THE CAUSES OF DAMAGE TO THE BRASS FITTINGS OF WATER SUPPLY SYSTEM

KRAUS Martin[1], BYSTRIANSKÝ Jaroslav[1], MAREŠ Vratislav[2]

[1] *VSB – Technical University of Ostrava, FMMI, RMTVC, Ostrava, Czech Republic, EU,* martin.kraus@vsb.cz
[2] *Center of Advanced Innovation Technologies, VSB - Technical University of Ostrava,*
Czech Republic, EU

Abstract

The mechanism of dezincification is a relatively common cause of water networks defects and is involved with the composition and the terms of the water flow. This process is a typical representative of the selective corrosion of brass when a portion of the original material from copper and zinc alloy into a spongioid copper changed. This occurs either in the full layer near the surface, or locally. Spongioid copper has no strength and step by step wall perforation of the product occurs. Dezincification also has a role in the formation of corrosion cracking of brass.

This paper deals with the problem at the heat station, after the installation of drinking water dosing of ClO_2. After approximately two years the failure occurred of the some components of hot water distribution system. Most notably was the leakage of water in bodies of water gauge and other brass parts. For the assessment of the material state light and SEM microscopy has been used, EDS analysis of chemical composition, microhardness measurement and XRF and XRD analyses for the characterization of corrosion products. The investigation affirmed the original premise of dezincification mechanism of damage as a result of the composition of the flowing media.

Keywords: Dezincification, brass, water supply, chlorides, microstructure

1. INTRODUCTION

All brasses with a zinc content of more than 15 wt.% are prone to dezincification. Dezincification mechanism lies in the fact that the cooper and zinc are dissolved and after cooper redeposit back. It allows by chloride mechanism - in corrosive environment must be chlorides present. Dezincification brass is a common cause of failure of brass fittings in water circuits. Significant is dezincification in waters with high content of oxygen and CO_2, with little or no flow [1-3]. Weakly acidic water with a small salinity at normal temperature usually leads to dezincification, neutral and weakly alkaline with high salinity, especially at elevated temperature, to a local dezincification. Dezincification is proceeding with the oxygen depolarization. Dezincification principle can derive from the differences of equilibrium potentials for some reactions that can go during dezincification [4, 5]. In the range into -0.03 V (SHE - Standard Hydrogen Electrode) can only happen to a slow dezincification at the surface. Cu is not dissolving. In the range from -0.03 V to 0.2 V (SHE) copper can oxidize by chloride mechanism according to the reactions 2, 3, 5, 6 with the zinc (reaction 1) and on the surface (where is a locally lower concentrations of chlorides) together reduce by reactions 4 or 6 [6]. The reactions of 2 and 3 are converted copper to Ionic forms of at lower potential, than would be expected by the equilibrium potential of copper by equation 4. In a more strongly oxidizing environments, potentials above 0.2 V (SHE) to the anodic oxidation of the copper and zinc occurs already, to dezincification does not occurs but the general corrosion is already high [2, 4, 7].

If the solution is ClO_2 in contact with structural materials, whether organic or metal may cause premature damage. From metals titanium is resistant to concentrated ClO_2 solution. For other construction materials corrosion occurs. At lower concentrations of ClO_2, what are common in drinking water, resist high-alloyed stainless steel (with a higher level of alloying) [8].

$Zn^{2+} + 2e^- = Zn$; $E_r = -0.90$ V (SHE) (1)

$CuCl_2 + e^- = Cu + 2Cl^-$; $E_r = -0.03$ V (SHE) (2)

$Cu^{2+} + e^- + 2Cl^- = CuCl_2$; $E_r = +0.01$ V (SHE) (3)

$Cu^{2+} + 2e^- = Cu$; $E_r = +0.16$ V (SHE) (4)

$Cu^{2+} + e^- + Cl^- = CuCl$; $E_r = +0.12$ V (SHE) (5)

$CuCl + e^- = Cu + Cl^-$; $E_r = +0.20$ V (SHE) (6)

The paper seeks to clarify the causes of failure of the some brass components of hot water distribution system, which occurred approximately two years later after the installation of drinking water ClO_2 dosing (for disinfection).

2. MATERIAL AND TEST METHODS

For the assessment of damage causes two water gauge were delivered and some other brass components.

From the housing of the water gauge were for metallographic analysis and SEM, a few specimens removed (see **Figure 1**), which are representative of different damage intensity, wall thickness, the technological differences, etc. For this evaluation by scanning electron microscopy the electron microscope JEOL JSM - 6490LV with EDS analyser Inca x - act was used.

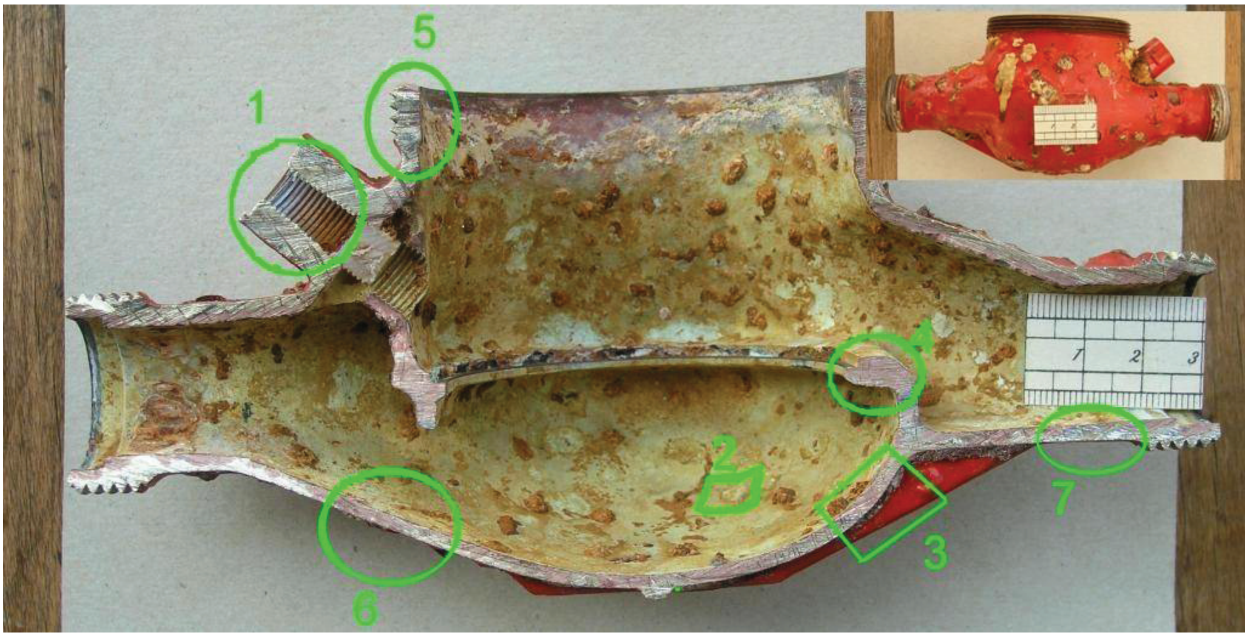


Figure 1 Specimen extraction for metallographic and SEM analysis; **spec. 1** - basic material, unaffected, not in direct contact with the environment, the maximum wall thickness; **spec. 2** - the bottom wall under the outer blister with through pore; **spec. 3** - the bottom wall with technological connection to the rib stiffeners; **spec. 4** - internal desk (housing for indicator); effect of media on both sides; **spec. 5** - thread area of gauge lid; least affect intensity; **spec. 6** - „average“ wall; **spec. 7** - pipe part, following the thread for the connection of gauge

For complete findings on the outer and inner water gauge surface were these tough deposits, layers, or corrosion products analysed: **A** - deposits from the inner wall of the upper chamber of water gauge; **B** - deposits from the inner wall of the lower chamber; **C** - blister incrustation of outer wall; **D** - sediment (oxide layer) the bottom side of the water gauge lid. By X-ray fluorescence analysis (XRF) was the elemental composition of individual deposits determined. By X-ray diffraction analysis (XRD) has been studied the incidence and types of solid phases present.

3. RESULTS AND DISCUSSION

In **Figure 2** the cut surface of specimen 1is in polished condition. In **Figure 3** then is the microstructure of base materials on the same specimen. Needle morphology is typical for two-phase brass, [1, 6]. **Figures 4** and **5** document the pore on scratch pattern of specimen 2 with visible crack spreading from the pore. This one is through, it is not clear, however, whether originated by the media or partially initiated already during the casting process. On both images is pronounced (dezincificated) area of the pink coloration with a typical round curving shape.

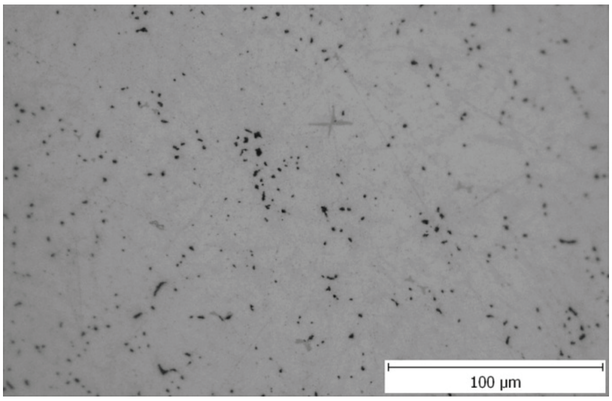


Figure 2 Basic material, spec. 1, polished state

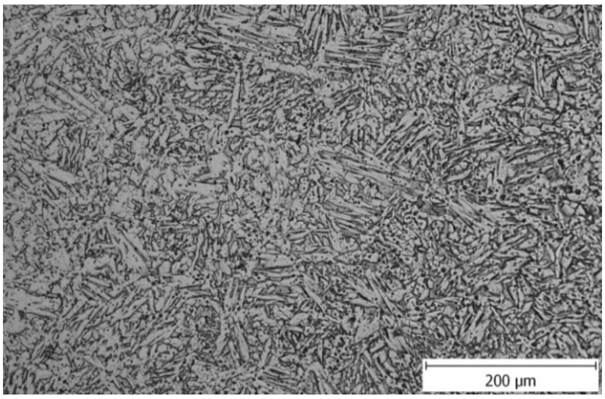


Figure 3 Basic material, spec. 1, etched state

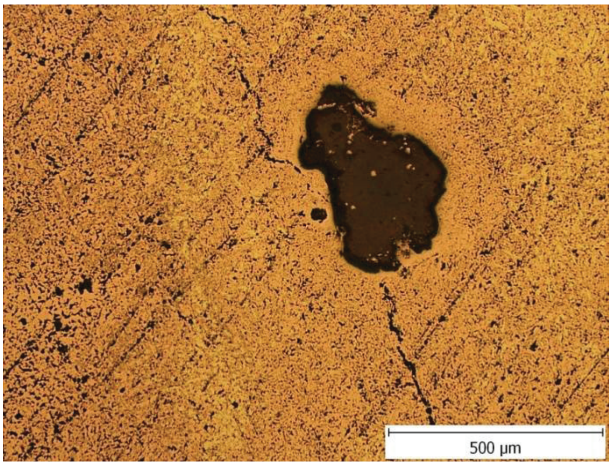


Figure 4 Scratch pattern, spec. 2, polished state

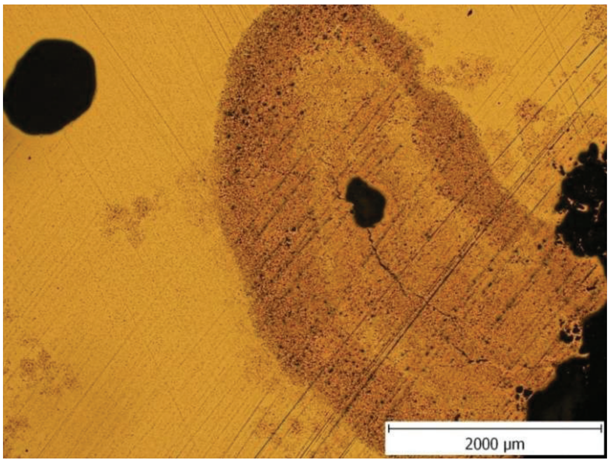
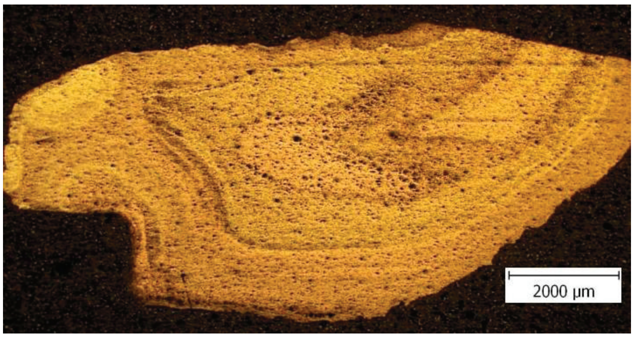


Figure 5 Scratch pattern, spec. 2, polished state

Specimen 4 evinces dezincification in full cross section, which is consistent with the fact that medium flows this part of water gauge from both sides (**Figure 6**).

Figure 7 shows the threaded part (spec. 5) of the gauge with attack, which is common throughout the full length of the gauge outer shell. Therefore, dezincificated spongious structure with significantly fluctuating attack depth of the wall thickness. Spec. 7 taken from the shell in place, which connects on the fittings, the considerable disintegration of structures evinces, with the visible crumble of the inner wall´s particles (**Figures 8** and **9**).



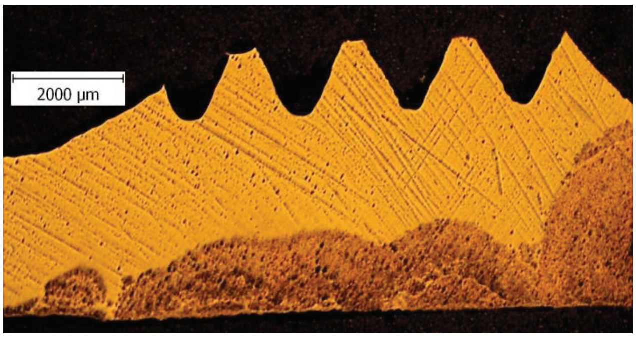
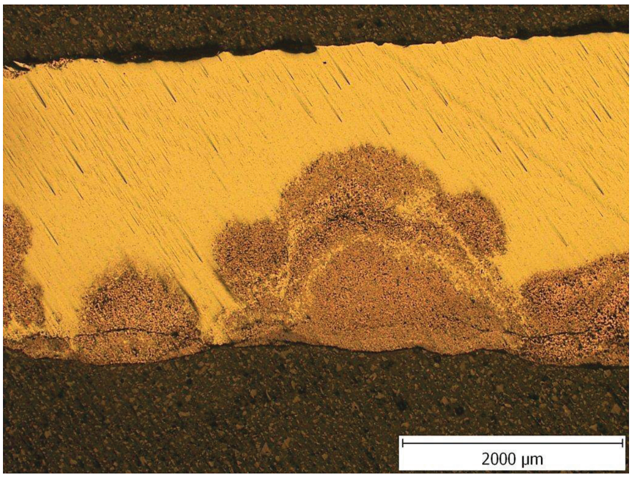


Figure 6 Dezincification- all cross section, spec. 4

Figure 7 Thread part under gauge lid, spec. 5



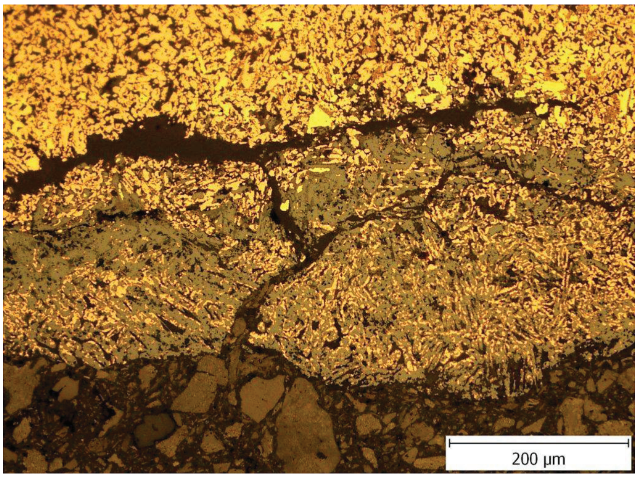
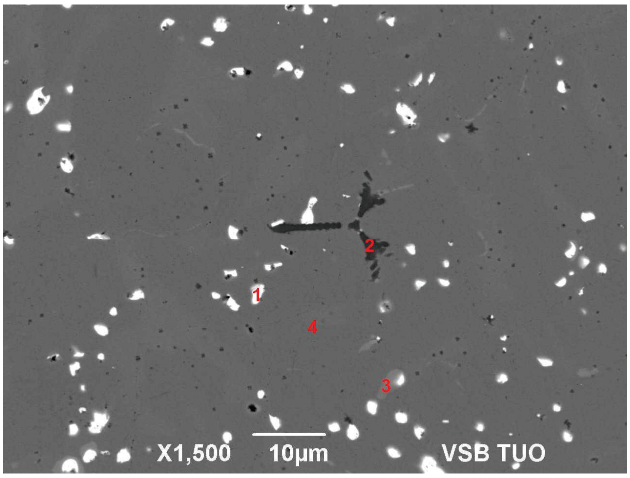


Figure 8 The attack of spec. 7

Figure 9 Detail of microstructure disintegration

Figure 10 and **Table 1** of are documenting the state of specimen 1, therefore the original material of water gauge. Surface analysis shows that this is a brass with an average content of approx. 61 wt.% copper and 34 wt.% of zinc. Microstructure is dual phase. Majority dark grey phase contains 65 wt.% Cu against 33.5 wt.% Zn. The minority phase (lighter) has about 53.5 wt.% Cu; 33 wt.% Zn and a relatively high content of Sn - over 11 wt.%. Further there are units (formations) on the basis of lead (Spectrum 1) and iron (Spectrum 2) occurring.



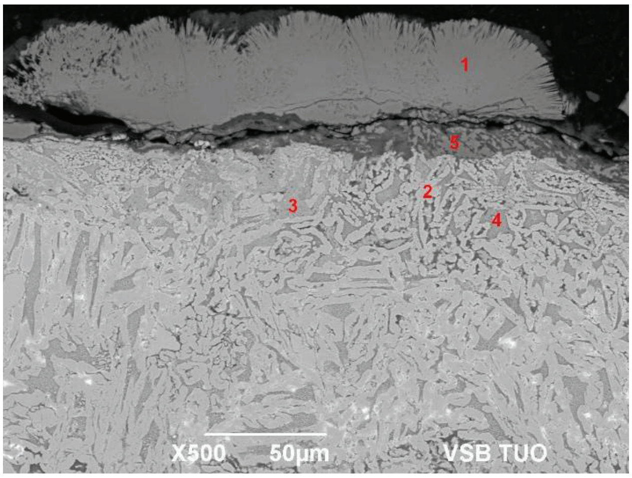


Figure 10 SEM analysis of basic material, spec.1

Figure 11 SEM microstructure analysis of spec. 5

Table 1 EDS analysis of specimen 1 composition (wt.%)

	O	Al	Si	Cr	Fe	Ni	Cu	Zn	Sn	Pb
area		0.93			0.76	0.44	60.8	34.2	0.99	1.87
Spectrum1	12.4	1.91					7.70	5.19		72.8
Spectrum2		1.56	10	1.13	77.2	1.60	4.79	3.63		
Spectrum3		0.83				0.67	53.4	33.2	11.8	
Spectrum4		0.77			0.46		65.3	33.4		

In **Figure 11** and in **Table 2** is described the situation at the inner surface of the specimen 5. Spectrum 1 and 5 corresponds to the zinc oxide deposits. Spectrum 2 to 4 shows on dezincificated area with almost absolute contents of copper, alternatively, copper and oxygen compounds. Area (surface) analysis in greater depth (or closer to the outer surface) has confirmed the composition of the base material, same as the sample 1. A similar situation also exists in the case of sample 7.

Table 2 EDS analysis of specimen 5 composition (wt.%)

	O	Al	Si	P	Fe	Ni	Cu	Zn	Sn	Pb
Spectrum1	44.5		11.7				0.67	43.1		
Spectrum2	1.16				0.43		98.4			
Spectrum3	15.5						84.5			
Spectrum4	23.2			2.09	2.00		55.6	8.27	6.02	2.78
Spectrum5	39.7		11.4		0.48		3.67	44.6		
area	1.38	1.05			0.77	0.57	61.3	35		

For comparison, an analysis was made also on the sample of water gauge lid and threaded pipe coupling that is connected by using the union nut to water gauge. Metallographic observations show when the lid on slightly different morphology of the basic microstructure (more globular). However, the damage is similar to the gauge body.

Control measurement of microhardness HV 0.01 showed a great difference in the mechanical properties between unaffected (golden) area and affected (pink- dezincificated) with the ratio cca 140 HV 0.01 to 60 HV 0.01.

XRF and XFD analysis showed that samples A and B are related to its composition on the base with a high proportion of zinc, iron and copper, the content of which is substantially higher in the sample A (over 15 wt.%). Sample D from the water gauge lid is based on copper oxides with a significant proportion of Silicon. Sample (C) has a great difference from the others. Its composition with high levels of zinc and chlorine indicates the presence an upper email components (due to the nature of incrustation unfortunately inseparable) and the process of dezincification corrosion products. This fact confirmed also SEM or. EDS analysis of same product taken from a different location of the gauge - see **Figure 12** (**Figure 1**, cut) and **Table 3**.

Table 3 EDS analysis of composition of blister incrustation (rigid leakage) on outer gauge wall

element	O	Al	Si	S	Cl	Fe	Ni	Cu	Zn
wt.%	32.49	0.80	0.26	4.74	15.59	0.41	0.99	0.62	44.10

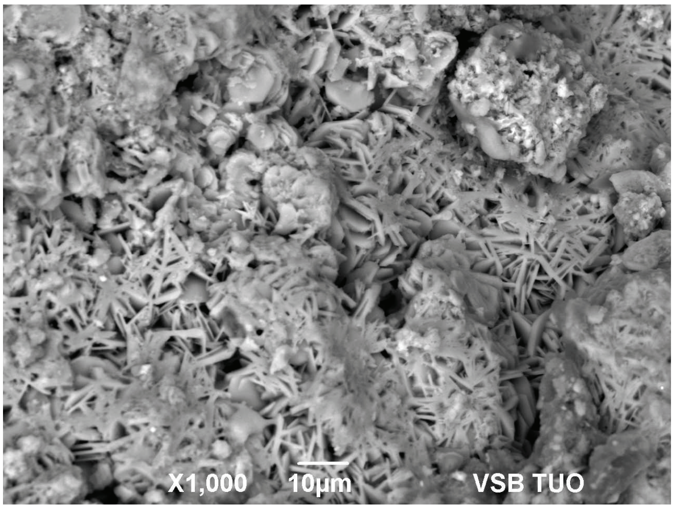


Figure 12 SEM - microstructure of blister incrustation (rigid leakage) on outer gauge wall

4. CONCLUSION

As the cause of damage to the delivered water gauges and other brass part of the water seems to be a selective type of corrosive attack, which is typical of brass with zinc content of over 15 wt.%, known as the dezincification and is related of chloride environments.

Walls of water gauges are attacked in the all area of contact with the flowing fluid (drinking water with the addition of ClO_2) with very varying depth of damage - from mild to complete perforation.

Performed SEM analysis showed a constant chemical composition of all brass components, approximately 61 wt.% copper and. 34 wt.% of zinc. The material seems to be relatively homogeneous and the composition is the standard used for applications in water supply systems. Visibly damaged areas showed except considerable porosity the copper content up to 100%.

Gauge lid is damaged by smallest level. It probably is related to the periodic presence of gaseous phase under the (air pocket). It is the highest point of water gauge.

The analysed compounds, deposits are rich in zinc and, in the case of external blistering incrustations also on chlorine. It is confirming the previous facts.

The mechanism of dezincification is a relatively common cause of defects in water supply network and it is associated with the composition and the terms of the water flow. Unfortunately the chemical analysis of water, before an enrichment of ClO_2, was not available for the assessment. It cannot be excluded that the dezincification might happen even without this addition. However, it is highly probable, the selected method of disinfecting water greatly accelerated this process. In the present composition of the water after the final modification, we can expect a gradual degradation of all brass components, those has a similar composition, as delivered water gauges.

Dezincification mechanism could be affected by the way of producing (casting technology) the housing of the gauge. This technology produced in brass heterogeneity of chemical composition. It supports the rise and spread of this attack. Increased oxidation-reduction potential of the environment It can be invoked both by the ClO2 or its semi-products of reduction.

If is not possible to change a chemical composition of fluid, as possible correction is recommending a change or increase the liquid flow, reduction of the oxygen content (to limit the oxidation ability of environment), or apply cathodic protection.

From the materials view point other brass types is possible used. For example so-called red brass (below 15 wt.% Zn) - these have, of course, inconvenient mechanical properties - or alloyed grades As, Sn, P, for dual phases Bi. Alternatively, choose materials from other groups, for example high-alloyed stainless steel.

For authenticated of material dezincification resistance can be used tests according to ČSN ISO 6509 [9] - cuprous chloride exposure. This test could not be used, because the non-damaged material was not available.

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