BRITISH STANDARD

BS EN
12502-2:2004

Protection of metallic materials against corrosion — Guidance on the assessment of corrosion likelihood in water distribution and storage systems —

Part 2: Influencing factors for copper and copper alloys

The European Standard EN 12502-2:2004 has the status of a British Standard

ICS 77.060; 23.040.99; 91.140.60

British Standards

National foreword

This British Standard is the official English language version of EN 12502-2:2004.

The UK participation in its preparation was entrusted to Technical Committee ISE/NFE/8, Corrosion of metals and alloys, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 19 January 2005

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 17 and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments

ISBN 0 580 45297 2

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 12502-2

December 2004

ICS 77.060; 23.040.99; 91.140.60

English version

Protection of metallic materials against corrosion - Guidance on the assessment of corrosion likelihood in water distribution and storage systems - Part 2: Influencing factors for copper and copper alloys

Protection des matériaux métalliques contre la corrosion - Recommandations pour l'évaluation du risque de corrosion dans les installations de distribution et de stockage d'eau - Partie 2 : Facteurs à considérer pour le cuivre et les alliages de cuivre

Korrosionsschutz metallischer Werkstoffe - Hinweise zur Abschätzung der Korrosionswahrscheinlichkeit in Wasserverteilungs- und speichersystemen - Teil 2: Einflussfaktoren für Kupfer und Kupferlegierungen

This European Standard was approved by CEN on 22 November 2004.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 12502-2:2004: E

Contents

Foreword

This document (EN 12502-2:2004) has been prepared by Technical Committee CEN/TC 262 “Metallic and other inorganic coatings”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2005, and conflicting national standards shall be withdrawn at the latest by June 2005.

This standard is in five parts:

- *Part 1: General;*

- *Part 2: Influencing factors for copper and copper alloys;*

- *Part 3: Influencing factors for hot dip galvanized ferrous materials*;

- *Part 4: Influencing factors for stainless steels;*

- *Part 5: Influencing factors for cast iron, unalloyed and low alloyed steels.*

Together these five parts constitute a package of interrelated European Standards with a common date of withdrawal (dow) of 2005-06.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

This document results mainly from investigations into and experience gained of the corrosion of copper materials in drinking water distribution systems in buildings. However, it can be applied analogously to other water systems.

The corrosion likelihood of copper and copper alloys depends on the formation of a corrosion product layer that begins to form as soon as these materials come in contact with water. The more this layer prevents ionic and electronic exchanges between the metal and water, the more protective it is and the higher the durability of the metal.

Copper and copper alloy drinking water systems are, in general, resistant to corrosion damage in normal use. However, there are certain conditions under which they will sustain corrosion damage.

As a result of the complex interactions between the various influencing factors, the extent of corrosion can only be expressed in terms of likelihood. This document is a guidance document and does not set explicit rules for the use of copper and copper alloys in water systems. It can be used to minimize the likelihood of corrosion damages occurring by:

- assisting in designing, installing and operating systems from an anti-corrosion point of view;
- evaluating the need for additional corrosion protection methods for a new or existing system;
- assisting in failure analysis, when failures occur in order to prevent repeat failures occurring.

However, a corrosion expert, or at least a person with technical training and experience in the corrosion field is required to give an accurate assessment of corrosion likelihood or failure analysis.

1 Scope

This document gives a review of influencing factors of the corrosion likelihood of copper and copper alloys used as tubes, tanks and equipment in water distribution and storage systems as defined in EN 12502-1.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12502-1:2004, *Protection of metallic materials against corrosion — Guidance on the assessment of corrosion likelihood in water distribution and storage systems — Part 1: General.*

EN ISO 8044:1999, *Corrosion of metals and alloys — Basic terms and definitions (ISO 8044:1999).*

3 Terms, definitions, and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 8044:1999 and EN 12502-1:2004 apply.

3.2 Symbols

$c(\mathrm{HCO_3^-})$	concentration of hydrogen carbonate ions in mmol/l
$c(\mathrm{SO_4^{2-}})$	concentration of sulphate ions in mmol/l
$c(\mathrm{O_2})$	concentration of oxygen in mmol/l

4 Types of corrosion

4.1 General

The most common types of corrosion are listed in EN 12502-1.

Internal corrosion of copper and copper alloys in water distribution and storage systems generally leads to the build-up of layers formed by corrosion products, which can or cannot be protective. In some cases corrosion can lead to the impairment of the function of the system or failure because of corrosion damage (see Table 1).

Table 1 — General characteristics of the different types of corrosion of copper and copper alloys

Type of corrosion	**Uniform corrosion**			**Pitting corrosion**			**Erosion corrosion**	**Selective corrosion**	**Stress corrosion**	**Corrosion fatigue**
Manifestation	Thin adherent layer	Adherent layer	Non-protective layer of corrosion products	Locally perforated protective layer			Protective layer destroyed mechanically or removed	Dezincification	Cracks perpendicular to the principal tensile stress	Cracks perpendicular to tensile stress and parallel to bending stress
Visible corrosion products	Brown/ black Cu_2O/ CuO	Green $Cu_2(OH)_2CO_3$[a]	Blue $Cu_2(OH)_2SO_4$ green $Cu_2(OH)_2CO_3$[a]	Pits covered with nodules $Cu_2(OH)_2CO_3$ (Type 1)[a]	Pits covered with nodules $Cu_2(OH)_2SO_4$ (Type 2 and microbially induced)[a]	No products covering the pits (Type 2)[a]	None	White products of $Zn(OH)_2$ and/or $Zn_5(OH)_6(CO_3)_2$	None	None
Corrosion effect	Negligible uniform corrosion attack	Negligible uniform corrosion attack	Significant uniform corrosion attack with release of corrosion products	Pitting corrosion attack			Profiled attack	Change in colour and structure of the alloy	Cracks visible to the naked eye or under microscope	Visible cracks
Possible corrosion damage	None	None	Staining of sanitary equipment	Leakage			Leakage	Leakage, disfunction of valves	Leakage	Leakage

[a] Within a layer of Cu_2O.

The types of corrosion considered for copper and copper alloys comprise the following:

- uniform corrosion;
- pitting corrosion;
- selective corrosion;
- bimetallic corrosion;
- erosion corrosion;
- stress corrosion;
- corrosion fatigue.

For each type of corrosion, the following influencing factors, described in EN 12502-1:2004, Table 1 and Clause 5, are considered:

- characteristics of the metallic material;
- characteristics of the water;
- design and construction;
- pressure testing and commissioning;
- operating conditions.

4.2 Uniform corrosion

4.2.1 General

Experience shows that corrosion damage to copper and copper alloys as a result of uniform corrosion is rare. The occurrence of uniform corrosion of these materials strongly depends on the properties of the surface layers that are formed.

Blue-green staining of sanitary equipment and blue-green coloured water arising from dripping taps is an indicator of copper ions in the water and hence of uniform corrosion, but it cannot be taken as an indicator of corrosion damage of the copper or copper alloy component itself.

Copper ions in water can promote pitting corrosion of less noble metals (e.g. zinc, iron) in the same circuit by depositing as metallic copper, which enhances the local activity of the cathodic oxygen reduction.

Protective layers consisting of copper corrosion products normally form on copper and copper alloys. In a few cases the layer is very thin, brown and homogeneous and consists of copper (I) oxide and copper (II) oxide. In most cases, however, there is sufficient hydrogen carbonate in the water to allow the formation of a layer of copper hydroxycarbonate $Cu_2(OH)_2CO_3$ above the copper (I) oxide and copper (II) oxide. This occurs during the initial operating period, progressively forming a green scale.

The actual copper concentration is influenced by the water composition and the time and conditions of operation such as high flow rates and water hammer.

Although copper corrosion products are only sparingly soluble, copper ions are released into water. The formation of copper ions caused by uniform corrosion and dissolution of corrosion products under stagnant conditions leads to an increase of the concentration of copper ions in the water. The detectable number of copper ions will depend on:

- the concentration of the carbonic acid species and total organic carbon ;
- the duration of stagnation of water in pipes;
- the age of the installation;
- the dilution caused by mixing with fresh water;
- the method of sampling.

The quantity of loosely adherent copper corrosion products that can be removed from the tube walls will depend on:

- the duration of low water velocity;
- the extent of any sudden turbulent flow.

4.2.2 Influence of the characteristics of the metallic material

Within a group of alloys with the same major alloying elements the material composition, heat treatment and differences of the surface condition resulting from the manufacturing process, are not known to influence the long-term behaviour of copper and copper alloys with respect to uniform corrosion.

4.2.3 Influence of the characteristics of the water

Under flowing conditions in oxygen-containing waters, the rate of uniform corrosion of copper mainly depends on the pH value of water. Generally, it increases with decreasing pH value of the incoming water and is negligible above pH 7,5.

In waters of low hydrogen carbonate content, i.e. when $c(\mathrm{HCO_3^-}) < 1{,}0$ mmol/l, corrosion products other than copper hydroxycarbonate can become those of the lowest solubility, e.g. copper hydroxysulphate $Cu_2(OH)_2SO_4$ which forms loosely adherent layers. Loosely adherent corrosion products are easily dislodged into the water stream. In these cases, the analytically observed copper concentration in the water can exceed the values expected from the dissolution of the corrosion products alone, since copper in particulate form will also be present.

In waters with pH values less than 7,5, the detectable number of copper ions generally increases with increasing total organic carbon.

The rate of uniform corrosion can be decreased by the addition of inhibitors, e.g. orthophosphates, or by alkalization of the water by addition of NaOH and/or Na_2CO_3, by addition of $Ca(OH)_2$ or by use of filters e.g. marble, limestone, dolomite.

4.2.4 Influence of design and construction

The formation of protective layers will be favoured by regular renewal of the water. This can be facilitated by avoiding areas of stagnation.

4.2.5 Influence of pressure testing and commissioning

If pressure testing is not carried out in accordance with the recommendations given in EN 12502-1:2004, 5.5, so that residual water is left in the system after draining, the likelihood for the formation of loosely adherent corrosion products is increased.

4.2.6 Influence of operating conditions

4.2.6.1 Influence of temperature

The effects of temperature and temperature variations on uniform corrosion are not known to influence the long-term behaviour of copper and copper alloys.

4.2.6.2 Influence of flow conditions

Regular renewal of the water, especially in the initial stage, promotes the formation of protective layers.

4.3 Pitting corrosion

4.3.1 General

4.3.1.1 Manifestations of pitting corrosion

There are different types of pitting corrosion of copper in water distribution and storage systems. Copper alloys are not endangered by pitting corrosion. The type of pitting corrosion depends on the water temperature, the water composition and the operating conditions.

Corrosion cells can develop under critical circumstances in the initial stage after the first filling of the system. Whether a corrosion cell stabilizes and results in macroscopic pitting, or as in most cases becomes repassivated, depends on the water composition and the service conditions.

4.3.1.2 Type 1: Pitting corrosion in cold water

Pitting corrosion of copper observed in cold water (Type 1) is characterized by hemispherical pits and an increased formation of green nodules consisting of copper hydroxycarbonate above the attacked area. Under these nodules, the pit is almost always covered by a continuous copper (I) oxide layer at the level of the former surface. Under this copper (I) oxide layer ruby-red macro-crystalline copper (I) oxide and sometimes finely crystalline white copper (I) chloride are present.

The corrosion rate of Type 1 pitting in cold water is relatively high which means that within a period of months to a few years complete perforation of the wall can occur. If failures do not occur within this time, the risk of failure decreases from that time on. However, a change of water composition can induce this type of corrosion in relatively old tubes because of reactivation of previously passivated cells.

If parts of heated water systems remain cold for long periods, they can demonstrate the characteristics of pitting observed in cold water.

4.3.1.3 Type 2: Pitting corrosion in heated water

Pitting corrosion of copper observed in heated water (Type 2) is characterized by pits with a narrow mouth and an irregular interior geometry. These pits are not normally covered with corrosion products. They are completely filled with copper (I) oxide and sometimes the mouths are covered by crusts containing blue copper hydroxysulfate. The corrosion rate of Type 2 pitting is usually lower than that of Type 1 pitting. Unlike Type 1 pitting as observed in cold water, there is a greater variety of manifestations of Type 2 pitting.

4.3.1.4 Microbially influenced pitting corrosion

Another seldom observed form of pitting corrosion, which is characterized by well defined areas of attack, within which there can be numerous pits covered by voluminous corrosion products, is influenced by microbial processes. Those pits are similar in appearance to those of Type 1 pitting being hemispherical and having a copper (I) oxide layer at the level of the original copper surface. Under this layer macro-crystalline copper (I) oxide is present and, above this layer, voluminous corrosion products consisting of copper hydroxysulfate are present. Surrounding the pits the surface is covered by a black layer of copper (II) oxide. Common to all cases of this type of pitting is the presence of organic films, e.g. polysaccharides, because of microbial activity. The corrosion rate of this type of pitting is about the same as that of pitting corrosion of Type 1 (see 4.3.1.2).

4.3.2 Influence of the characteristics of the metallic material

For copper tubes conforming to EN 1057 [1], the material composition has no influence on the likelihood of pitting corrosion. The likelihood of Type 1 pitting corrosion in cold water is mainly dependent on the condition of the surface in contact with water and is increased by carbonaceous or certain types of oxide films. The carbonaceous films usually result from the manufacturing process. Copper tubes which conform to EN 1057 are free from such detrimental films in the bore. Deleterious oxide films can result from the plumbing process (see 4.3.4).

There is no known influence of the surface conditions on Type 2 pitting corrosion in heated water or on microbially influenced pitting corrosion.

4.3.3 Influence of the characteristics of the water

4.3.3.1 General

With respect to pitting corrosion, the influence of the water composition on the corrosion likelihood should be considered for both the anodic and cathodic reactions and separately for cold and heated waters.

4.3.3.2 Type 1: Pitting corrosion in cold water

In the presence of detrimental oxide or carbonaceous films and unfavourable operating conditions the water composition determines the corrosion likelihood. In favourable water compositions, the corrosion likelihood can become so small, that neither detrimental films nor unfavourable operating conditions nor faulty plumbing techniques (see 4.3.4) are critical. Even with unfavourable water compositions, corrosion failures will only occur when other unfavourable circumstances are present.

The nature and the concentration of the anions have an important influence on the anodic partial reaction of the corrosion process. The influence is determined by the ratio of the anions rather than by the concentration of individual anions. However, currently not enough is known about ways in which a critical anion quotient can be indicated. Influences are as follows:

Hydrogen carbonate:	Increasing concentration of hydrogen carbonate ions decreases the corrosion likelihood.
Chloride:	In contrast to the situation with other metallic materials, the corrosion likelihood of pitting corrosion decreases with increasing concentration of chloride ions.
Sulphate:	Increasing concentration of sulphate ions increases the corrosion likelihood.
Nitrate:	Nitrate ions have an influence similar to that of sulphate ions.

The likelihood of pitting corrosion in cold water can be reduced by altering the concentration ratio of the anions by anion exchange or selective membrane filtration.

High levels of suspended solids in the water resulting from corrosion of the water mains or from incomplete removal of manganese, iron or silt from the raw water, increase the likelihood of pitting corrosion under deposits on the bottom of horizontally installed tubes.

For waters having usual oxygen concentrations (> 0,1 mmol/l^1), the oxygen reduction, being the cathodic partial reaction of pitting corrosion, is not limited by the oxygen content. Pitting corrosion does not occur with $c(O_2) \leq 0{,}003$ mmol/l.

According to experience, pitting corrosion does not usually occur in surface waters, as a result of their content of natural organic inhibitors that are normally absent in borehole waters. More information about the nature of these substances is not available at the present time. Their effect, however, can be traced back to their influence on the cathodic partial reaction (oxygen reduction) of the semi-conductive oxide layer.

The likelihood of pitting corrosion is enhanced when critical anion concentrations are coupled with a water quality favouring the formation of oxide layers of good conductivity.

4.3.3.3 Type 2: Pitting corrosion in heated water

Pitting corrosion of copper in heated water is mainly caused by the water composition and the water temperature and is restricted to acidic waters (pH <7,0) with relatively low hydrogencarbonate (<1,5 mmol/l^{-1}) and high sulphate levels

In such waters the corrosion likelihood is increased if the concentration ratio, S

$$S = \frac{c(\mathrm{HCO_3}^-)}{c(\mathrm{SO_4}^{2-})} < 1{,}5$$

This type of pitting corrosion can be avoided by increasing the pH of the water.

4.3.3.4 Microbially influenced pitting corrosion

Microbially influenced pitting corrosion can occur in waters obtained from surface sources, characterized by low values of conductivity, low hydrogen carbonate content and pH values above 8.

Water treatment in order to increase the hydrogen carbonate content, has been an effective countermeasure against this type of pitting corrosion.

4.3.4 Influence of design and construction

A design that favours stagnant conditions (e.g. dead legs) or very low flow increases the likelihood of pitting corrosion under deposits. Deposits (e.g. swarf, loose scale moved on by the water, packing material, silt) settle out particularly in horizontal tubes. Precautions against the entrance of such materials will decrease the likelihood of pitting corrosion under deposits, e.g. installation of a water filter.

At high temperatures >400 °C without controlled atmosphere (e.g. during brazing, hot bending, annealing in order to form sockets), oxide films develop that can increase the likelihood of pitting corrosion in cold water.

The pitting corrosion likelihood can be substantially reduced if tubes are joined using, e.g. compression fittings or soft solder and annealing, in order to form sockets and hot bending are avoided.

Fluxes used for soldering or brazing are, by their nature and purpose, aggressive towards metals. If excessive flux enters the bore of the tube and remains there, local attack (pitting) can result. Attack by corrosive flux is usually characterized by local pitting near soldered or brazed joints and in the immediate neighbourhood of streamers of flux, or traces of such streamers. In some cases flux can become detached from streamers and be carried downstream during pressure testing. If it reattaches to the tube it can cause attack remote from fittings.

Flux residues will be active before water has entered the tube because of their chemical composition. If corrosive agents are leached out from flux streamers the residues can still cause deposit attack. Corrosion likelihood is best minimized by using water soluble flux with restricted aggressivity and flushing the system to remove any flux residues as soon as possible after completion of the soldering or brazing operation (see EN 29454-1 [2]).

4.3.5 Influence of pressure testing and commissioning

If an increased likelihood of pitting corrosion exists, the corrosion behaviour is substantially determined by the condition of the copper (I) oxide layer formed in the initial period after the system is put into operation.

The corrosion likelihood increases if the formation of the protective layer is disturbed or prevented in any way. The removal of foreign substances, e.g. any debris, sand, can be achieved by appropriate flushing (preferably with an air/water flushing device) of the system immediately after the first filling.

If pressure testing is not done according to the recommendations given in EN 12502-1:2004, 5.5, so that residual water is left in the system after draining, the likelihood for pitting corrosion is increased.

4.3.6 Influence of operating conditions

4.3.6.1 Influence of temperature

Pitting corrosion Type 1 does not occur at service temperatures permanently above 30 °C. If this form of pitting occurs in heated water pipes, it indicates that cold water has been standing in these pipes for a long time.

The likelihood of pitting corrosion Type 2 in heated water is higher at temperatures above 60 °C.

The likelihood of pitting corrosion influenced by microbial activity is low if the water temperature is higher than 55 °C.

4.3.6.2 Influence of flow conditions

Provided that other conditions are the same, pitting corrosion in cold water and microbially influenced pitting corrosion are more likely in pipes with stagnant or seldom renewed water than in pipes with frequent change of the water. Tubes operated in turbulent flow conditions (above a critical Reynolds Number of approximately 2 300) have a significantly reduced corrosion likelihood for pitting corrosion.

4.4 Selective corrosion

4.4.1 General

The most familiar type of selective corrosion in copper alloys is dezincification of brass (copper-zinc alloys). It is characterized by the removal of zinc from the alloy forming white corrosion products and leaving porous copper. It leads to a change of colour of the alloy (from brass yellow to copper red) and a decrease in the mechanical strength. Dezincification occurs either as a uniform layer type or as a localized plug type.

4.4.2 Influence of the characteristics of the metallic material

The likelihood of dezincification decreases with increasing copper content. Brasses with copper content exceeding 85 % have high resistance to dezincification. The likelihood of dezincification of brasses is to a large extent determined by the microstructure, which varies according to production technique and heat treatment, even for materials of the same composition. The main structural constituents of brasses used in supply water systems are α-phase and β-phase. The α-phase is promoted by a high copper content in the alloy. The β-phase is more susceptible to dezincification than the α-phase. Moreover, the α-phase can be inhibited against dezincification by alloying while the β-phase cannot. Consequently, a brass with a continuous distribution of β-phase is more susceptible to dezincification than a brass with a discontinuous β-phase. A continuous β-phase can occur, e.g. in castings with dendritic structure and in the longitudinal direction of extruded material.

For dezincification inhibition of the α-phase dezincification resistant brasses are alloyed with a very low percentage of: arsenic (As), antimony (Sb), or phosphorus (P). The susceptibility of a brass to dezincification can be determined in accordance with the test described in EN ISO 6509 [3]. In the case of copper-tin-zinc-lead-alloys (gun-metal) the likelihood of dezincification is so low, because of the high copper and low zinc content, that it is described as immune to dezincification.

The surface condition has no known effect on dezincification.

4.4.3 Influence of the characteristics of the water

Dezincification is observed under the following conditions:

- low levels of hydrogen carbonate ions;
- high chloride to hydrogen carbonate ion concentration ratio.

4.4.4 Influence of design and construction

The design and construction of a water system can influence the laying down of deposits, increasing the likelihood of plug type dezincification. The likelihood of dezincification is also increased by contact with more noble materials (bimetallic corrosion).

4.4.5 Influence of pressure testing and commissioning

Commissioning of a water system can influence the laying down of deposits, leading to plug type dezincification.

4.4.6 Influence of operating conditions

4.4.6.1 Influence of temperature

The likelihood of dezincification increases at elevated temperatures.

4.4.6.2 Influence of flow conditions

Low flow rates and stagnant conditions encourage the laying down of deposits, leading to plug type dezincification.

4.5 Bimetallic corrosion

4.5.1 General

As copper and copper alloys are relatively noble metals, they will, in many situations, be the noblest metal when two different materials are in contact in a water distribution and storage system and hence they are not endangered by bimetallic corrosion. In a few combinations, bimetallic corrosion can cause damage to the material.

Copper and copper alloys are nearly as noble as stainless steel and normally they can be placed adjacent to each other. This is possible because stainless steel has a poor cathode efficiency for the oxygen reduction. However, a very high cathode/anode area ratio can create problems.

4.5.2 Influence of the characteristics of the metallic material

In certain waters, free machining brass suffers from dezincification. The corrosion potential of brass will be low and more noble materials such as copper, gun-metal and stainless steel can act as cathode.

4.5.3 Influence of the characteristics of the water

The influencing factors of the water are rather complex because the extent of bimetallic corrosion is controlled by the activity of the cathode. This in turn is influenced, e.g. by precipitation of calcium carbonate.

The likelihood of bimetallic corrosion is increased when the ratio of the concentration of activating anions (e.g. chloride and sulfate ions) to inhibiting anions (e.g. hydrogen carbonate ions) is high.

4.5.4 Influence of design and construction

The detailed design has much influence, because changes in the cathodic/anodic area ratio of great importance. The smaller the anodic area in comparison to the active cathodic area, the higher the resulting corrosion rate can be.

4.5.5 Influence of pressure testing and commissioning

Commissioning and pressure testing parameters are not known to influence the long-term behaviour of copper and copper alloys with respect to bimetallic corrosion.

4.5.6 Influence of operating conditions

4.5.6.1 Influence of temperature

Corrosion processes are usually increased with temperature. However, the enhanced deposition of calcium carbonate can cause a lower corrosion likelihood for bimetallic corrosion.

4.5.6.2 Influence of flow conditions

As flow usually increases the rates of both anodic and cathodic processes, the likelihood of bimetallic corrosion can be increased or decreased.

4.6 Erosion corrosion

4.6.1 General

Erosion corrosion is a result of exceeding a critical degree of turbulence, especially in circulating water systems. It leads to non-uniform corrosion, sometimes showing characteristic horseshoe shaped pits and/or islands of non-corroded metal. When active, the metal displays a brightly polished appearance. The attack predominantly takes place where the water flow is disturbed, e.g. at tube bends, valves and fittings.

4.6.2 Influence of the characteristics of the metallic material

With phosphorous deoxidized copper there is no known direct influence of the material composition on the likelihood of erosion corrosion.

Copper alloys, e.g. brasses, normally have better resistance to erosion corrosion than phosphorous deoxidized copper.

The surface condition has no known effect on erosion corrosion.

4.6.3 Influence of the characteristics of the water

The likelihood of erosion corrosion increases with decreasing pH value and the presence of gas bubbles or solid particles in the water.

4.6.4 Influence of design and construction

Erosion corrosion is mostly caused by design faults and incorrect installation leading to locally increased turbulence in the water system. Critical aspects are pipework with reduced cross-sections and/or sudden changes of flow direction.

4.6.5 Influence of pressure testing and commissioning

Pressure testing and commissioning parameters are not known to influence the long-term behaviour of copper and copper alloys with respect to erosion corrosion.

4.6.6 Influence of operating conditions

4.6.6.1 Influence of temperature

The likelihood of erosion corrosion increases with increasing water temperature.

4.6.6.2 Influence of flow conditions

Erosion corrosion is principally influenced by the local flow velocity, especially under conditions where gas bubbles occur because of reduced static and/or dynamic pressure.

Under normal conditions in water systems, the calculated water velocity in copper pipework for cold waters is thought to be uncritical below 3 m/s for intermittent service and 2 m/s in the case of longer draw-off periods (greater than 15 minutes). In heated water circulation systems, the critical calculated flow velocity is approximately 0,5 m/s.

4.7 Stress corrosion

4.7.1 General

Stress corrosion is characterized by cracks produced as a result of the simultaneous influence of a specific corrosive agent and tensile stress in the material.

4.7.2 Influence of the characteristics of the metallic material

Copper and copper alloys have a different susceptibility to stress corrosion. Copper and gun-metal are considered to be resistant to this type of corrosion. Brasses have a high susceptibility to stress corrosion, which increases with increasing yield strength. In addition, for all susceptible materials, internal tensile stress originating from the production process increases the likelihood of stress corrosion. The overall likelihood of stress corrosion can be reduced by annealing the finished component.

The surface condition has no known effect on stress corrosion.

4.7.3 Influence of the characteristics of the water

In the case of copper alloys susceptible to stress corrosion, stress corrosion can only occur in waters with a significant content of nitrite and/or ammonia. Drinking water does not normally contain these substances in concentrations sufficient to induce stress corrosion. However, nitrates in water can be reduced in critical areas, e.g. in crevices or under deposits, to nitrites and/or ammonia.

4.7.4 Influence of design and construction

Design and construction parameters that introduce tensile stress into the material influence the long-term behaviour of copper alloys with respect to stress corrosion.

During construction of a water system, tensile stresses can be induced in the components that can cause stress corrosion in conjunction with the specific corrosive agents. Critical stresses can be induced by e.g. overtightening brass threads or use of male tapered threads with female parallel threads.

4.7.5 Influence of pressure testing and commissioning

Pressure testing and commissioning parameters are not known to influence the long-term behaviour of copper alloys with respect to stress corrosion.

4.7.6 Influence of operating conditions

Operating conditions are not known to influence significantly the long-term behaviour of copper alloys with respect to stress corrosion.

4.8 Corrosion fatigue

4.8.1 General

Corrosion fatigue is characterized by cracks produced as a result of the simultaneous influence of corrosion and cyclic stress.

4.8.2 Influence of the characteristics of the metallic material

There is no known influence of the material composition and the surface condition of the material on the likelihood of corrosion fatigue.

4.8.3 Influence of the characteristics of the water

Corrosion fatigue can occur irrespective of the water composition. However, the water composition can influence the rate of crack propagation.

4.8.4 Influence of design and construction

In heated water systems, cyclic stresses can occur because of thermal expansion and contraction or vibrations. Cyclic stresses can be minimized by proper design and construction to allow for expansion and contraction and avoiding vibrations.

4.8.5 Influence of pressure testing and commissioning

Pressure testing and commissioning parameters are not known to influence the long-term behaviour of copper and copper alloys with respect to corrosion fatigue.

4.8.6 Influence of operating conditions

Besides the thermal variations and vibrations mentioned in 4.8.4, no other parameters are known to influence the long-term behaviour of copper and copper alloys with respect to corrosion fatigue.

5 Assessment of corrosion likelihood

In order to assess the corrosion likelihood of copper and copper alloys in a water distribution and storage system, all the influencing factors, listed in EN 12502-1:2004, Table 1, and their possible interactions should be taken into consideration. This assessment should be carried out separately for all types of corrosion relevant to the specific corrosion system. Because of the complexity of the influencing factors and of their interaction, in most cases only a qualitative assessment is possible.

Bibliography

[1] EN 1057, *Copper and copper alloys — Seamless, round copper tubes for water and gas in sanitary and heating applications*.

[2] EN 29454-1, *Soft soldering fluxes — Classification and requirements* — Part 1*: Classification, labelling and packaging (ISO 9454-1:1990)*.

[3] EN ISO 6509, *Corrosion of metals and alloys — Determination of dezincification resistance of brass (ISO 6509:1981)*.

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover.
Tel: +44 (0)20 8996 9000. Fax: +44 (0)20 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: +44 (0)20 8996 9001.
Fax: +44 (0)20 8996 7001. Email: orders@bsi-global.com. Standards are also available from the BSI website at http://www.bsi-global.com.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre.
Tel: +44 (0)20 8996 7111. Fax: +44 (0)20 8996 7048. Email: info@bsi-global.com.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration.
Tel: +44 (0)20 8996 7002. Fax: +44 (0)20 8996 7001.
Email: membership@bsi-global.com.

Information regarding online access to British Standards via British Standards Online can be found at http://www.bsi-global.com/bsonline.

Further information about BSI is available on the BSI website at http://www.bsi-global.com.

Copyright

Details and advice can be obtained from the Copyright & Licensing Manager.
Tel: +44 (0)20 8996 7070. Fax: +44 (0)20 8996 7553.
Email: copyright@bsi-global.com.

BSI
389 Chiswick High Road
London
W4 4AL