

MFP

MATERIALS
PERFORMANCE

An Official NACE International Publication

August 1993 • Volume 32 • Number 8



Historical Perspective

CORROSION BY POTABLE WATERS IN BUILDING SYSTEMS

Arthur Cohen
Copper Development Association Inc.,
260 Madison Ave., New York, NY 10016

Corrosion can be a costly and annoying concern in a building's potable water system. General, pitting attack (cold and hot), concentration cell, dezincification, erosion, and galvanic corrosion in these systems can be avoided by a number of techniques, including materials selection, system design, and chemical treatment.

Historically, a number of materials have been used to convey domestic waters in buildings. These include: steel and galvanized steel, copper and copper alloys, ferritic and austenitic stainless steels (AUSS), and certain nonmetallics.

The performance of these materials varies. At some locations, galvanized steel has been used successfully for more than 100 years. In other locations, galvanized steel failed rapidly.

This is understandable because hard waters normally deposit protective calcium carbonate scales in all plumbing systems. Figure 1 is a typical example of severe scaling in a galvanized-steel-pipe hot-water distribution system. Soft waters, by contrast, are highly aggressive because they do not provide this protection. Conditions that lead to corrosion or scaling are listed in Table 1.¹

Corrosion of Metallic Materials

Steel and Galvanized Steel

Steel and galvanized steel deteriorate by pitting, which can perforate the pipe and fitting wall. Galvanized steel systems often must be replaced because of flow-restricting tubercle formation (Figure 2) or the brown staining on porcelain fixtures when galvanized coating dissolves from the steel and fitting surfaces.

The galvanized coating can become cathodic to steel in certain waters if heated to temperatures above 60°C (140°F).²

Pitting of galvanized steel can be facilitated by the electrochemical deposition of copper from water on the zinc surface, which sets up microgalvanic corrosion cells. It is for this reason that galvanized steel should never be installed downstream of copper tubes and fittings.

The other form of deterioration that can occur in steel and galvanized steel systems is oxygen differential-type concentration cells. Typically, this occurs under discontinuous deposits and crevices. Once initiated, concentration cell corrosion (as well as pitting attack) can be accelerated by the occluded cell phenomenon, where chloride ions migrate to and concentrate at the localized corrosion sites, forming hydrochloric acid in the pits (Figure 3).

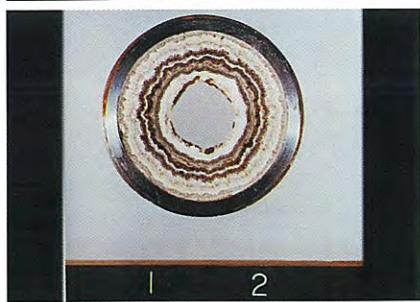


FIGURE 1

Severe scaling in a galvanized steel pipe hot-water distribution system.



FIGURE 2

Typical flow-restricting tubercle formation in a galvanized steel pipe system.



FIGURE 3

Typical oxygen differential-type concentration cell in threaded joint.

TABLE 1
Potable Water Categorization Is Applicable to All Metals for Scaling
But Only to Iron, Steel (Not Stainless), and Galvanized Steel for Corrosivity¹

Category	Calcium (Ca), ppm	Sulfate (SO ₄), ppm	Silica (SiO ₂), ppm	Dissolved Oxygen, ppm	Character
1A	0-18	As found	0-15	1-10	Extreme corrosion hot and cold.
1B	0-18	0-25	0-15	0-1	Moderate corrosion hot and cold. Extreme corrosion with CO ₂ > 8 ppm.
1C	0-18	0-60	>15	1-5	Slight corrosion cold, considerable hot. Aggressiveness reduced and perhaps not troublesome due to high natural SiO ₂ .
2A	18-35	>Ca but not <25	0-15 ^(A)	1-10	Considerable corrosion hot, moderate cold. May be slightly scale forming very hot.
2B	18-35	0-25	0-15	1-10	Moderate to slight corrosion hot and cold. May be scale forming hot.
2C	18-35	<Ca	>15	1-8	Corrosion unlikely. May be scale forming hot.
2D	18-35	<Ca	As found	0-1	Corrosion unlikely. May be scale forming hot.
3A	35-75	<1-1/2Ca	0-15	1-10	Moderate corrosion hot, slight cold. Considerable scale formation hot.
3B	35-75	>1-1/2Ca	0-15	1-10	Considerable corrosion hot, slight cold. Considerable scale formation hot.
3C	35-75	< 1-1/2Ca	> 15	1-10	Considerable scale formation. Slight corrosion hot.
3D	35-75	As found	As found	0-1	Considerable scale formation. Corrosion unlikely.
3E	35-75	>1.5Ca but <3Ca	>30	1-10	Corrosion unlikely hot and cold. Excessive scale formation.
4A	>75	<2Ca	0-30	1-10	Excessive scale formation. Corrosion unlikely to slight cold, slight to moderate hot.
4B	>75	>2Ca	0-30	1-10	Excessive scale formation. Galvanic corrosion considerable hot and cold.
4C	>75	<3Ca	>30	1-10	Excessive scale formation. Corrosion unlikely.

^(A)With SiO₂ over 15 ppm, corrosion may be reduced in proportion to SiO₂ content.

Notes: Presence of chlorides in concentrations greater than 100 ppm, with high sulfates, renders a water more corrosive than indicated by category above. Presence of carbon dioxide in concentrations exceeding 5 ppm accelerates corrosion processes where category groups indicate corrosion. In concentrations exceeding 20 ppm, it may cause an indicated noncorrosive water to be corrosive.

Terms: Extreme or excessive—where effects necessitate immediate corrective action. Considerable—where corrective action is desirable. Moderate—where corrective action is questionable and depends on economy effected. Slight—where effect is too slight to warrant corrective action. Unlikely—where effects are possible but not probable.

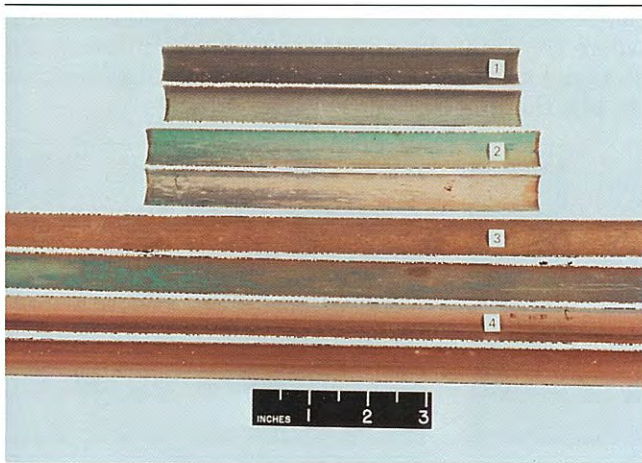


FIGURE 4

Typical etched surface of copper tube associated with plumbing fixture staining.

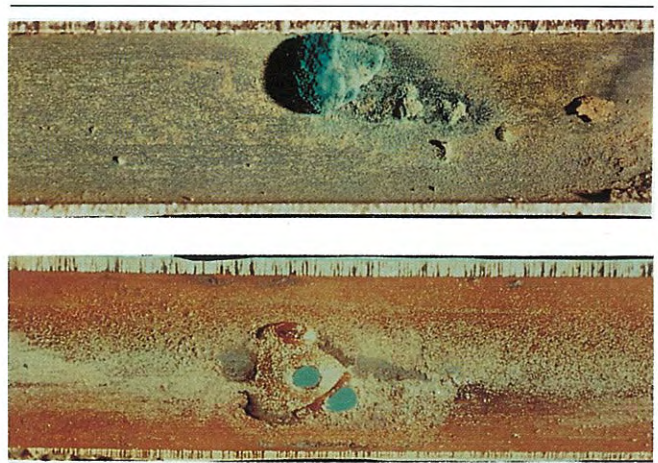


FIGURE 5

Typical interior surface of copper water tube that has failed due to pitting corrosion.

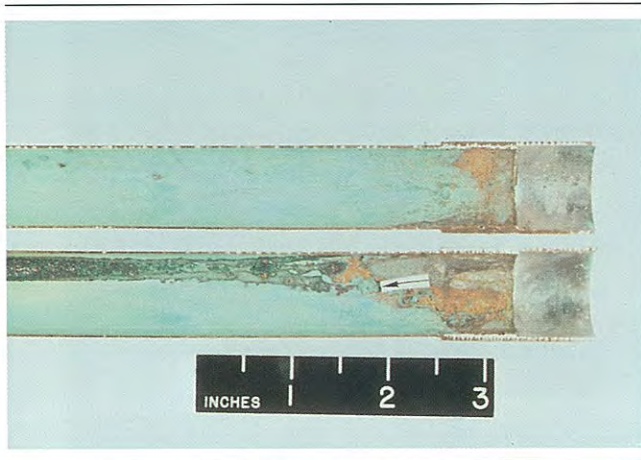


FIGURE 6
Typical flux run originating in plumbing system joint.

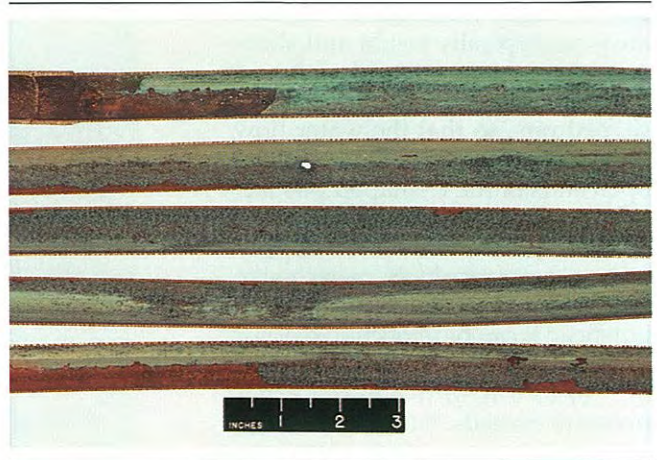


FIGURE 7
Pitting attack of copper plumbing tube due to trace amounts of hydrogen sulfide in the water conveyed.

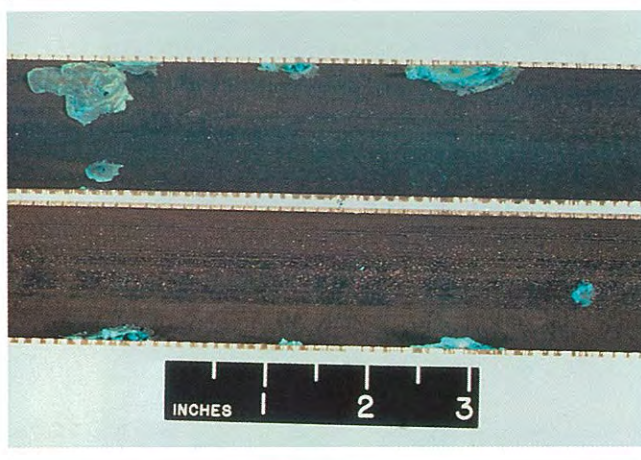


FIGURE 8
Hot water pitting corrosion of copper plumbing tube caused by the microdeposition of manganese dioxide.

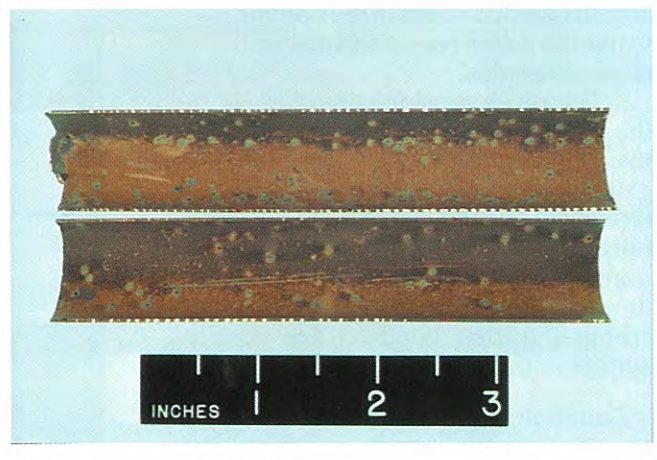


FIGURE 9
Hot water pitting corrosion of copper plumbing tube caused by the microdeposition of hydrated hematite.

Copper and Copper-Based Alloys

Electrochemical deterioration of copper in domestic water systems includes general corrosion (cuprosolvency),^{3,4} cold water pitting,^{3,6} hot water pitting,⁷ erosion-corrosion,⁴ and oxygen differential-type concentration cell corrosion.

Cuprosolvency

Cuprosolvency is annoying because it causes colored water (blue/green) and staining of plumbing fixtures. Generally, it is caused by soft, low alkalinity, low mineralization water having a pH of 7 or lower. Typical copper plumbing tube associated with staining is shown in Figure 4.

Cold Water Pitting

Pitting of copper tubes and fittings in cold water generally is associated with ground waters containing free carbon dioxide in conjunction with dissolved oxygen. Sometimes, this pitting attack is accelerated by the presence of chlorides and sulfates.

The typical interior surface of copper water tube that has failed due to pitting corrosion is shown with the tubercle intact in the top half of Figure 5, and after chemical cleaning to remove the tubercle and scale in the bottom half.

Cold water pitting attack has also been linked to chloride-containing soldering-flux residues in the form of flux runs on the waterside

surfaces in plumbing system joint areas (Figure 6). Cold water pitting attack has also been associated with very small quantities of hydrogen sulfide in the conveyed water (Figure 7).

Hot Water Pitting

Hot water pitting of copper is associated generally with microdeposition of cathodic materials such as manganese dioxide (Figure 8), hydrated hematite (Figure 9), and aluminum hydroxide (Figure 10) as a result of underlying copper metal losing its protective film.

Erosion-Corrosion

Erosion-corrosion of the waterside surfaces of copper tube and fit-

tings is easily recognized. Affected areas are typically bright and shiny (void of corrosion products) and usually contain U- or horseshoe-shaped pits, so that the water flow direction can be established by the open ends of the U-shaped pits facing downstream (Figure 11).

Erosion-corrosion of copper tube systems results from excessive localized water velocity and/or turbulence.⁴ It can be expected to occur if water velocities exceed 1.2 to 1.5 m/s (4 to 5 ft/s), when the water pressure exceeds 550 kPa (80 psig), and/or the water is heated to temperatures over 60°C (140°F). It is facilitated by waters softened to near-zero hardness with appreciable quantities of dissolved oxygen and carbon dioxide. The presence of abrasive suspended solids in the flowing water have also been associated with erosion-corrosion.

Too often, erosion-corrosion is the direct result of improper workmanship. Unreamed cut tube ends, globules of solder on the inside surface in the joint area, tube ends not fully inserted into the fitting prior to soldering, tube ends not cut square, dents/dings in tube, and tube crimped during bending are examples of this.

Concentration Cell Corrosion

Oxygen differential concentration-cell corrosion can occur in copper tube systems when discontinuous deposits such as silica, iron oxide, and construction debris settle on the copper surfaces. Corrosion tends to occur beneath these deposits in low oxygen-content water where chlorides concentrate. The phenomenon can be facilitated by an unfavorable cathode-to-anode area ratio.

Stainless Steels

Although several attempts have been made, there is no known long-term history of successful stainless steel (SS) application in domestic water service in the United States. It is known, however, that use of a thin-wall type 409 (UNS S40900) welded SS tube was unsuccessfully introduced. The material is no longer available for this application. This alloy is a ferritic SS and does not contain sufficient chromium to satisfy the requirements of the intended



FIGURE 10
Hot water pitting corrosion of copper plumbing tube caused by the microdeposition of aluminum hydroxide (Al(OH)₃).

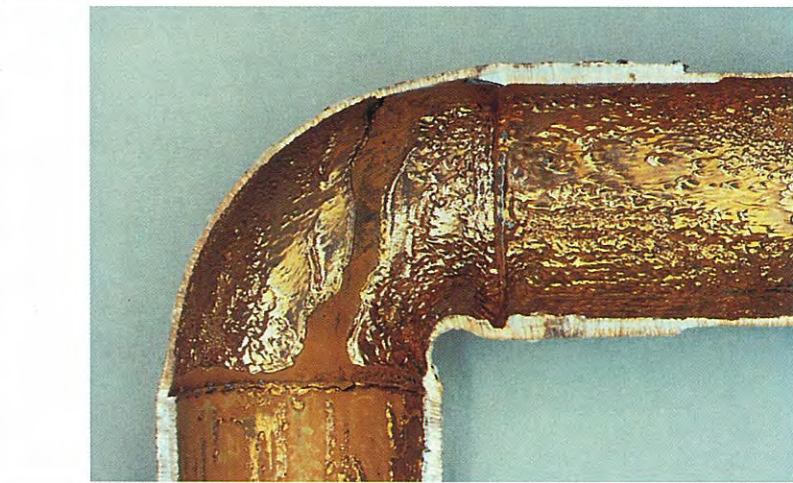


FIGURE 11
Typical impingement corrosion characterized by eroded interior surface. Such erosion is caused by excessive water velocities compounded by sudden changes in flow direction. Unreamed tube ends leave burrs that promote increased turbulence.

application. Further, SS are particularly sensitive to chloride-induced pitting attack and crevice corrosion. Chlorides in commonly used soldering fluxes were very likely the primary reason for the demise of thin-wall type 409 for potable water service.⁸

Nickel-containing AUSS have been used extensively and successfully in Europe. System cost (material and installation) and lack of service experience are the primary reasons that AUSS tube and fittings are not used to any large extent in the United States.

Although SS systems conceivably could be installed without soldering (such as mechanical fittings),

these systems still would be susceptible to underdeposit corrosion associated with suspended solids or other debris in the water.

Copper-Based Alloys

Copper-based alloys currently are not widely used for domestic water service. They are used to a limited extent for fittings but are widely used in valves. Plug-type (Figure 12) and layer-type (Figure 13) dezincification typically occurs in waters having high chlorides and/or low temporary hardness, when the water is stagnant, and probably has a relatively low pH.

Dezincification is characterized by its reddish copper color and the

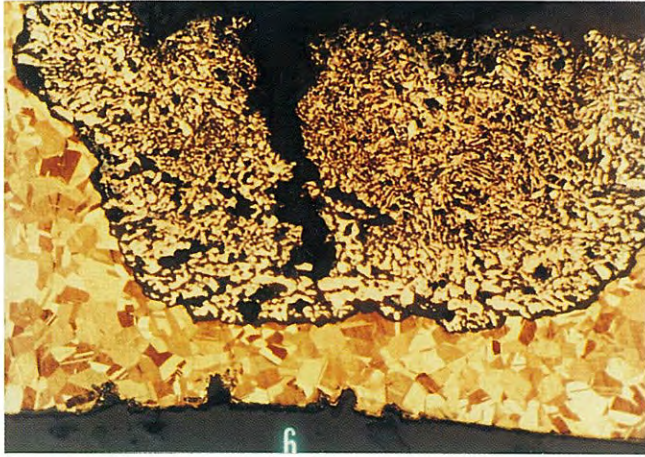


FIGURE 12
Plug-type dezincification (cross section).

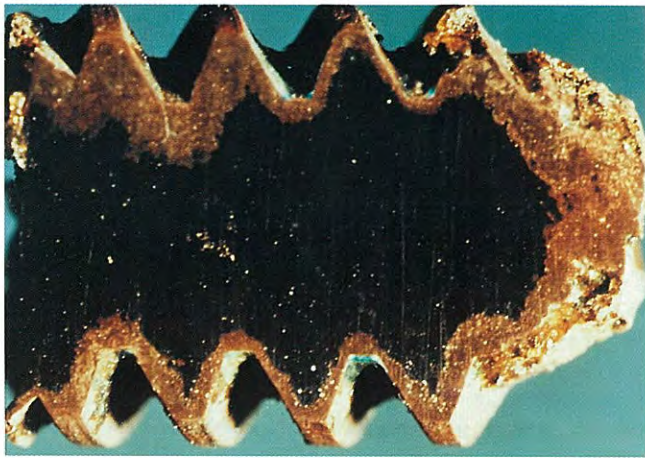


FIGURE 13
Layer-type dezincification (cross section).

absence of structural integrity even though there is no overall dimensional change in the component.

Nonmetallic Materials

While plastic materials are not susceptible to electrochemical corrosion, serious concerns have arisen regarding the use of these materials in potable water service.

Polyvinyl chloride (PVC) is temperature limited and should not be used for domestic hot water service. Chlorinated polyvinyl chloride (CPVC) does not have this temperature limitation. However, cases are known where CPVC domestic hot-water systems have failed because PVC fittings mistakenly were installed. PVC cold water lines should

not contact CPVC to avoid thermal failure of the cold water lines.

How to Avoid Corrosion

Understanding the mechanisms by which materials fail in domestic water systems provides guidance with minimizing these concerns.

Steel and Galvanized Steel

The use of steel and galvanized steel pipe and fittings should be restricted to those waters which can be expected to develop a protective calcium carbonate scale. Alternatively, galvanized steel can be used for aggressive water service if these waters are continuously treated with small additions of automatically controlled, properly balanced, liquid

sodium silicate-polyphosphate organic blends, starting when the pipe system is put into service. In general, galvanized steel pipe and fittings should not be used for hot-water service at temperatures above about 60°C, unless there is documented evidence that the potential reversal between zinc and steel will not take place. Under no circumstances should galvanized steel be installed downstream of copper tube systems. Similarly, galvanized steel couplings should not be used to connect copper plumbing systems, and steel nipples should not be used to close bronze valves (Figure 14).

Copper and Copper-Based Alloys

Corrosion concerns regarding copper water tube and fittings can be avoided by several techniques, including treatment of the water, proper system design, and proper installation.

Cold water pitting of copper can be prevented by elimination of free carbon dioxide through controlled addition of hydrated lime, caustic soda, or soda ash. Waters having a pH of 8.5 cannot contain carbon dioxide. Experience has shown, however, that cold water pitting is eliminated when the free carbon dioxide level is less than 5 mg/L.

Soldering flux, chloride-induced cold-water pitting of copper can be eliminated by the use of a mildly corrosive flux which satisfies the requirements of ASTM B 813⁹ and when the systems are assembled per the requirements of ASTM B 828.¹⁰

Despite improvements in soldering technology, plumbers still must avoid excessive flux application.

Sulfide-induced cold-water pitting can be avoided by ensuring that this aggressive species is reduced to an acceptable level by the water distributor. Typically, this is accomplished by aeration using properly sized and maintained equipment.^{11,12}

Hot Water Pitting

Hot water pitting can be overcome by avoiding the deposition of aggressive species such as manganese dioxide, hydrated hematite, and aluminum hydroxide on the hot metal surface. The severity of these

concerns can be further overcome by ensuring that the temperature of the water does not exceed a safe and energy-efficient 54°C (130°F).

Excessive amounts of dissolved manganese and iron can be avoided by aeration and subsequent filtration by the water distributor prior to delivery to the system.

Where the source of the aluminum is the coagulant (for example, aluminum sulfate), the hot water pitting concern associated with this element can be overcome by reducing the quantity of coagulant, by using an alternative coagulant such as iron sulfate, or by raising the pH of the water to approximately 8.5.⁷

Erosion-Corrosion

Erosion-corrosion of copper tube systems can be prevented by restricting the routine flow rate of water in the system to a maximum of 1.2 to 1.5 m/s (4 to 5 ft/s); limiting the temperature of the circulating hot water to about 54°C (130°F); and controlling the water pressure to a maximum of about 552 kPa (80 psig).⁴

Chemical treatment with small amounts of automatically controlled, properly balanced liquid sodium silicate/polyphosphate organic blends can minimize erosion-corrosion of copper tubes where aggressive water and adverse operating conditions could cause premature corrosion leaks. Above all, proper workmanship must be used during installation of the copper tube system.

Copper-Based Alloys

It is established but not widely appreciated that copper alloys are available that will *not* experience dezincification in aggressive waters. In general, binary copper/zinc alloys containing more than 15 percent zinc should be avoided.¹³

Dezincification of valve stems can be avoided by specifying that these components be fabricated from *inhibited* alloys.¹⁴

Nonmetallics

While nonmetallic tubular materials have been used successfully, their limitations must be recognized during installation and use. Unless these limitations are considered, nonmetallic systems cannot achieve their intended application.



FIGURE 14
Steel nipple used to close bronze valve.

Polybutylene has made some inroads into the hot and cold potable-water distribution market in some areas in the United States when its installed cost is perceived to be somewhat lower than for copper. Whether or not plastic is ever less costly in the long run remains to be established. Serious questions regarding durability and health-related issues remain unresolved.

Unfavorable plastic pipe performance is highlighted in the CBS 60 Minutes news report, "Greatest Thing Since Sliced Bread," which described multiple failures experienced in San Antonio, Texas.¹⁵

Summary

A number of engineering materials have been used over the years for conveying domestic waters. These include steel and galvanized steel, copper and copper alloys, certain grades of stainless steel, and some nonmetallic materials.

Each material has both advantages and limitations that must be considered during the material selection process.

Corrosion concerns can be avoided through a number of techniques, including proper treatment of the water, quality design and workmanship, and controlled system operating conditions.

References

1. M.F. Obrecht, J.R. Myers, *Heating/Piping/Air Conditioning* 45, 5, (1973): pp. 77-83.
2. G. Schikorr, *Trans. Electrochem. Soc.* 76 (1939): p. 247.
3. W.S. Lyman, A. Cohen, *MP* 11, 2 (1974): pp. 48-53.
4. A. Cohen, *Heating/Piping/Air Conditioning* 5 (1978): pp. 81-87.
5. W.S. Lyman, A. Cohen, J.R. Myers, "Causes and Prevention of Pitting Corrosion in Copper Plumbing Systems in the USA," *Proceedings of the International Symposium on Corrosion of Copper and Copper Alloys in Buildings*, Tokyo, Japan, March 1982.
6. A. Cohen, J.R. Myers, *Mitigation of Copper Tube Cold Water Pitting*, CORROSION/84 paper no. 153, (Houston, TX: NACE, 1984).
7. P. Tunturi, S. Ylasaari, *A Special Case of the Pitting Corrosion of Copper in a Hot Water System*, *Proceedings of the 5th Scandinavian Corrosion Congress*, 42-2 to 42-14, Copenhagen, 1986.
8. L.S. Redmerski, A. Moskowitz, *MP* 8, 6 (1969): pp. 33-38.
9. ASTM Standard B-813, "Standard Specification for Liquid and Paste Fluxes for Soldering Applications of Copper and Copper Alloy Tube," (Philadelphia, PA: ASTM, 1992).
10. ASTM Standard B-828, "Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings," (Philadelphia, PA: ASTM, 1992).
11. S.W. Wells, *J. AWWA* 46 (1954): pp. 160-190.
12. J.E. Fobworthy and H.K. Gray, *J. AWWA* 50 (1958): pp. 872-878.
13. *ASM Metals Handbook*, Vol. 1 (Materials Park, Ohio, ASM International: 1961), p. 1003.
14. L.P. Costas, *MP* 16, 8 (1977): pp. 9-16.
15. "Greatest Thing Since Sliced Bread," 60 Minutes, CBS News broadcast, December 30, 1990.

Presented as paper no. 509 at CORROSION/93 in New Orleans, Louisiana.

Water Treatment to Mitigate Corrosion of Copper Plumbing Systems

Arthur Cohen

Copper Development Association Inc., 260 Madison Ave., New York, NY 10016

James R. Myers

JRM Associates, 4198 Merlyn Drive, Franklin, OH 45005

This article describes several water treatment techniques used successfully by water utilities or private dwellings, which prevent corrosion of copper plumbing systems. The techniques include the addition of hydrated lime, caustic soda, soda ash, or a silicate to the distributed water.

For over two decades, the Copper Development Association (New York, New York) has conducted field investigations of copper (Cu) plumbing system failures. While these investigations certainly do not represent every failure, the types encountered have clearly demonstrated that cold water pitting, flux, and erosion-corrosion are the main causes of failure.

The waterworks industry has recognized its responsibility to provide nonaggressive water to its consumers with the American Water Works Association (Denver, Colorado) adopting "Quality Goals for Potable Waters."¹ The Safe Drinking Water Act² of 1973, promulgated by the U.S. Environmental Protection Agency (Public Law 93-523), and the companion 1986 Amendments³ and the 1991 Lead-Copper Rule⁴ require the water distributor to monitor the

corrosivity characteristics of the water.

Influence of Water Composition

The role of water chemistry on the influence of corrosion of Cu has been reported by a number of investigators.⁵⁻⁹ The problems of predicting a potable water's corrosivity can be appreciated by examining Table 1, which identifies a number of the chemical and physical factors which may be involved in the corrosion of Cu. Review of earlier articles provides information regarding how the corrosion of Cu can be viably and cost effectively mitigated by water treatment. There is no universal water treatment for overcoming all corrosion concerns in potable waters. For example, elevating the pH of a water can reduce the free carbon dioxide (CO₂) to such a level that cold water pitting does not occur.

However, the same treatment would be of little benefit with respect to hot water pitting.

Water Treatment Alternatives

A number of Cu corrosion concerns (for example, cuprosolvency and cold water pitting) can be avoided by alteration of the water's pH. It is common practice by water utilities in many communities to raise the pH to eliminate cuprosolvency and the associated green staining of plumbing fixtures. The benefits of these treatment programs can be seen in Figure 1.¹⁰

Different chemical treatments can be used to elevate the pH of potable waters, including additions of hydrated lime, caustic soda, soda ash, or silicates.

Lime Addition

Lime is the most effective and lowest-cost alkali available for water treatment.

The Suffolk County Water Authority on Long Island, New York, draws most of its water from shallow wells which have low hardness

TABLE 1
Factors Affecting the Corrosion of Copper by Potable Waters

Component	Influence
pH	Low pH tends to promote cuprosolvency
Dissolved oxygen	In the absence of oxygen, copper will not corrode
Free chlorine residuals	Excessive concentrations and time exposure can promote the corrosion of copper
Free carbon dioxide	May promote cold water pitting of copper
Calcium	Reduces corrosion if a protective film is formed
Silica	Reduces corrosion if a protective film is formed
Flow rates	High velocities and/or localized turbulence facilitate(s) the corrosion of copper.
Temperature	In the absence of protective film formation (e.g., CaCO ₃), rises in temperature increases the corrosion rate.
Metal ions	Iron, manganese, and aluminum above certain concentrations may promote the hot water pitting of copper.
Chlorides	May facilitate cold water pitting of copper
Sulfates	May facilitate cold water pitting of copper
Sulfides	May promote pitting of copper

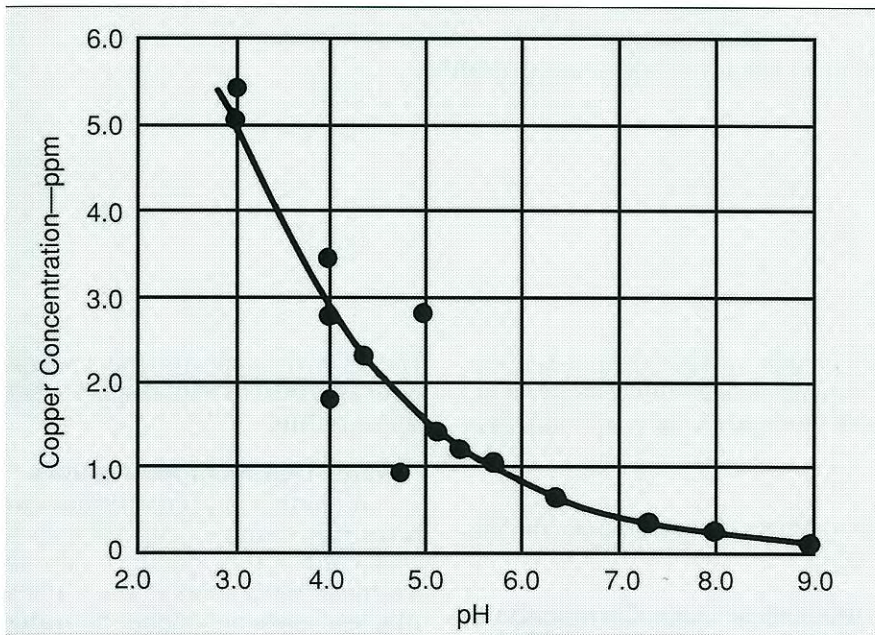


FIGURE 1

Effect of pH on corrosion of Cu. Water with adjusted pH was allowed to flow through 18.3 m (60 ft) of new 19 mm (0.75-in.) Cu tube at a rate of 0.25 L (1/15 gal) per minute. Samples were collected at 1 and 1.25 h and analyzed for Cu concentration. The results were averaged and plotted vs pH.

and alkalinity contents (less than 10 mg/L). Their deep wells contain so much CO₂ that these waters virtually effervesce when released from confined zones. These waters may have pH values near 4.5. This clearly demonstrates that each well supply must be individually treated to overcome the water's corrosivity. Most of the approximately 151.4 billion L (40 billion gal) of water produced in Suffolk County each year is treated with hydrated lime, which raises the pH of the shallow well water to over-

come cuprosolvency and raises the pH of the deep wells to overcome cold water pitting. Dosages vary from 100 lb/million gal for the shallow wells to nearly 200 lb/million gal for the deep wells (Table 2). This dosage range is necessitated by the difference in chemistry between the two water sources.

The increase in total hardness represented by these additions of lime is quite tolerable, usually involving only an increment of less than 15 mg/L in the treated water.

However, the solubility of hydrated lime is limited. At room temperature, its solubility in CO₂-free water is 1.2 gm/L, and this figure decreases with increasing temperature.

Caustic Soda

Caustic soda (sodium hydroxide, NaOH) is an alternative to hydrated lime for pH control.

NaOH is usually purchased by water distributors as a 50-percent solution in tank truck lots. The advantages of NaOH include ease of handling and storage. A 50-percent caustic solution becomes saturated with respect to NaOH at 11°C (53°F), causing the hydrate to crystallize and solidify completely at temperatures below 5°C (41°F).

Therefore, solution must be stored indoors and heated. If outside storage capacity is available, it should be diluted with water to 19 wt%, where the freezing point is about -29°C (-20°F). While the solution may be stored in steel, fiber glass is preferred because of its superior resistance to corrosion.

NaOH increases sodium (Na) levels in the finished water, but the increases are relatively moderate compared to Na intake from other sources. In the two examples cited above, increases of 5 and 13 ppm are calculated. With adult fluid intake of 1.5 to 3.0 L/day, Na intake from drinking water represents about five percent of the habitual total intake of 3,000 to 4,000 mg, as long as Na content of the water does not exceed 200 mg/L ppm. The World Health Organization has recommended an "action" level for Na at 200 mg/L based on taste.

Adverse health effects may be anticipated with Na levels exceeding 20 mg/L for that special group whose diet is restricted to 500 mg/day because intake from food cannot be feasibly reduced below 440 mg/day. Allowing another 20 mg from incidental sources and assuming water intake of 2 L/day, those on more common diet limits of 1,000 mg/day of Na may use water containing 270 mg/L.

Caution must be exercised if pH adjustment using NaOH is practiced where water softeners may also be used with brine-regenerated ion exchange columns.

Soda Ash

A third alternative for elevating the pH of domestic waters involves the addition of soda ash (Na_2CO_3). Its use has declined because of higher dosages required for the same neutralization benefits as lime or caustic, and because of the appreciably greater cost of the chemical itself. Na_2CO_3 is soluble at about 6 wt% at -2°C (28°F) and increases to 15 percent at about 15°C (60°F).

It was used sometimes when pH adjustment was desired without the addition of hardness in potable waters, and where insufficient alkalinity is naturally present for stability.

Silicates

Although more commonly used to mitigate corrosion of galvanized steel systems, certain liquid silicate/phosphate formulations can be used to create protective films on Cu tube surfaces. Typically, this is accomplished by proportionately feeding the formulation to the water so that its natural silica content is raised by 15 to 20 mg/L. In addition to protective-film formation, sodium silicate (Na_2SiO_3) additions also provide the secondary benefit of increased pH.

These and slightly higher silicate additions have been known to mitigate the erosion-corrosion of Cu tube and fittings in certain circulating, domestic hot water systems.

Aeration (Air Stripping)

A nonchemical alternative to the treatment of potable waters is aeration. Aeration removes free CO_2 , which eliminates the cold water pitting concern. It can also reduce sulfide content to tolerable levels, eliminating the pitting phenomenon associated with this aggressive species, and oxidize manganese (Mn) and/or iron bicarbonates to their filterable oxides (MnO_2 and/or Fe_2O_3), eliminating the hot water pitting of Cu by microgalvanic corrosion. Aeration also can reduce the cost of chemical treatment requirements downstream.

A wide variety of devices may be used to remove gases from liquids in water treatment, including spray-nozzle aerators, coke or slatted-tray aerators (with or without counter-flow air), diffused-air aerators, or packed-tower aerators. In recent applications, counterflow towers have been constructed to provide maximum water

TABLE 2
Representative Chemical Analyses of Well Waters
for Suffolk County, New York^(A)

Component	Hydrated Lime		Caustic Soda	
	Well No. 1 (Shallow)	Well No. 2 (Deep)	Well No. 3 (Shallow)	Well No. 4 (Deep)
pH	6.0	5.0	6.5	5.7
Chlorides as Cl	10.5	3.5	6.0	16.0
Total hardness as CaCO_3	20.0	8.0	18.0	50.0
Total alkalinity as CaCO_3	15.0	6.0	18.0	16.0
Iron as Fe	0.04	0.35	0.01	0.02
Nitrate as NO_3	3.2	0.01	0.9	5.9
Sulfate as SO_4	10.8	2.0	3.0	15.5
Sodium as Na	6.0	3.4	4.8	13.0
Potassium as K	0.7	0.6	0.4	1.65
Calcium as Ca	5.5	2.0	4.4	10.5
Magnesium as Mg	2.0	1.0	1.5	4.1
Specific conductance (μS at 25°C)	80.0	28.0	60.0	175.0

^(A)Values where applicable are expressed in mg/L

surface area for thorough contact with air.

Overtreatment

Although water treatment can eliminate corrosion, hot water pitting of Cu by aluminum (Al) generally results from overtreatment where aluminum sulfide has been used to clarify surface waters by coagulation. It has been reported that concentrations of Al greater than 0.1 mg/L promote the hot water pitting of Cu.¹¹

Similarly, lime additions and pH adjustments cannot be made indiscriminately. There have been cases where overtreatment to solve a cold water pitting problem has caused scaling conditions in the hot water lines.

Summary

Although Cu is essentially immune to waterside corrosion, conditions can arise where this noble metal can experience corrosion because of the chemical composition of the water conveyed. In these rare instances of corrosion, the deterioration process can be viably and cost effectively controlled by a number of water treatment alternatives. These include the addition of hydrated lime, caustic soda, soda ash, and silicate-phosphate blends to the water. A number of Cu corrosion concerns can be overcome by simple aeration of the water.

References

1. "Quality Goals for Potable Waters." Jour. AWWA 60, 1317 (1986).
2. Safe Drinking Water Act, PL 93-523, December 16, 1974.

3. Safe Drinking Water Act, 1986 Amendments, PL 99-339, June 19, 1986.
4. Federal Register (56FR 26460), Final Lead and Copper Rule, June 7, 1991.
5. M.R. Schock, C.H. Neff, "Chemical Aspects of Internal Corrosion: Theory, Prediction and Monitoring," Proceedings of AWWA Water Quality Technology Conference, Nashville, TN (1982).
6. T.E. Larson, Illinois State Water Survey Bulletin 59 (1975).
7. A. Cohen, W.S. Lyman, MP 11, 2 (1972).
8. G.J. Kirmeyer, G.S. Logsdan, Jour. AWWA 75, 78 (1983).
9. A. Cohen, J.R. Myers, "Mitigation of Copper Tube Cold Water Pitting by Water Treatment," CORROSION/84 paper no. 153, (Houston, TX: NACE, 1984).
10. K.E. Schull, "Experimental Approaches to Corrosion Control," Proceedings of AWWA Water Quality Technology Conference, VIII (1979)
11. P. Tunturi, S. Ylasaari, "A Special Case of the Pitting Corrosion of Copper in a Hot Water System." Proc. 5th Scandinavian Corrosion Congress 42-2 to 42-14, Copenhagen (1968).

Reprinted with permission of
MATERIALS PERFORMANCE

