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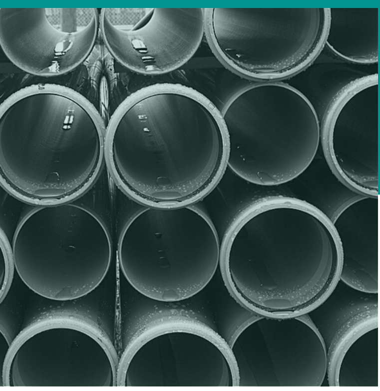
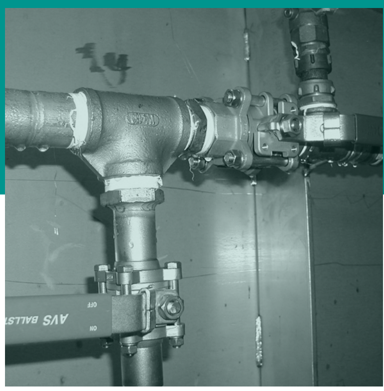
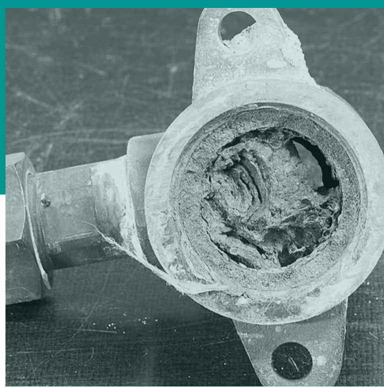
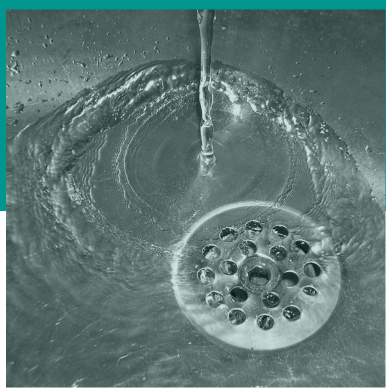
Kaunisto Tuija

Failure Mechanisms of Brass Components

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Author(s)
Kaunisto Tuija

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FAILURE MECHANISMS OF BRASS COMPONENTS

Abstract:

Brasses are most commonly used copper alloys that are widely used in valves and taps. Corrosion resistance of brasses is usually good also in water installations, but in non-optimal operating conditions the service life may decrease due corrosion.

The common corrosion failure mechanisms of brass components are dezincification, stress-corrosion cracking and corrosion fatigue.

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Yhteyshenkilö:
Tuija Kaunisto, tuija.kaunisto@wander.fi

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Publisher:
WANDER Nordic Water and Materials Institute,
Kalliokatu 10 B, FIN-26100 Rauma, Finland
www.wander.fi, vesi-instituutti@vesi-instituutti.fi

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1 Corrosion of brass

Brasses are most commonly used copper alloys, which contain copper, zinc and often lead to improve machining property. The microstructure of brass contains α-phase up to zinc content of 37 %, but at higher zinc content also another crystal form, β-phase, is formed. The properties of these phases differ from each other, but a suitable (α+β)-structure in brass results in good manufacturing and strength characteristics. (Metalliteollisuuden Keskusliitto 2001)

Corrosion resistance of copper metals is usually good also in water systems. Corrosion resistance of brass will decrease to some extent when zinc content is increased, and in non-optimal operating conditions the service life of brass components may decrease due to corrosion. Prerequisites for corrosion reactions are oxygen and water or moisture on the brass surface. The common corrosion failure mechanisms for brass components and their causes are described in Table 1.

Table 1. *Corrosion failure types of brass components and their joints.*

CORROSION TYPE	AFFECTING FACTORS		
	Product quality	**Design and installation**	**Operating conditions**
Dezincification	Unsuitable microstructure due to manufacturing		Water quality (chloride, acidity and low water hardness)
Stress-corrosion cracking	Residual stresses originating from manufacturing	Service loading (e.g. over-tightening of compression nuts)	Access of chemicals to the surface (ammonia, nitrite etc.) Local dezincification sites
Corrosion fatigue		Prevention of thermal expansion	Pressure shocks caused by valves and taps Water quality

2 Dezincification

Dezincification of brasses is a type of selective corrosion in which zinc dissolves from brass, and only a porous copper structure remains. The component will maintain its shape, but it will lose strength and water or gases may penetrate into porous brass. Brass also loses the yellow color and changes into copper-red color. Dezincification may proceed locally or uniformly on the whole surface. Indications of dezincification are whitish corrosion products on the surface and small leaks. Dezincification may cause brass valve blockages and fractures caused by loss of mechanical strength.

Tendency for dezincification increases with the zinc content in the brass. Alloys containing less than 20 % zinc are not prone to dezincification. The brass resistance against dezincification increases with the higher the proportion of copper rich α-phase in the brass microstructure. If the copper content is below 62 %, the brass structure contains also a high amount of β-phase. The dezincification resistance of brass component can be obtained with proper alloy and suitable heat treatment. Dezincification can be prevented in the α-phase almost completely with an addition of small amount of arsenic, antimony or phosphorus, but β-phase dezincification cannot be prevented with alloying. To prevent the proceeding of dezincification, the β-phase should not be in the brass as a continuous network, but rather as separate zones in the α-phase microstructure. This structure can be ensured with proper manufacturing methods. (AWWA 1996)

Dezincification is more common in warm water installations. High chloride concentration, low alkalinity (bicarbonate concentration) and low hardness of water increase the risk of dezincification (Kunnossapitoyhdistys 2006). In Finland dezincification has been observed in coastal areas due to high chloride concentration in potable water. The pH value within normal potable water pH range affects only to precipitation tendency of corrosion products. Precipitates are not always formed in acidic water, but as the pH value increases, the precipitation tendency of corrosion products on surfaces increases. Many countries recommend an upper limit for potable water pH to prevent blockage of valves by precipitates. To prevent dezincification, the water quality targets present the upper limit for pH to be 8.3 and to maintain the ratio of bicarbonate and chloride above 2 (Suomen kuntaliitto 1993).

According to Finnish construction regulation (Ministry of the Environment 2007) the brass components in water installations inside the buildings has to be manufactured from dezincification resistant brass and testing of the components for dezincification is required in the Finnish type approval rules.

3 Stress corrosion cracking

Stress corrosion cracking occurs due to combined effects of sustained tensile stress and corrosive environment, resulting in cracking in the metal structure. The corrosive environment that causes stress corrosion cracking is specific for each metal type. Brasses containing more than 20 % zinc are relatively sensitive for stress corrosion cracking in ammonia containing environment. Stress corrosion cracking has been previously called also to season cracking. (ASM International 2005)
Applied stresses may result from manufacturing like cold working, cutting, punching and welding, or from service loading caused by static load or for example excessive tightening of compression nuts.
Chemicals causing stress corrosion cracking of brass are for example ammonia, sulfate, nitrite and fluoride (Lee and Shih 1995). Ammonia can originate from cleaning agents and heat-insulating materials. Small amounts of ammonia can be emitted for example from some cellular rubber insulates of air conditioner or cooling system, and the aggressive chemical environment built up by ammonia and condensation water may result in stress corrosion cracking of brass components. Nitrites can be formed from nitrates in drinking water during reduction of nitrate. Also some sealing materials (e.g. some silicones) and some disinfectants may contain aggressive compounds (Heinemann 2004).
Critical chemical concentrations for stress corrosion cracking are very small and dependent on the stress level. Minimum values for chemical concentrations or required stress level are not known. Even rather low stresses may cause stress corrosion cracking when component is exposed to aggressive chemicals. To prevent stress corrosion cracking the residual stress formed in brass components during manufacturing is removed in the end of the processing by thermal stress relief (Metalliteollisuuden Keskusliitto 2001). Components have to be correctly installed by skilled person and contact with nitrogen containing compounds has to be prevented. The access of aggressive chemicals to the inner or outer surface is difficult to prevent, because also many detergents and washing agents may contain harmful substances.

Tightening of compression fittings during installation has to be done according to manufacturer’s instructions and excessive force has to be avoided in tightening the nut. The Finnish type approval requirements of brass components in potable water systems demand testing for stress corrosion cracking resistance, in addition to dezincification resistance.

Stress corrosion cracking can promote dezincification and vice versa (ASM International 2005). Brasses with high zinc content and thus β-phase are very sensitive for dezincification and stress corrosion cracking. Probable starting points for stress corrosion cracking are corrosion pits, local dezincification sites and scratches. Stress corrosion cracking is difficult to detect while in progress, and crack growth in the brass components in use cannot be prevented by any repairing actions afterwards.

4 Corrosion fatigue

The fractures of brass components can result in from mechanical load or combination of mechanical load and corrosive environment. When the structure is exposed to vibration, cyclic stress or thermal stress, the service life is dependent on the fatigue strength of the component. In corrosive environment the fatigue strength is usually remarkably lower than in non-corrosive environment. In water installations corrosion fatigue is caused by combined effect of aggressive water and cyclic stress on the component. Corrosion fatigue shows as longitudinal or cross sectional cracks on the brass component surface. (ASM International 2005)

The cyclic stress can result in from restricted thermal expansion, pressure shocks caused by valves or taps, or vibration caused by pumps, compressors and valves. Pipes should be installed so that their thermal expansion is possible. Joints and fittings should be installed by professionals, since these are typical sites of corrosion fatigue failures.

5 Operating conditions

Variations in operating conditions, installation practices and component quality can cause failures in some part of the water distribution system, although other parts may remain intact. The main operating factors are water quality, temperature and flow rate.

The most important factor that affects corrosion failures during use is the water quality. The drinking water delivered by water companies may not always be of good technical quality, although it fulfills the hygienic requirements set for drinking water. The water quality may also change in the distribution network. The variation of different materials used in the water installations and network may complicate the optimization of water treatment process to prevent the corrosion, since the water quality parameters affecting the service life of components differ between the used materials. There are also plenty of households using well water in Finland. Natural waters are commonly corrosive for metallic materials, and, therefore, the well water quality has to be tested prior to choice of piping material. The technical quality of well water can be improved with various water treatment processes, e.g. alkalization by limestone.

Good quality water can change in the water distribution network into low quality water and even become a health risk, especially if the conditions in the distribution network are suitable for microbiological activity. Drinking water usually contains nutrients for microbes, but concentration of these nutrients is not limited by EU or national drinking water regulation (Kekki et al. 2007). Formation of biofilms on pipe surface is not wanted, since biofilms are probable growth environments also for pathogenic bacteria (Percival et al. 2000).

The most important water quality parameters affecting corrosion are oxygen concentration, pH (acidity), salt content (chlorides and sulfates), total hardness (calcium and magnesium concentration) and alkalinity (bicarbonate concentration). There are no universal guidelines or limit values for water corrositivity due to different characteristics of materials. Table 2 shows target values for technically good water quality.

Table 2*. Target values for good technical water quality for metal and cement based materials of water distribution systems. (Kekki et al. 2008)*

pH	Bicarbonate	Calsium	Free carbon dioxide	Chloride	Sulfate
7,5 - 8,0	>60 mg/l	>20 mg/l	<15 mg/l	<100 mg/l	<100 mg/l

Increase of water temperature usually accelerates corrosion. Too high temperatures are harmful, as well as stagnating conditions or too high flow rates, although the formation of precipitates is prevented by circulating the water continuously. One parameter affecting the formation and quality of protective layers in the piping surface is the pressure test of the piping prior to use. The water used in the pressure test should be clean and without any suspended matter, and long stagnation periods prior to use has to be prevented. Especially harmful is a situation where the pipe is only partly filled with water. The effects of the pressure test on the corrosion failures occurring later in the use of piping are difficult to prove.

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