internal stress raisers. In some cases, welds are ground to further minimize stress raisers. NACE International Standard RPO590, “Recommended Practices for Prevention, Detection, and Correction of Deaerator Cracking,” contains further details on prevention, detection, and correction of deaerator cracking. High-solids (carbonates and bicarbonates) BFW will result in significant formation of carbon dioxide. The resulting carbon dioxide-laden condensate causes erosion-corrosion attack on carbon steel. Failure occurs by deep pitting, furrowing, or channeling. Corrosion inhibitors can be added to minimize this attack. Solids also can be a problem if they are carried over into the condensate. Since the solids become alkaline from loss of carbon dioxide, they can readily crack austenitic SS and severely corrode aluminum. In one case, aluminum tubes designed for condensing steam failed in 48 hours from solids carryover. Clean condensate, free of solids and gases, is relatively non-corrosive and can be handled in carbon steel with a minimal corrosion allowance. When oxygen is present above about 100 ppb in steam condensate,18 Cr - 8 Ni SS is required. However, low carbon or stabilized SS is required because sensitized 304 (UNS S30400) or 316 (UNS S31600) can fail from intergranular stress corrosion cracking at temperatures above about 110°C (200°F).

