A Review of Current Knowledge

CAUSES OF COPPER CORROSION IN PLUMBING SYSTEMS

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Review of Current Knowledge

This review is one of a series of Reviews Of Current Knowledge (ROCKs) produced by FWR. They focus on topics related to water supply, wastewater disposal and water environments, which may be the subject of debate and inquiry. The objective of each review is to produce concise, independent scientific and technical information on the subject to facilitate a wider understanding of the issues involved and to promote informed opinion about them.

Review of Current Knowledge

CAUSES OF COPPER CORROSION

IN PLUMBING SYSTEMS

Cover page image © P Munn

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Review of Current Knowledge

CONTENTS

Forward

This edition has been fully revised from the earlier 2003 and 2010 editions. The aim of this publication is not to be an authoritative text book but rather to assist practitioners to diagnose the many different types of corrosion failures, which can occur in copper plumbing systems and help to avoid them occurring. It is not meant to be a substitute for expert opinion in serious cases.

The following covers failures which can occur in both hot and cold domestic water systems, not closed central heating systems. Although failures of copper and brass fittings can occur in central heating systems, they are extremely rare as the dissolved oxygen content of the water is normally insufficient to cause corrosion. That is not to say that copper corrosion failures are common in domestic (drinking) water systems. Considering the hundreds of miles of copper pipework which is installed in the UK each year, the number of failures is quite low.

1   INTRODUCTION

Corrosion of copper pipes and copper alloy fittings results in costly damages for owners of buildings, not only in terms of the replacement of pipework systems but also the consequential damages from leaks. Installers are often held responsible for these damages, although they may not themselves be directly to blame. Thankfully, the large majority of plumbing systems operate without any concerns and give a trouble-free long life.

Problems of corrosion of copper and copper alloys in plumbing systems occur when the protective copper corrosion product layers either do not properly form in the first place or become disrupted during service for some reason. This is usually down to a combination of adverse circumstances during installation, commissioning and service. The problems manifest themselves in either leaks or high copper levels and blue water. Copper pipes can leak due to various forms of pitting attack or erosion corrosion while copper alloys, especially brass fittings, can undergo dezincification or stress corrosion cracking.

Problems are far more likely to occur in large complex systems, such as those found in hospitals, hotels and large office buildings or country houses, where pipe runs are long and the hot water is distributed through a recirculating system. On the other hand, problems with copper corrosion are rarely encountered in normal residential houses. For instance, erosion corrosion which may occur in large buildings with recirculating hot water systems virtually never happens in normal residential houses even if the water is fully softened. Where problems do occur in residential houses, it is more often than not in pipework to little-use en-suite bathrooms, where water stagnation occurs.

Review of Current Knowledge

There are many different forms of pitting attack, which may result in leaks in copper pipes, such as Type 1 pitting; Type 2 pitting; microbiological influenced pitting corrosion (MIC); flux attack; and under-deposit corrosion. Most of these forms of pitting attack are very rare as are other phenomena such as rosette corrosion of copper cylinders. A plumber may spend his/her whole career without ever encountering some of these phenomena. Therefore, this guide will concentrate on the most common forms of attack and how they can be avoided.

The above only refers to internal corrosion of copper pipes and fittings. However, a form of external corrosion of copper pipework called formicary corrosion has resulted in costly leaks and the necessary replacement of pipework systems. This can occur under phenolic foam insulation due to the presence of moisture. Because it occurs under insulation or lagging and it results in very slow leakage of water, it often goes unnoticed until the pipework system has been too badly damaged for effective remediation. Although this is something which only really affects large buildings, such as hospitals, the consequences can be severe, resulting in the wholesale replacement of the pipework system.

What Normally Happens

When copper pipes are first installed, they have a shiny metallic copper surface. On contact with aerated natural waters, copper ions will be released into the water due to corrosion of the copper. However, in flowing aerated water, surface films formed of copper corrosion products begin to form on the bore of the pipes, which quickly reduces the copper corrosion rate and copper levels in the water. In cold waters of near neutral pH, the stable film formed is the cuprous oxide or copper (I) oxide [Cu_2O], which in its pure state is ruby red but usually has a brown-black colour when formed on copper pipes. In hot water systems, the black cupric oxide or copper (II) oxide [CuO] is more stable. On top of these layers a green malachite or copper hydroxy carbonate [$Cu_2(OH)_2CO_3$] layer will begin to form within a few days. Eventually, the bore of the copper pipe will be covered with a stable protective patina of copper oxides overlaid with a continuous copper hydroxy carbonate layer, as shown in Fig. 1.

The copper corrosion product layers, once properly formed, are normally stable, adherent and are relatively insensitive to changes in water composition and operating conditions. The copper pipework system can then go on to give a long trouble-free life, well in excess of 20 years.

Figure 1   Stable continuous malachite layer on bore of copper cold water pipe
© P Munn

What Things Can Go Wrong

As stated above, when problems occur it is usually down to a combination of adverse circumstances. These include: particular water quality; poor design of systems; poor installation or commissioning practice; and operational issues.

Often one hears from plumbers that the failure is due to 'a dodgy batch of copper pipe', i.e. a problem of pipe manufacture. However, this is very rarely the case these days. There is only one way that the pipe manufacturer can influence the corrosion of the copper and that is by leaving carbon film residues on the bore of the pipework after the extrusion process – a failure that can lead to Type 1 pitting. Since the advent of BS EN 1057, this issue has largely gone away, although Type 1 pitting can still occur if carbon films do remain or due to other reasons. Similarly, the advent of dezincification resistant brasses (DZR brass) has much reduced the incidence of dezincification of fittings, although from time to time fittings stamped 'DZR' are still susceptible to this form of attack.

Probably the main cause of most of these forms of pitting is water stagnation, either after hydraulic pressure testing before the system is handed over, or later during operation. A flow of fresh aerated water is needed to build up stable, regular and protective layers on the bore of the pipe. Under stagnant conditions, these layers do not properly form in the first place or adverse chemical or microbial conditions develop, which may lead to the layers spalling off pipework or

localisation of the corrosion processes. Fortunately, this is something that can easily be avoided by following good practice, as outlined in BS EN 806 part 4.

Water quality plays a role in many forms of attack but it may not be practical to change this, especially for mains supply waters. However, private water supplies, which may cause cuprosolvency, MIC or under-deposit corrosion can be treated by passing the water over UV, sand or dolomitic limestone filters to reduce the risk of these forms of attack. Nevertheless, it needs to be pointed out that, even if the mains supply water could support Type 1 pitting, without the other adverse circumstances, the attack would almost certainly not occur.

In the past, corrosion of lead pipes was a major issue for human health, as was the use of leaded solders. However, the use of lead pipework and leaded solders has been prohibited for many years and so this is no longer an issue, except perhaps in very old buildings with original pipework.

The following sections deal with the many different types of copper corrosion in plumbing systems. For ease of use, each section follows the same format: manifestation, cause, and how it can be avoided.

2   CUPROSOLVENCY AND BLUE WATER

Cuprosolvency refers to the high general corrosion rates of copper with the release of elevated dissolved copper ions in the water, while blue water is the term used to describe the discolouration of the water and sanitary fittings. In the 2010 edition of this publication, these two issues were discussed separately. However, in this updated edition they have been put together, since although strictly speaking they are not identical, they are related phenomena.

Manifestation

Blue water may come about due to high concentrations of dissolved copper in the water or because of the release of particulate matter from loosely adherent copper corrosion products. Blue water may be produced if the dissolved copper concentration is above 1.5 mg/L. However, it is more commonly produced due to particles of insoluble copper corrosion products in the water, i.e. copper hydroxide, $Cu(OH)_2$, or copper hydroxy carbonate or copper hydroxy sulphate. These may not be noticeable in a glass tumbler of water but become more apparent in a sink or bath full of water. If the blue water is caused by particulate matter, the particles will settle out on standing and the water will become clear. Severe staining of sanitary ware may occur, especially under taps in sinks and baths. Fig. 2 shows an

irregular, patchy carbonate layer on the bore of a copper pipe, which gave rise to blue water.

Figure 2   **Build up of an unstable, irregular carbonate layer on the pipe bore, resulting in blue water** © P Munn

Cause

As described in the introduction, the initial corrosion rate of new copper pipework is quite high. However, this quickly falls as a protective patina of copper corrosion products builds up on the bore of the pipe. After about a year of service, the corrosion rate of copper and its alloys are of the order of 1–10µm/yr in fresh waters at temperatures of 10–60˚C.

Cuprosolvency is caused principally by acidic waters. The protective cuprous oxide (Cu_2O) does not form in flowing conditions below around pH ~6 and copper and its alloys are not normally recommended for continuous service below pH 6. This is not an issue for mains water supplies as the European drinking water regulations specify a pH range of 6.5–9.5. However, it can occur in private water supplies taken from borehole waters containing high carbon dioxide levels, which lower the pH to below 6.5. Upland surface water sources, especially with peaty soils, when the pH of the water can be quite acidic and the bicarbonate concentration very low can also result in the same effect.

Water composition also plays a role in the formation of blue water due to the release of copper corrosion products, which is more common in naturally soft waters but can also occur in waters of very high pH(>9), when stable copper hydroxide forms. There is also good evidence that copper pipework exposed to soft waters containing high phosphate levels is more prone to develop unstable copper corrosion product layers, possibly containing copper phosphate, which can easily spall off the bore of the pipes. The phosphate derives from the dosing of phosphate into water supplies by water companies in order to reduce corrosion of old lead pipes.

It is much easier for protective layers to form in flowing, fresh aerated water; cuprosolvency and the formation of poorly protective, loosely adherent layers are much more likely under stagnant water conditions, especially in the early stages after installation.

Finally, there is also evidence that the growth of microbial layers (biofilms) on the bore of the copper pipework, which inhibit access of oxygen to the copper surface, may result in blue water occurring.

How it can be avoided

Avoid stagnation in the pipework system, especially in the first few weeks following installation. This can be done by running all taps for one or two minutes/week. If using a private water source with low pH or possible microbial contamination, pass the water over a UV filter and a dolomitic limestone filter. If blue water is caused by microbial growth, then super-chlorination (>5mg/l of free chlorine) may help (at least as a temporary measure).

3   EROSION CORROSION

Erosion corrosion is a physico-chemical process, which affects principally soft metals due to flow rates which are too high. Localised turbulent flows result in release of gas bubbles (air), which on collapsing remove protective surface layers allowing corrosion of the exposed metal to occur. The process repeats itself until eventually wall penetration occurs. It is similar in some ways to the phenomenon of cavitation but, while erosion corrosion involves both erosion and corrosion processes, cavitation is a purely physical process which is due to the formation of steam bubbles at localised pressure drops (found sometimes in pumps and propellers). Although it can occur in both hot and cold water systems, erosion corrosion is usually found in hot water recirculating systems when leakage can occur in a matter of weeks to months. Particulate matter in the water can increase erosion of the protective patina.

Manifestation

Erosion corrosion damage is easily identified by the appearance of localised shiny areas of copper with grooves or horseshoe shaped depressions within unattacked areas of copper, as shown in Fig. 3. Sometimes the pipe itself can become paper thin over a larger area while sometimes isolated pinholes can develop. The pits formed are steeply undercut on the leading edge, often giving rise to horseshoe grooves, with 'the horse' appearing to walk upstream.

Figure 3   Erosion corrosion on hot water recirculating return pipe © P Munn

Cause

The principal cause of erosion corrosion is water velocities which are too high, which results in turbulent flow immediately downstream of elbows, tee pieces and changes in section. The critical flow velocities needed depend on several factors, including temperature, water composition, design of the pipework system and installation practices. Generally, one can say that the critical velocities are 3 m/s in cold water and 1.5 m/s in hot water systems running on hard water. However, in naturally soft waters or waters that have been base-exchange softened, the critical velocities are significantly lower. Where waters have been softened to virtually zero hardness, erosion corrosion can occur in hot water recirculating systems at flow rates even as low as 0.5 m/s.

Complex pipework systems in plant-rooms where there are several elbows, tees and changes in section over a short distance are particularly prone to erosion corrosion. In addition, poor workmanship where cut ends of pipes are not deburred or large lumps of solder remain on the inside of joints after soldering increase the risk of turbulent flow immediately downstream and hence the likelihood of erosion corrosion.

Although generally erosion corrosion is caused by continuous high water velocities, especially in hot water return lines, it can also occur due to transient high water velocities when taps are opened. This can come about due to water pressures which are too high either at the mains or in larger buildings, when

pressures are not correctly set. This results in localised high flow rates in the pipework close to the opened taps.

How it can be avoided

In hot water systems, turn down the circulating pump velocity if possible or choose a circulating pump of smaller size. If the water is base-exchange softened, make sure that the water has a residual hardness of 60–80mg/l as $CaCO_3$ in order to increase the stability of the protective patina without resulting in limescale deposition. This can be done by blending the outlet from the softener with incoming mains water. Water pressures should be checked and, if necessary, adjusted so that they are not too high and are balanced around the system.

For new systems, pipework should be designed so that flow rates do not exceed the critical velocities given above. Installers should deburr cut ends of pipes and not use too much solder when soldering joints.

4   TYPE 1 PITTING

Type 1 pitting is one of the most common forms of pitting attack which can occur in cold water systems where the temperature never exceeds 40˚C. So-called Type 1 pitting waters are hard borehole waters of certain compositions. It never occurs in pipework distributing surface waters, as these waters contain natural organic inhibitors which prevent this form of attack. Since the introduction of BS EN 1057, which requires the removal of carbon films from the bore of copper pipes following the extrusion process, the incidences of Type 1 pitting have decreased significantly, although it can still occur.

Manifestation

Type 1 pitting can result in pinhole leaks in cold water pipes any time from a few months to a few years. The bore of the pipe shows mounds of green copper carbonate, which are usually spaced along the bore with larger mounds found along the bottom, see Fig. 4. When the mounds are removed by cleaning with acid, the underlying copper surface is found to contain hemispherical pits, sometimes containing white copper chloride crystals and ruby red copper (I) oxide. Fig. 5 shows a close-up of a Type 1 pit. A cross-section through a Type 1 pit is shown in Fig. 6. It can be seen that a membrane of copper oxide at the original copper surface separates the copper carbonate mound from the pit containing copper chloride crystals.
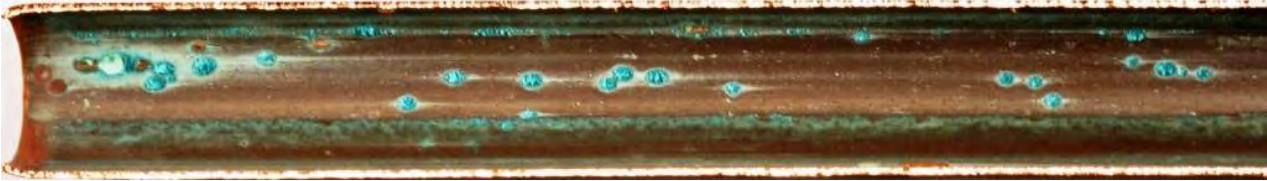
Figure 4   **Type 1 pitting of cold water pipe**   © P Munn

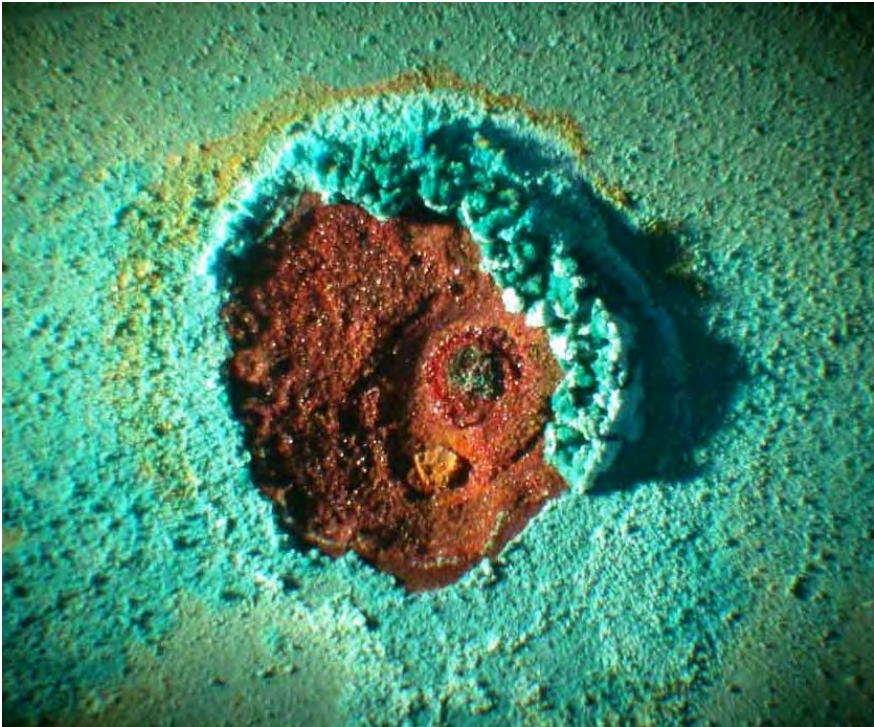**Figure 5**   **Close-up of Type 1 pit** © P Munn

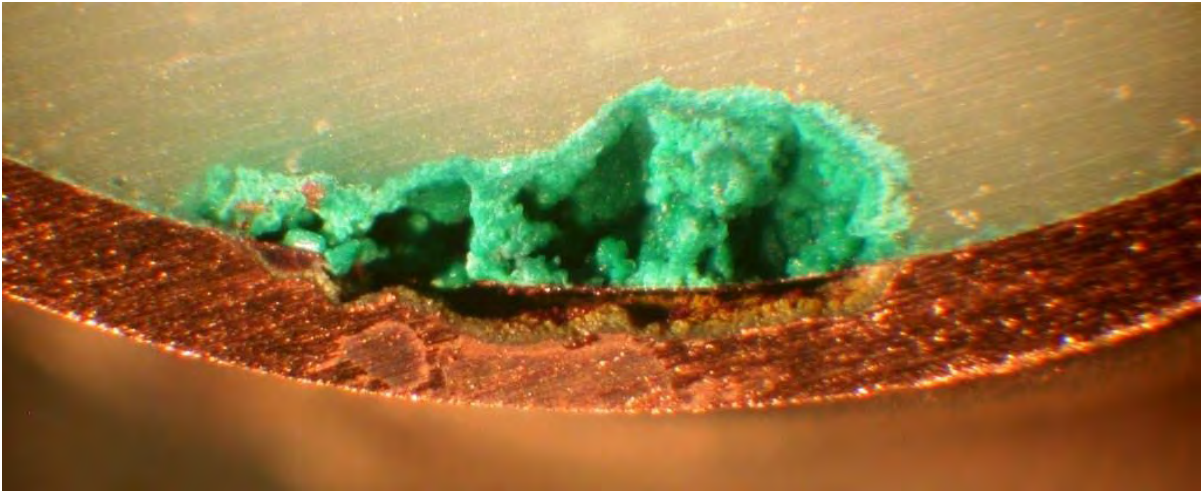**Figure 6**   **Cross-section through a Type 1 pit**   © P Munn

Cause

In the past, Type 1 pitting was nearly always associated with the presence of a carbon film on the bore of the copper pipe. For this reason, it is sometimes referred to as 'carbon film pitting'. Occasionally, fragments of carbon film still remain on pipes, even those stamped EN 1057. A carbon film acts as an efficient cathode and any small gaps in the film become anodic to the surrounding surface and undergo pitting attack. However, even in the total absence of carbon films, Type 1 pitting can still occur from time to time.

Hard borehole waters which can promote Type 1 pitting tend to have a pH of around 7 to 7.8 with decreasing pH in this range increasing the pitting tendency. In addition, relatively high sulphate, chloride, nitrate, sodium and dissolved oxygen and low bicarbonate (linked to pH) increases the aggressiveness of the water to pitting attack. The British Non-Ferrous Metals Research Association empirically derived a pitting propensity ratio (PPR) based on these water parameters. However, many supply waters will have the characteristics which produce a high PPR value without causing Type 1 pitting to occur. Usually, water stagnation, especially in the early stages is another key factor which will determine whether Type 1 pitting will occur. There is also some more recent evidence that hard waters containing phosphate (due to phosphate dosing by water companies) increases the likelihood of Type 1 pitting, especially when new pipework is exposed to high phosphate-containing waters.

Although it is beyond the scope of this publication to go into the mechanisms of the various forms of attack in any detail, there is evidence that any conditions which produce high levels of copper (I) chloride (cuprous chloride) on the surface of the copper (or under deposits) will cause Type 1 pits to develop. Therefore, there may be several ways in which Type 1 pitting can be caused.

How it can be avoided

Only use copper pipe from a reputable supplier and which is stamped EN 1057. Avoid water stagnation, especially in the first few weeks after pressure testing and handover.

5   FLUX ATTACK

Excessive use of soldering flux is often initially blamed as the cause of pinhole leaks in plumbing systems. This is because it is well known that fluxes are, by their nature, aggressive to copper. However, since modern fluxes tend to be less aggressive and water dispersible, nowadays flux is rarely the cause of leaks.

Nevertheless, it is something that can easily be avoided with a little care during the installation and commissioning of systems. Fig. 7 shows an example of a flux run which resulted in the pinholing of a copper pipe.
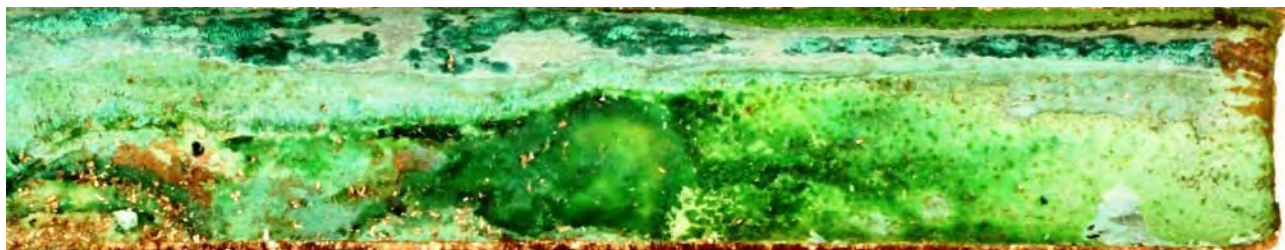

Figure 7 **Flux run resulting in pinholing of cold water pipe (towards bottom edge of image)** © P Munn

Manifestation

Irregular shaped pits associated with flux runs inside the pipework close to soldered joints. Long flux runs on the outside of pipework are indications of poor soldering practice.

Cause

Flux contains aggressive chemicals such as zinc chloride or ammonium chloride as the activator, which remove the copper oxide layer allowing the solder to run freely at the joint. When heat is applied to melt the solder, excess flux may flow along the pipe causing a 'run'. Occasionally a 'blob' of flux may settle on the bottom of the bore some distance away from the joint, resulting in a localised pit. If flux runs are not removed by flushing the system after installation, then attack can continue when the system is filled with water.

Flux attack has been described by Francis (2010) in his recent book (see Further Reading – General) as just another form of Type 1 pitting because it is caused by an excess of cuprous chloride. Although this may well be the case, most people still see it as a distinct form of attack in its own right.

How it can be avoided

Abide by good installation practice as described in WRAS approved installation method on solders and fluxes and in BS EN 806: part 4.

Use flux sparingly and choose a water soluble (dispersible) flux.

Flush out pipework thoroughly immediately after pressure testing according to BS EN 806: part 4.

6   MICROBIAL INFLUENCED CORROSION (MIC)

Another form of pitting corrosion, which may occur in both hot and cold water systems, is due to microbial influenced corrosion. This has been found to occur especially in hospitals and other large buildings where there are long pipe runs, often with stagnant conditions and high ambient temperatures. Leaks from this form of pitting may take anything from one to 12 years to occur. Francis (2010) has described this as Type 3 pitting, although it is classed as MIC in BS EN 12502-2: 2004. (In the 2010 version of this publication, Type 3 pitting is described as a distinct type of pitting. However, if indeed it is a separate type of failure, it is extremely rare in the UK and is therefore not discussed in this edition).

Manifestation

This form of pitting may appear similar to Type 1 pitting on first inspection, i.e. with nodules of copper carbonate predominantly on the bottom of horizontal pipe runs, although it sometimes appears as large irregular-shaped mounds of carbonate along the bottom of pipes. Within the carbonate mounds, however, copper hydroxy sulphate is often present. Surrounding these areas of attack, the surface is usually covered with a black layer of copper (II) oxide (cupric oxide). Fig. 8 shows an example of MIC occurring in a cold water pipe at a hospital.

Present within the deposits above the copper surface, is usually a biofilm containing polysaccharides, secreted by micro-organisms, especially. *Pseudomonas*. A classic form of MIC is the presence of a high density of tiny pits, known as 'pepper-pot corrosion' underneath the surface layers. However, they can also appear as hemispherical pits surrounded by, or coalescing with, much smaller pits. Fig. 9 shows an example of pepper-pot corrosion caused by MIC, revealed after cleaning the surface with dilute acid.

Figure 8   **Microbial Influenced Corrosion on a cold water pipe**   © P Munn
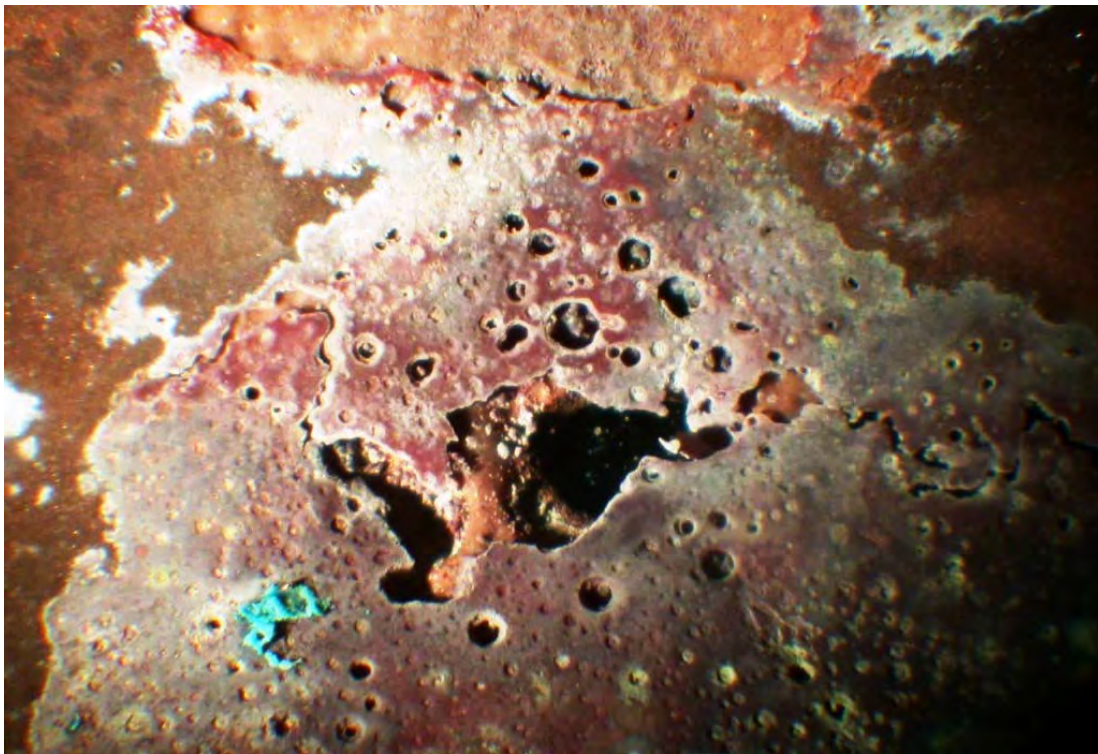

Figure 9   **'Pepper-pot' corrosion caused by MIC**   © P Munn

Cause

There are several factors which make pitting due to MIC more likely. Stagnant water conditions, where the temperature of the water in the pipes reaches ambient temperatures of around 22–30°C is ideal for the growth of microorganisms. Soft surface waters with high organic carbon also encourage microbial growth, although MIC can also occur in pipes fed by hard borehole waters.

Slime-forming bacteria, especially *Pseudomonas*, produce biofilms on the bore of the pipe and the anaerobic conditions existing underneath the biofilm encourages the growth of opportunistic bacteria, especially sulphate-reducing bacteria (SRB). Any debris left in the pipe after commissioning can also encourage the growth of *Pseudomonas* and SRB within and underneath the debris. Acids and hydrogen sulphide produced by the metabolism of these anaerobic bacteria attack the copper, producing deep narrow pits.

How it can be avoided

Long pipe runs to little used outlets should be avoided at the design stage. All hot water pipes should be lagged. After pressure testing, flush out all pipework thoroughly and chlorinate large systems according to BS EN 806: part 4. Installers should not allow water to stagnate for extended periods between hydraulic pressure testing and handover of the system. If necessary, go around the building and open all outlets for at least one minute, twice a week until the system is handed over. If a private water supply is used, it may be necessary to filter water coming into the building and pass it over a UV filter.

7   TYPE 2 PITTING

This is sometimes referred to as hot soft water pitting. It has been found to occur more in Scandinavia and is very rare in the UK.

Manifestation

These deep pits are not normally covered with corrosion products. The pits have a narrow mouth and an irregular internal geometry. They are filled with crystalline copper (I) oxide [Cu_2O], sometimes capped by blue basic copper sulphate. Type 2 pits grow much slower than Type 1, with leakage of pipes occurring between 8 and 12 years. Fig. 10 shows an example of Type 2 pitting while Fig. 11 shows a cross-section through a Type 2 pit.
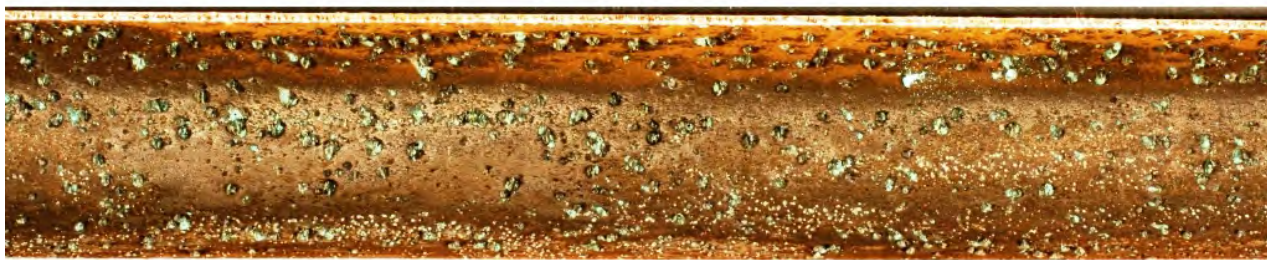

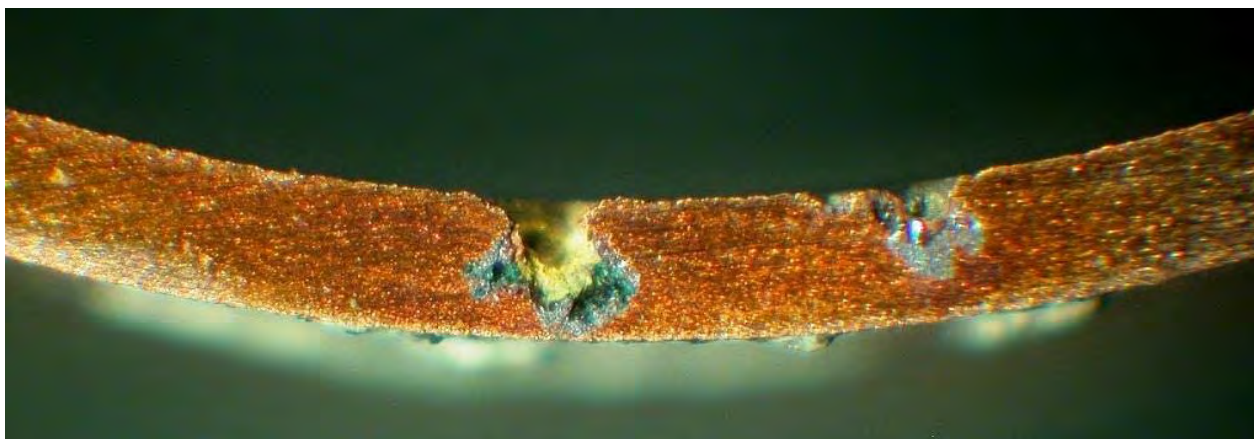**Figure 10   Type 2 pitting in a hot water pipe**   © P Munn

Figure 11 Cross-section through Type 2 pits   © P Munn

Cause

For Type 2 pitting to occur, the water needs to be soft with a bicarbonate:sulphate ratio <1. These pits can only develop at temperatures >60˚C. The presence of manganese in the water increases the likelihood of Type 2 pitting occurring.

How it can be avoided

Reduce the system operating temperature to less than 60˚C. A temperature of 55˚C for hot water systems will not only prevent the risk of Type 2 pitting in soft water but also MIC and the growth of *Legionella* bacteria.

Increasing the bicarbonate in the water is not straightforward but is possible. If manganese is present in the water, this can be filtered out by use of a commercial manganese filter.

8   UNDER DEPOSIT CORROSION

This is referred to in the 2010 edition of this publication as 'Concentration Cell Corrosion'. However, the term 'Under Deposit Corrosion' is more descriptive as it occurs underneath deposits left in the bottom of copper tubes.

Manifestation

Localised corrosion or pits taking place underneath installation or other debris around the 6 o'clock position in pipes.

Cause

The corrosion occurs due to a difference in the dissolved oxygen concentration in the water beneath and above the deposit, which sets up a localised concentration

cell. May cause leaks in rare cases. Flux deposits can also cause Under Deposit Corrosion as well as chemical attack.

How it can be avoided

Avoid as much as possible deposit entering the pipework on installation. Flush out pipework after pressure testing in accordance with IBS EN 806: part 4.

9   ROSETTE CORROSION IN HOT WATER CYLINDERS

Since the specification of hot water cylinders was changed in 2002 to disallow the use of aluminium protector rods, this form of corrosion is virtually unheard of in the UK.

10   FORMICARY CORROSION OF COPPER PIPES (EXTERNAL)

This is a form of external corrosion which can occur on copper pipework under phenolic foam insulation. It can lead to very slow leakage from pipes in nine months to two years. It is more common in refrigeration tubes or chilled water systems in large buildings but can also occur in mains cold water pipework.

Manifestation

Since the corrosion takes place under lagging, the first thing that is noticed is the lagging becoming wet and dripping. After removal of the lagging, the underlying copper pipework is discoloured, often having a very dull or blue-purple appearance, as shown in Fig. 12. The pits are too small to be seen with the naked eye but when cross-sections are taken through the area of attack and viewed under a microscope, numerous twisting and interlocking tunnels are observed, as shown in Fig. 13. This is why the attack is sometimes called 'ant's nest corrosion'.

Figure 12   **Appearance of formicary corrosion on the outside of copper pipe after removal of lagging**   © P Munn

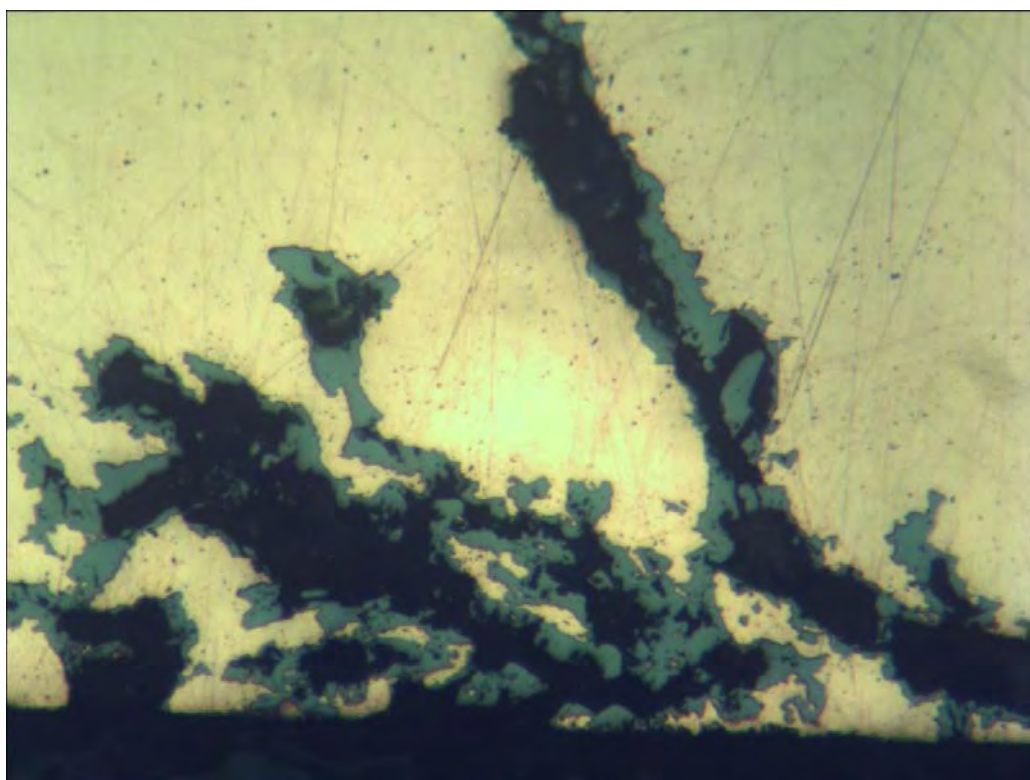**Figure 13**   **Cross-section through formicary attack (outer edge of pipe at bottom) © P Munn**

Cause

Formic acid or other carboxylic acids leaching from the phenolic foam attack the copper by forming a complex of cuprous formate. This oxidises to copper (I) oxide which, because it has a larger volume, results in fine cracking. Exposed copper then reacts further with the formic acid leading to deeper, more convoluted cracking. For any attack to occur, the presence of moisture is required. The moisture can be present within damp insulation at the lagging stage or may condense from the atmosphere and penetrate though insulation without a barrier layer or at cut ends of insulation.

How it can be avoided

If phenolic foam insulation is used, make sure that it is dry and contains an intact vapour barrier. When installing, tape all cut ends of the insulation with aluminium tape to form a complete seal.

11   DEZINCIFICATION OF BRASS FITTINGS

This phenomenon is perhaps the most well known form of dealloying. In the case of alpha-beta brasses, dezincification is the selective removal of the zinc-rich beta phase from the alloy, which leaves behind a much weakened porous structure. It can occur in both hot and cold water systems but occurs markedly quicker in hot water systems. Dezincification occurs either as a uniform layer type or 'meringue' type, or as a localised plug-type.

Manifestation

The normal yellow colour of the brass becomes a more reddish colour. In meringue type dezincification, voluminous corrosion products can cause blockages in fittings. The brass fitting itself becomes mechanically weak and can eventually fail, leading to leakage. Fig. 14 shows a cross-section through a brass fitting which has suffered from meringue type dezincification. The depth of the attack can be clearly seen in the polished cross-section.
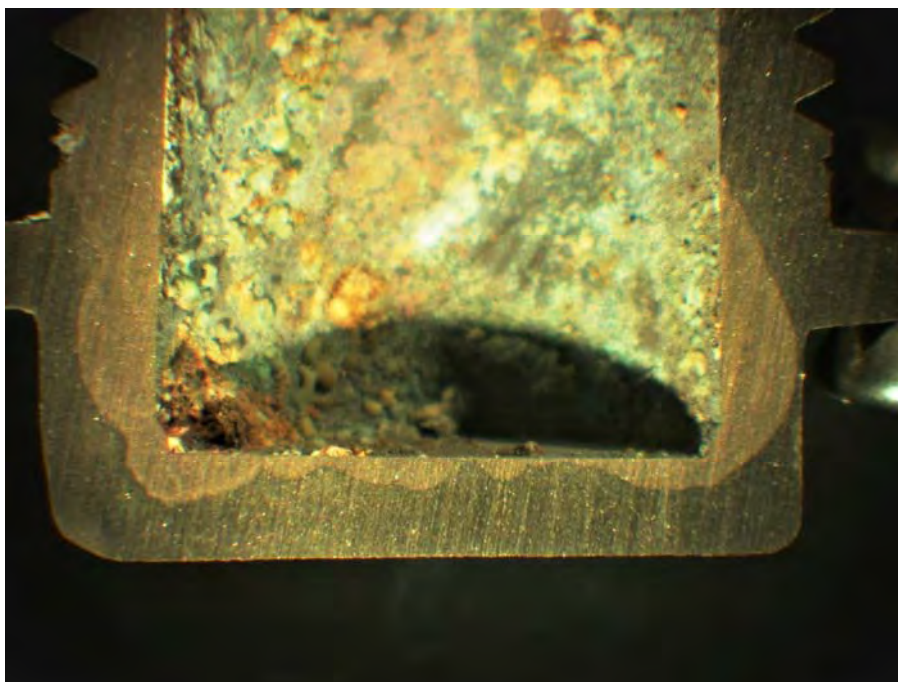

Figure 14   **Meringue type dezincification in a brass fitting**   © P Munn

Cause

Under certain water compositions, brasses with more than 15% zinc can undergo selective dissolution of zinc. This can occur in both the alpha (copper-rich) phase and beta (zinc-rich) phase of the alloy, but dezincification is much more severe in the beta phase. Alloying with small amounts of arsenic protects the alpha phase from dezincifying. However, alloys with a continual beta phase will still be susceptible to this attack. Dezincification resistant (DZR) brasses containing low levels of arsenic and a limited beta-phase should be immune from dezincification, as is gun metal (alloys of Cu-Sn-Zn-Pb).

The waters which promote dezincification have a chloride: bicarbonate ratio >0.33 with a high pH. At pH>8.2, meringue type dezincification with voluminous corrosion products can occur. At a lower pH in the range of pH 7.6–8.2, no build-up of deposit occurs but the fitting can still slowly dezincify. Low flow rates and stagnant conditions encourage the laying down of deposits and plugtype dezincification.

How it can be avoided

Always use fittings made from DZR brass or gun metal. However, even brasses marked DZR can still undergo dezincification from time to time, if the microstructure of the alloy has a continual betaphase. Avoid long periods of water stagnation.

12   STRESS CORROSION CRACKING OF BRASS

Stress corrosion cracking (SCC), also known as environmental assisted cracking, can occur with certain alloys exposed to specific environments and under tensile stresses. The stresses may arise during manufacture (residual) or applied during service. Commercially pure copper and brass fittings are susceptible to SCC in the presence of ammonia. Since, the concentration of ammonia is normally very low in drinking water, SCC of copper pipes or brass fittings from the water-side, i.e. from the inside, is extremely rare in drinking water installations. However, SCC of brass fittings in cold water systems has been found to occur very occasionally under phenolic foam insulation on the outside of the fitting where condensation under the lagging has occurred.

Manifestation

Leaks at brass fittings occur under foam insulation. When the insulation is removed, cracks are visible in the fitting, in particular in the threaded nuts, which are under tensile stress (see Fig. 15)
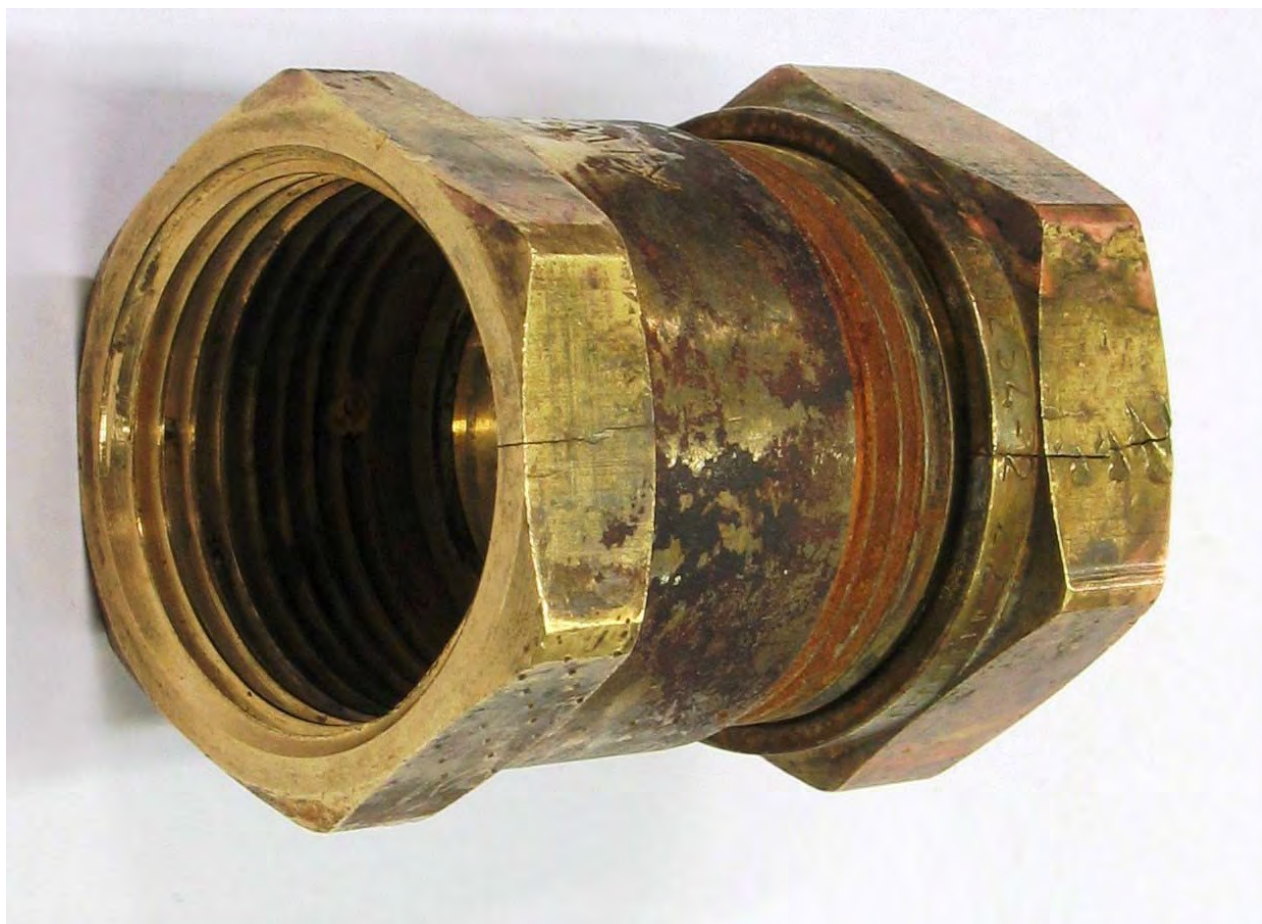
Figure 15   **SCC in a brass fitting** © P Munn

Cause

For SCC to happen in brass fittings, there needs to be a combination of ammonia and a high tensile stress (either residual or applied or a combination of both). Leaching of ammonia from phenolic foam insulation can occur if water or condensation penetrates under the insulation to the brass surface. Since condensation is much more likely at low temperatures, it is more likely to occur in cold water systems, In the cases where this has been found, the fitting has been over-tightened so that there was a high applied tensile stress on one component of the fitting.

How it can be avoided

If using phenolic foam insulation, prevent condensation on pipe by taping over joints in insulation with aluminium foil. Do not over-tighten fittings.

13 FURTHER READING

General

Water Supply (Water Quality) Regulations (England & Wales) 2016

BS EN 806-4:2010 Specifications for installations inside buildings conveying water for human consumption. Installation.

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