Overcoming Corrosion Concerns in Copper Tube Systems

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Copper water tube systems have a long and successful application history. On rare occasions concerns about aggressive water, system design, material selection, system operation, and defective workmanship occur. Proper materials selection, system design and operations, correct workmanship practices, and effective water treatment alternatives for mitigating corrosion concerns are described, while concurrently enabling the 1991 Lead - Copper Rule Amendment of the 1974 Safe Drinking Water Act to be satisfied.

Copper water tube systems have a long and succesful service history in domestic (potable) and industrial water systems.[1-2] For example, copper pipe used to convey water to the royal bath for the Egyptian Pharaoh Cheops' pyramid was recently excavated and found still usable. Nearly 5,000 years later, copper continues to demonstrate its outstanding performance for conveying domestic and industrial waters.

On rare occasions, water conditions can deleteriously affect copper's performance.

Fortunately, when the chemical composition of the product conveyed is involved, adverse conditions can be rendered innocuous by viable and cost-effective water treatment. Such programs can be designed and applied to single family residences as well as major water treatment plants serving large urban areas.[3-4]

Some corrosion concerns effectively mitigated by proper water treatment include:[5]

- General corrosion (cuprosolvency: blue/green water concerns);
- Cold water pitting (CO_2, and sulfide-induced);
- Hot water pitting (aluminum, manganese, and iron-induced); and
- Erosion-corrosion.

Health Concern

The Lead-Copper Rule of 1991,[6] an amendment to the 1974 Safe Drinking Water Act,[7] stipulates that lead and copper contents will not exceed 0.015 and 1.3 mg/L, respectively. The establishment of these maximum contaminant levels focused increased attention on the corrosion of copper water tube systems. These systems include copper water tubes, fittings, valves, faucets, and meters and the solders and fluxes used in their assembly. The source of the lead could also be lead service lines, or goose necks, rather than components of the copper plumbing system.

Responsible water treatment authorities and their consultants recognize their obligation to treat water supplies in compliance with the requirements of the Lead-Copper Rule. Unfortunately, water treatment is not a universal solution for all conditions. Other factors include: materials selection,[1,5] system design and operation,[8] flux,[9] and workmanship.[10]

All materials exposed to potable waters must meet the requirements of ANSI/NSF 61, Drinking Water System Components - Health Effects.[11] Testing to demonstrate these materials comply with requirements is underway.

Materials Section

Water Tube

Copper water tube in the U.S., Canada, and Mexico is produced to the requirements of standard specification ASTM B 88, seamless copper water tube (UNS C12200).[12] The companion wrought fittings are produced to ASME B16.22, wrought copper and copper alloy solder joint pressure fittings.[13]

Copper alloy C12200 (phosphorus deoxidized, high residual phosphorus) contains a minimum of 99.9% copper (including silver) and a phosphorus range of 0.015 to 0.040%. While other coppers have occasionally been permitted, only alloy C12200 is presently recognized. The primary difference between these coppers is their electrical and thermal conductivities, properties which are unimportant for plumbing tube. Companion wrought fittings also are normally produced using alloy C12200.

Valves, Fittings, and Meters

Valves, water meters, and fittings are typically produced to either ASTM B 62 (UNS C83600), composition bronze or ounce metal castings;[14] ASTM B 584 (UNS C84400), copper alloy sand castings for general applications;[15] ASTM B 763 (UNS C84400), copper alloy sand castings for valve applications;[16] or AWWA C700, cold water meters, displacement type, bronze main case;[17] and AWWA C800, underground service line valves and fittings.[18]

Solders

The 1986 amendments to the Safe Drinking Water Act prohibit lead-containing solders for joining copper water tube systems.[19] Acceptable solders include 95:5 tin-antimony, several tin-silvers, and some proprietary alloys. Some acceptable alloys are identified in ASTM B 32, solder metal.[20]

System Design and Operation

Copper water tube systems can be safely operated up to at least 140°F (60°C). When soft waters containing appreciable quantities of dissolved oxygen and carbon dioxide are involved, water velocities should not exceed 4 to 5 ft/s (1.2 to 1.5 m/s). When water temperature is likely to exceed 140°F, and higher velocities are involved, alloy C70600 (90:10 copper-nickel) should be specified. All valves, expansion joints, fittings, controllers, and other system components should also be of a suitable copper alloy. Otherwise, erosion-corrosion can take place which could damage the system and lead to unacceptable metallic contaminant levels and corrosion-induced leaks.

Erosion-corrosion also can be a concern when the local water pressure exceeds about 80 psig (550 kPa). Even properly designed and operated systems can be adversely affected by erosion-corrosion. A classic example is corrosion resulting after the replacement installation of oversized circulating pumps in hot water systems.

Solder Flux-Related Corrosion

The use of certain fluxes and their overapplication can result in adverse pitting attack.[9] This is typically a cold water concern. It is not normally associated with hot water systems because the aggressive species involved (especially chlorides) is soluble in the water conveyed, and is usually removed before pit initiation can occur. Soldering flux-induced pitting attack can occur in the vicinity of joints and at significant distances from the joints. Pitting is often observed at the periphery of sticky petrolatum-base flux runs.

Suspected soldering flux-related corrosion can normally be identified using energy dispersive spectroscopy. Chlorides, and occasionally zinc, will be identified in the corrosion induced pits. Soldering fluxes commonly contain activating chloride ions such as zinc and ammonium chlorides. Regardless of the investigative technique, the ammonium radical is not found in the pits because this ion is highly water soluble.

Soldering fluxes used to install copper water tube should comply with the requirements of standard specification ASTM B 813, liquid and paste fluxes for soldering applications of copper and copper alloy tube.[21]

Workmanship

For years, plumbing technicians have been instructed in the proper installation of copper water tube systems. Emphasis was placed on proper assembly techniques which include: square cutting, reaming, mechanical cleaning, fluxing, full insertion of tubes into fittings, and soldering.

Unless all the steps of these interrelated assembly procedures are observed, system damage can occur. Unreamed tube ends can result in erosion-corrosion immediately downstream of joints. The same phenomenon can occur when solder globules exist on the inside surfaces. The latter is understandable because protrusions disrupt the water's laminar flow and create localized turbulence in the water immediately downstream.

Nearly all workmanship-related concerns can be eliminated by ensuring copper tube systems are installed in accordance with standard practice ASTM B 828, making capillary joints by soldering of copper and copper alloy tube and fittings.[22]

Summary

System Concept

Until recently, all copper water tube system components were addressed as independent items. These included separate specifications for tubes, fittings, valves, flanges, water meters, fluxes, solders, and other hardware. It is now recognized the total plumbing system approach prevails when various factors are interrelated. For example, the solder must be compatible with the flux and excessive use of these materials must be avoided. The capillary gap between the tube and fitting also must be properly sized by the fitting manufacturer to effect a satisfactory soldered joint.

Effective Water Treatment

A number of viable and cost-effective treatment programs can be used to mitigate the corrosion of copper. These include adding lime to overcome cuprosolvency,[3] and adding soda ash or caustic soda to prevent cold water pitting.[3,23] The treatment program depends on the chemical composition of the raw water, the form of the corrosion involved, and economics.

Environmentally acceptable chemical additions can successfully mitigate the corrosion of copper by raising the pH of the water. Raw waters with a pH from 4.5 to 5.5 (as reported by the Suffolk County Water Authority, Long Island, New York) resulted in cuprosolvency.[3] This is overcome by simply raising the pH of the water to 7.5 using lime. Soda ash[4] and caustic soda[24] have been successfully used for mitigating the cold water pitting of copper. The latter occurs by raising the pH of the water to reduce its dissolved carbon dioxide to a concentration below about 5 mg/L. Dissolved carbon dioxide cannot exist in cold water at a pH in excess of 8.3 (the phenolphthalein end point).

Other chemical additions can be used to mitigate the corrosion of copper, including certain sodium silicate formulations.[3] Silicates deposit a protective layer on the copper tube/fitting surfaces and isolate them from the aggressive water. A secondary benefit of silicate treatment is that it typically increases the pH of the water.

Hot water pitting of copper by waters containing deleterious amounts of manganese and iron can be effectively overcome by installing iron and manganese removal systems at the treatment plant.

Sulfide removal systems can also be used when unacceptable amounts of this aggressive species creates a pitting concern.

Cases are known where aluminum-related hot water pitting of copper was effectively mitigated by reducing the amount of aluminum sulfate used for coagulation at the treatment plant. Often aluminum-related hot water pitting can be effectively prevented by decreasing the temperature of the water to a safe and energy-efficient 130°F (54°C), or by increasing the pH of the water.

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