Guides to Good Practice
in Corrosion Control

Avoidance of Corrosion in Plumbing Systems

NPL
National Physical Laboratory

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This guide had been prepared by Ken Tiller of Lithgow Associates under contract from NPL for the Department of Trade and Industry.

1.0 Introduction

This guide acts as a source of advice for all those who use copper and stainless steel pipework in hot and cold potable water systems. Its purpose is to create an improved awareness of the factors responsible for corrosion problems and to highlight and compliment the existing technical literature (Appendix A).

Some problems, which have been experienced in the past, particularly with imported copper pipes, were undoubtedly due to the poor quality of the material. In some instances pre-used copper pipes have been identified as the culprit. Neither of these issues are likely to be a problem today. The complaint that the pipe material is at fault is seldom valid. Experience over the years clearly indicates that when corrosion problems do arise it is more likely to be a combination of the factors listed below:

- Changes in water chemistry
- Defects in design
- Incorrect installation and fabrication
- Failure to observe recommended commissioning and maintenance procedures.

This guide highlights the current recommended procedures, that are considered to be “Best Practice”. These should help to reduce the factors that cause corrosion and which are known to be associated with the practical aspects of installing and commissioning hot and cold potable water systems.

2.0 Types of corrosion experienced

It is not the intention of this guide to discuss the mechanisms of the various forms of corrosion that occur as these are published in detail in the technical literature. Appendix B lists the important publications that are recommended to the reader for further information on this subject. However, the six most frequently occurring types of corrosion are described below.

2.1 General corrosion

The whole surface corrodes at an approximately even rate. Pipe failures usually take several years.

2.2 Pitting corrosion

This is a localised form of attack that occurs in a random pattern around and along the inside of the pipe. In the case of copper there are two recognised forms.

Type 1 only occurs in cold water systems using moderately hard to hard waters derived from deep wells. It is associated with the presence of a residual carbon film on the surface of the metal after manufacture. Improved cleaning of the bore of the pipe has more or less eliminated this factor.

Type 2 occurs in soft hot waters, is closely associated with the chemistry of the water, and is seldom experienced in the UK. Nevertheless, soft waters in the UK, which contain the element manganese at a low concentration of 0.03 mg/L [3 ppm], will encourage pitting attack at temperatures of 60 °C and above.

Deposits of flux in the bore of the pipe also encourage pitting, see Figure 1. This is particularly a problem when chloride containing fluxes are used with stainless steel pipes.

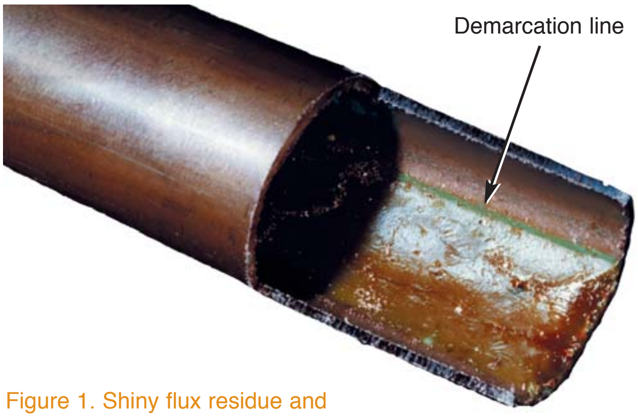

Figure 1. Shiny flux residue and demarcation line showing that the pipe was half filled

2.3 Erosion corrosion

This is the combined action of wear, caused by the movement of the liquid or particulates in the pipe, and corrosion. It is caused by high flow velocities, and turbulence and is enhanced by softened waters. In general the metal surface has a shiny appearance and the attack undercuts the metal in the direction of flow. It is characterised by horseshoe shaped regions as if the horse had walked upstream. Adherent deposits on the surface of the metal and bend sections are the most vulnerable areas to this form of attack. Significant erosion-corrosion can occur when particulates are trapped in the system. See Figure 2 (over page).

Figure 2. Copper pipe showing erosion-corrosion at start of bend

Design aspects and fabrication issues are important in this instance. Avoid sharp bends, flux, and solder runs, poorly fitted unions and fittings, etc. Most importantly, ensure that the flow velocity is correct for the pipe diameter.

2.4 Stress corrosion cracking (SCC)

Stress Corrosion Cracking is caused by stresses present in the material and corrosion. This is likely to occur in highly stressed areas such as tightly formed bends and unions. It is characterised by the formation of fine cracks, which propagate through the pipe wall. This may be intergranular or transgranular depending on environmental circumstances. Stainless steels are vulnerable to this type of corrosion in systems where deposits have formed and the salt [chloride] has concentrated or when the level of this is high in the water and the temperature is above 60 °C. A separate guide to SCC is available. See Appendix B.

2.5 Bimetallic/Galvanic corrosion

Two possible sources of trouble exist. The first is that the water may dissolve small amounts of a metal in one part of the system which causes corrosion of a different metal downstream. For example, the pick-up of copper leads to corrosion of galvanised pipework. The other harmful effect occurs when different materials are coupled together initiating galvanic attack. The more reactive metal will corrode and the rate of corrosion of the less reactive metal will be reduced. See Figure 3.

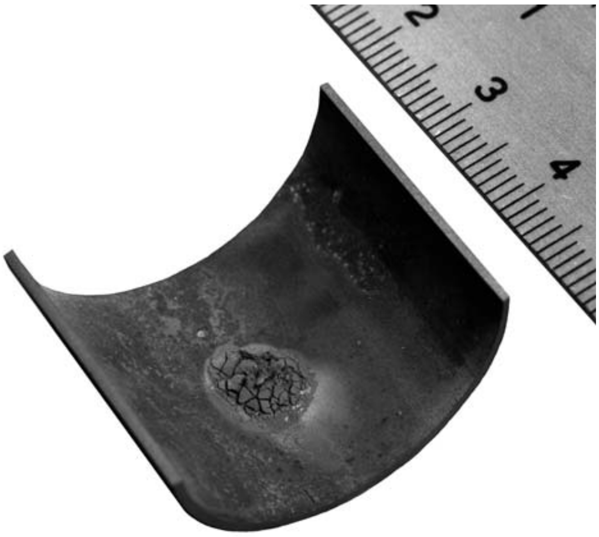

Figure 3. Corrosion deposits around a particle of iron in a copper pipe

The NPL Guide to Bimetallic Corrosion and the BSI document PD 6484 provide valuable information on this subject. See Appendix B. Copper can be connected to stainless steel provided it is via a compression or capillary union.

2.6 Microbial corrosion

As the name implies, this is a result of the action of the bacteria and their metabolic products that range from certain types of acid to gaseous products such as hydrogen sulphide. Their unique ability is to produce biofilms. These are complex organic materials that adhere to the metal surface creating conditions that allow chemical entities to stimulate the corrosion of the metal particularly under stagnant conditions. More specific details are given in the references under Appendix B. Suffice to say that under the appropriate environmental conditions all the metals used in plumbing are susceptible to this form of corrosion that inevitably includes severe pitting of the materials. Figure 4 shows an example of this type of corrosion.

Figure 4. Microbial corrosion in a copper pipe

3.0 Design considerations

Both design and operating conditions influence the overall performance of the materials used in hot and cold potable water systems. Detailed layout of the system is the responsibility of the design and consulting engineers. Nevertheless, the following have proved to be important.

3.1 Flow velocity

Low flow in partially filled oversized pipework encourages deposition of detritus. This encourages pitting attack in the lower half of the pipes. When these conditions occur in copper pipes waterline attack is prevalent.

When the flow velocity is above that specified for the pipe diameter, it is quite common for pipes to sustain erosion and corrosion simultaneously particularly at bends and where imperfect unions exist. This also applies where adherent deposits are present on the surface of the pipe, i.e. solder and flux. Pipe ends that have not been deburred give the joint an irregular geometry and are vulnerable.

3.2 Pipe layout

This should be arranged to ensure that pipe runs do not allow build-up of stagnant or semi-stagnant water conditions to prevail, i.e. dead-ends or pipe runs which only supply little used services. These conditions lead to build-up of sedimentary matter suitable for the growth of microorganisms and hence microbial corrosion. Pitting corrosion is also encouraged under the sediment.

4.0 Installation practices

A correctly designed system can still suffer from corrosion if poor installation practices are allowed to occur.

The following checklist of Do's and Don'ts should be used if "Best Practice" is to be achieved:

✔ All pipes and fittings to be stored in dry clean conditions

✔ Pipe ends to be capped at site and at day joints

✔ Cut pipe ends to be deburred and re-rounded using the correct tools

✔ Solder and flux must conform to the appropriate specification and be used in accordance with the manufacturers recommendation

✔ Apply flux to pipe end only. Avoid excess, and if possible remove any flux prior to heating

✔ Make sure the flux is compatable with the pipe material

✔ Thoroughly flush out system before use

✔ Ensure disinfection is carried out in accordance with BS 6700 (1997) and thoroughly flushed out after treatment.

✖ Avoid the use of acid, ammoniacal and chloride bearing flux

✖ Do not overheat during fabrication of unions

✖ Do not over tighten compression fittings

✖ Pipes which have sustained internal damage should be rejected

✖ Avoid bimetallic contacts or use of different metals in the system

✖ Never leave a system partially filled with water for long periods immediately after installation

✖ Avoid build-up of stagnant or semi-stagnant water in pipe runs

✖ Avoid unnecessary use of water softeners.

5.0 System maintenance and control

All systems must be checked regularly for leaks at valves and pumps in order to avoid external corrosion at these locations. Flanges and similar unions should also be included during these inspections.

Planned maintenance schedules should be drawn up by the respective parties involved and responsible for the plant. Any water treatment regimes in use must be monitored on a regular basis and strict control of any inhibitor system installed maintained. Variations in concentration of the inhibitor must be addressed since this could lead to loss of protection and possible corrosion of the plant. System maintenance is a highly specialised activity best carried out by suitably qualified and experienced professionals. Always seek advice from established and accredited organisations.

6.0 Refurbishment and retrofitting issues

Irrespective of the size of the system, it will either require updating, refurbishment or selective retrofitting of pipe runs.

A simple drain down is all that is required for domestic systems. When the work is completed it should be flushed out to remove all contamination and detritus refilled with water and recommissioned. If an inhibitor has been used previously, this can be replaced accordingly.

Large plants require a more engineered approach and particularly so if it is required to remain operational at all times. In these cases, the plant is usually divided into sections which can be valved off without hindrance to the remaining sections. This type of project is best carried out by established organisations only and in accordance with approved codes of practice and specifications.

7.0 Summary

This guide has highlighted the many factors that are now recognised to be responsible for the corrosion problems experienced by hot and cold potable water systems. In many instances, it is not the materials that are at fault but rather a combination of factors that cause corrosion. Most of these are closely associated with fabrication and the practical aspects of building and commissioning the plant. However, this need not continue to be the case if the appropriate documents are acquired and consulted. Similarly there is a wealth of experience available from numerous organisations, particularly those listed in Appendix A.

Fabrication issues such as flux and solder runs in the bore of the pipe suggests that there is a case to answer for improved on-site monitoring. It also suggests that bench standards should be established and perhaps personnel unable to reach the approved standard should be encouraged to attend training courses. See Appendix C.

8.0 Appendix A - Useful institutions

National Corrosion Service
National Physical Laboratory
Queens Road
Teddington, TW11 0LW
Helpline: 020 8943 6142
E-mail: ncs@npl.co.uk
www.npl.co.uk/npl/cmmt/aqueous/about_ncs.html

Institute of Corrosion
4 Leck Street
Leighton Buzzard, Bedfordshire
LU7 9TQ
Tel: 01525 851771
www.icorr.demon.co.uk/about.html

The Institute of Plumbing
64 Station Lane
Hornchurch
Essex RM12 6NB
Tel: 01708 472791
Fax: 01708 448987
E-mail: info@plumbers.org.uk
www.plumbers.org.uk/

Scottish and Northern Ireland Plumbing Employers' Federation
2 Walker Street,
Edinburgh, EH3 7LB
Tel: 0131 225 2255 Fax: 0131 226 7638
E-mail: info@snipef.org
www.snipef.org

Copper Development Association
Verulam Industrial Estate
224 London Road
St. Albans
Herts, AL1 1AQ
Tel: 01727 731200
Fax: 01727 731216
E-mail: copperdev@compuserve.com
www.brass.org/contact.htm

Stainless Steel Advisory Service
C/O The institute of Materials
The Innovation Centre
217 Portobello
Sheffield, S1 4DP
Tel: 0114 224 2240
E-mail: 0114 274 0444
www.materials.org.uk

Nickel Development Institute
42 Weymouth Street
London,
W1G 6NP

NACE
www.nace.org

9.0 Appendix B - Useful publications

BS 6700 (1997) Specification for design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages

Copper Tube In Domestic Water Systems TN33 (1993)
The Copper Development Association

Domestic Hot and Cold Water Systems for Scottish Health Care Premises (1994) The Scottish Office HMSO
ISBN 0-11-495236-1

Stainless Steel Plumbing Technical Series 11 019
The Nickel Development Institute (NiDi)

Prevention and Control of Water-Caused Problems in Building Potable Water Systems (1995) NACE Publications
ISBN 1-877914-86-X

10.0 Appendix C - Training

In the UK there are at least 190 centres which provide training courses for plumbers and other personnel involved in the design and installation of plumbing systems.

These training courses provide for both NVQs and City and Guilds qualifications and are available on full, part-time and evening sessions. Both NVQ and C&G routes are accepted by the Institute of Plumbing, if required.

The National Corrosion Service

This Guide has been written by Ken Tiller of Lithgow Associates and edited by Bill Nimmo, Manager of the National Corrosion Service.

The National Corrosion Service (NCS) is operated by NPL on behalf of the DTI to provide a gateway to corrosion expertise for UK users. By acting as a focal point for corrosion enquiries, the NCS can make the UK's entire base of experts available to solve problems or can, using in-house expertise or teams, carry out consultancy. The NCS also helps raise awareness of corrosion problems and methods of control.

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