GEBERIT

January 2019

MAKE IT RIGHT

BEST PRACTICE GUIDELINES TO REDUCE THE IMPACT OF CORROSION ON PRECISION CARBON STEEL

KNOW HOW INSTALLED

FOREWORD
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Dr Jane Lomas, of Amtec Consultants Ltd, is a Fellow of the Institute of Corrosion as well as the Honorary Secretary and a Council member of the Institute. With a PhD in Corrosion Engineering, Dr Lomas has worked in corrosion consultancy for over 30 years.

Corrosion is a natural process. It occurs because man mines ore from the ground and extracts the metal to form building components. The metal prefers to be in the form of oxides or rust and has a driving force to return to that state.

Some metals are more stable than others, but all metals can provide a useful lifetime, provided that they are carefully selected for the service environment and suitably looked after. It is usually when the factors that influence corrosion are not carefully considered or managed, that problems occur.

Joining different metals together can often result in galvanic corrosion, for example in HVAC systems, but this does not have to occur. Good control over external lagging of pipes to avoid moisture ingress into the lagging can avoid corrosion of pipe external surfaces and potential problems at joints or valves.

Good system maintenance of the fluids inside an HVAC system can prevent corrosion of the inside of components and stop microbial corrosion from occurring.

Successful systems are a combination of the skills of many people and companies. They rely on knowledgeable design; the selection of suitable materials for the service environment; controlled manufacture of the components; careful installation; thorough cleaning and commissioning; regular inspection & monitoring and an excellent maintenance regime.

When all these factors come together, as this document demonstrates, the system will perform satisfactorily for its design life.

SETTING THE SCENE

Before investigating the causes and prevention of damaging corrosion when working with precision carbon steel, it is important to set the context.

Firstly, when handled, installed, operated and maintained correctly in accordance with manufacturer and industry standards, precision carbon steel pipework offers a long and productive life.

Clearly though, corrosion can and does occur in all metals – as has been the case in numerous examples when precision carbon steel has been switched for stainless steel or traditional mild steel in a failed attempt to avoid the issue.
This document will highlight the reasons for corrosion and identify some of the bad practices that can aggravate the potential for such corrosion.
It will also put forward clear, demonstrable and practical solutions to overcome bad practice, showcasing the potential and the performance/installation benefits of precision carbon steel when used correctly.

IN CONTEXT:
A BRIEF HISTORY OF PRECISION CARBON STEEL

* With record copper prices, many smaller installers turned to precision carbon steel to try and maintain margins. Further support was offered by proactive pipework manufacturers and an industry-wide initiative to address a known skills shortage via press-fit installations.

** The UK's first major report of internal corrosion came when the opening of a new critical care unit at Belfast's Royal Victoria Hospital was significantly delayed after corrosion of pipework was detected in the new heating system during final checks. The project became a PR disaster, coinciding with the rapid rise of social media and subsequently a flurry of untruths around the performance of precision carbon steel – the impact of which is still felt today.

*** With copper prices back to a seven-year low, some installers have switched back to copper. Unfounded concerns over precision carbon steel in some areas have also led people to switch to cheap, imported mild steel pipework or more expensive stainless steel for building services.

1950s

Press-fitting invented by Gunna-Larsson

1969

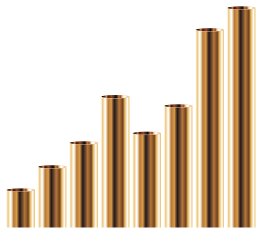
Carbon steel systems introduced by Mannesmann

2001

Externally galvanised carbon steel press-fittings launched

2011

Copper prices reach an all-time high*



2012

Royal Victoria Hospital Belfast hits the headlines**

2015/16

Copper prices fall dramatically***

NHS guidance document is issued *(Ref: EFA/2016/001. Issued 04 may 2016)*

NHS

CORRECT APPLICATIONS AND BENEFITS

When used correctly, precision carbon steel is a durable, cost-efficient solution.

However, like all materials, it is only suitable for specific applications. In the case of precision carbon steel, this includes closed water systems - where oxygen levels are inevitably lower than open systems - with closed expansion tanks and appropriate de-aeration.

It should not be installed outside buildings without adequate protection, in open systems or with excessive water treatment – all of which were reportedly evident when carbon steel sales grew faster than application and design knowledge in the post-recession period of economic activity.

BENEFITS

- **Tried and tested material, proven in commercial applications over 50 years**
- **More cost-effective than stainless steel and copper (subject to copper prices)**
- **Option for external zinc coatings or external polypropylene coating to help prevent condensation**

PRESS-FITTING

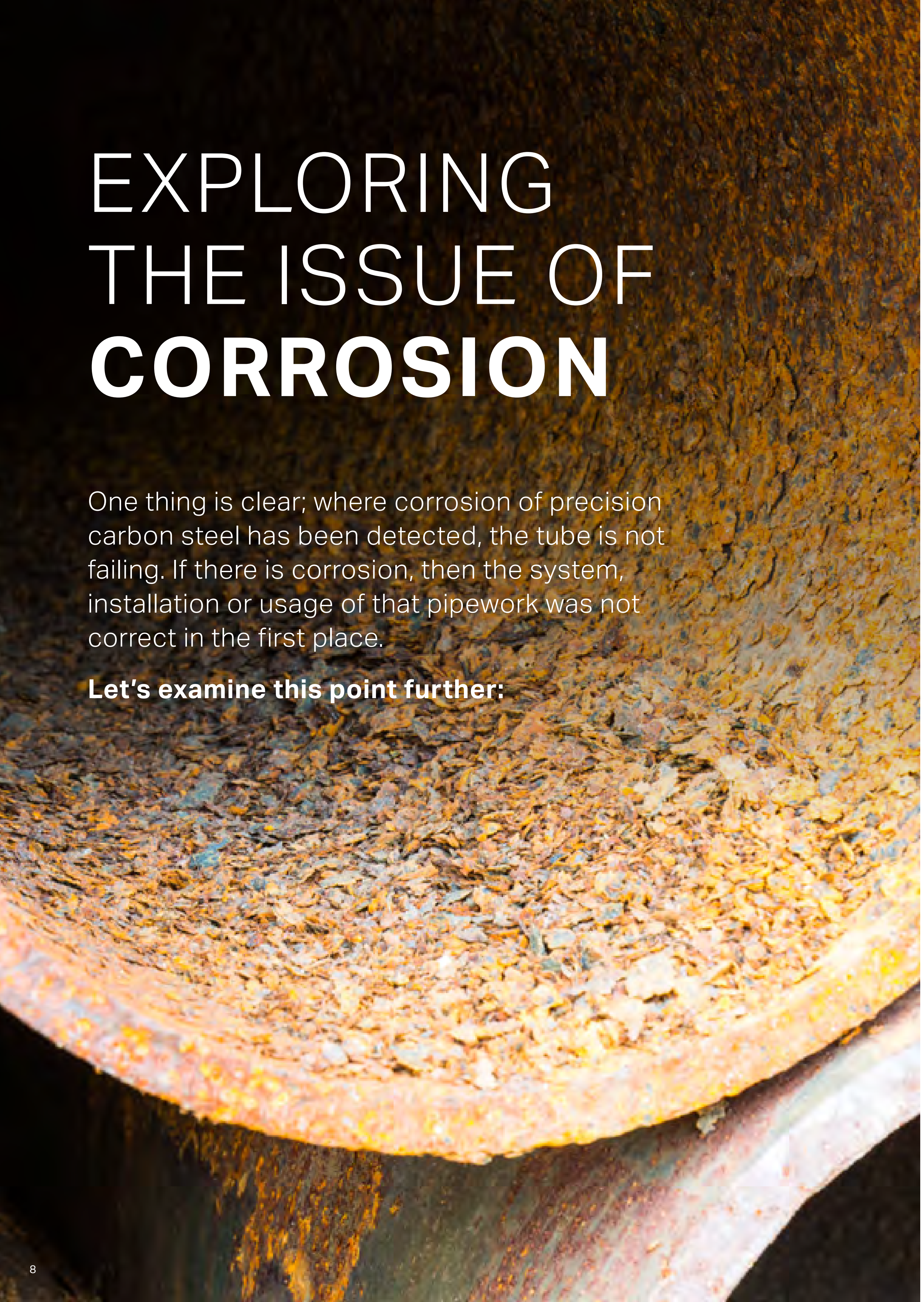
Precision carbon steel can be connected with press-fitting systems which offer fast, reliable connections without the need for hot works.

Traditional jointing methods can be cumbersome and difficult to implement, in many cases simply unsuitable and impractical for the job at hand.

In contrast, press-fit solutions like Geberit Mapress can deliver a host of installation benefits, with no hot works, and no cooling down period. Coloured pressing indicators offer easy identification of material and unpressed joints during the installation process.

THE FACTS:

- **Tens of millions of metres**
  of carbon steel installed pipework, including a vast number of commercial applications
- **Specified and successfully installed**
  in high profile projects including London 2012
- **Cost effective and durable solution,**
  with proven performance through successful, problem-free installations across Europe
- **Extremely low failure rate**
  where failure has occurred it has been related to incorrect installation, poor commissioning practices, systems with poor or no maintenance and unsuitable applications



EXPLORING THE ISSUE OF **CORROSION**

One thing is clear; where corrosion of precision carbon steel has been detected, the tube is not failing. If there is corrosion, then the system, installation or usage of that pipework was not correct in the first place.

Let's examine this point further:

CORROSION SCIENCE

Corrosion is defined as the gradual destruction of materials by chemical and electrochemical reaction with their environment. General corrosion occurs when most or all of the atoms on the same metal surface are oxidised, i.e. the metal loses electrons to oxygen (and other substances) in the air or in water. As oxygen is reduced, it forms an oxide with the metal.

Pipework corrosion is caused by oxygen in the presence of water and is accelerated through galvanic action - an electrochemical process in which one metal corrodes preferentially when it is in electrical contact with another, in the presence of an electrolyte such as water. If the water has dissolved salt or is acidic, then corrosion will be accelerated.

As steel is an alloy of primarily iron and carbon, it is susceptible to corrosion in the presence of an electrolyte. Specifically, this is due to oxidisation of the iron, which creates rust, or iron oxide.

This is less of an issue with stainless steel, which has additional levels of chromium to increase its resistance to corrosion by forming a chromium oxide layer on its surface. BS EN 10088-1 states that a steel must have a minimum of 10.5% (by weight) chromium and a maximum of 1.2% carbon to be classified as stainless. However, this protection comes with a premium, which is why stainless steel is often reserved for hygiene-controlled operations.

Carbon steel and mild steels, have lower levels of other elements including chromium. The iron wants to return to its natural state (iron oxide), which is why it chemically bonds with oxygen readily under the right conditions. This can lead to rust if good practice is not applied.

PREVENTING OXYGEN FROM ENTERING THE SYSTEM

Of course, we cannot prevent oxygen from entering any water-filled system. There will always be an element of 'dissolved oxygen' during the initial fill of any closed water system, but this will only lead to light general rusting of the internal surfaces. Providing the water is not constantly replaced, there should be no source of additional oxygenation.

The key is to prevent further oxygen from entering the closed water system and causing irreparable levels of corrosion. This would usually occur from one of three routes:

1 → **From aerated water** - this is most likely during the initial water fill, during system flushing or from fresh make-up water during operation by means of auto-topping up

2 → **From pressurisation problems** - for example, negative pressures at the top of the system can result in air being drawn in through Automatic Air Vents (AAVs) or seals

3 → **From oxygen diffusion** - which can occur through the use of non-barrier plastic pipework or open systems

GOOD PRACTICE:
A SIX STEP PROCESS

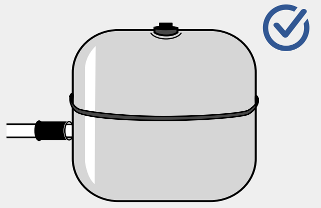
Now that we have examined the causes and effect of corrosion, let's explore the best practice measures to prevent it.

Following a few simple rules throughout the specification and installation process can help to prevent corrosion and ensure the long-lasting integrity of this tried-and-tested material.

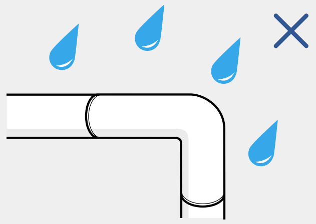
It really is that simple.

1. GOOD PLANNING

- Plan heating and cooling systems as a **closed system** with a closed expansion tank and appropriate ventilation



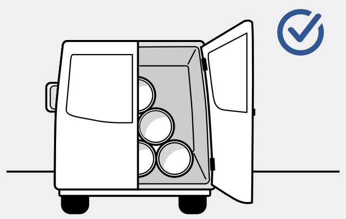
- Look out for **continuous overpressure in the system**
- Work with manufacturers and use all available resources to determine the **best materials for each application**
- If condensation is expected, ensure effective corrosion protection in accordance with **BS 5970: 2012** or worksheet **AGI Q 151**
- Best practice is to **not** install precision carbon steel externally



- Mass loss corrosion device handover for peace of mind

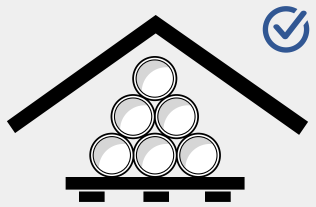
2. TRANSPORT

- Use a **closed or well covered means of transportation** to reduce the risk of moisture reaching the material

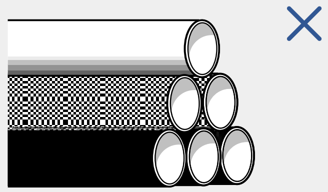


3. STORAGE

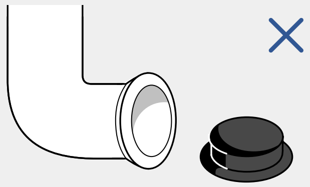
- Store in a **dry environment** and **avoid storing on the floor**



- Carbon steel can be stored in contact with other materials in dry conditions **but if there is a chance of moisture during storage, contact with other metals should be avoided**



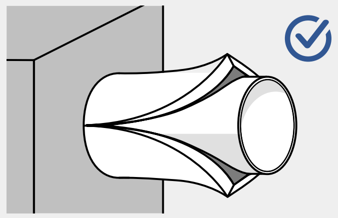
- **Do not cover with plastic foil** as this can increase the risk of condensation and thus corrosion
- **Do not remove protective caps during storage**



- **Store different pipe dimensions separately to avoid deformation**

4. INSTALLATION

- **Follow the plan** – install pipework in accordance with specifications and apply insulation and coatings as stated
- **Only remove protective caps immediately before use on site**
- During longer interruptions, **use downward facing bends to protect open ends from dirt**. Do not refit protective caps as this can cause condensation
- Testing should be completed with **compressed air** where feasible but if performing a pressure test with water, the recommended water quality should be used and the system should be left filled where possible
- Protect pipes laid in screeds with a barrier against diffusion in accordance with **BS 5970: 2012** or worksheet **AGI Q 151**, with closed-cell insulation material and corrosion protection as a minimum



- **Do not use any parts with visible red rust**
- **Do not use lubricant** – this is unnecessary for press-fittings
- ENSURE Adequate training for installers on specific materials and applications

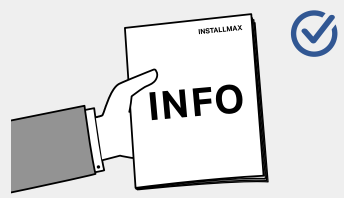
5. COMMISSIONING

- Fill the system **once** with the required water quality and **leave it filled**
- Completely ventilate the system and **do not empty commissioned systems again**

6. MAINTENANCE

- If you must empty an already running system, refill as quickly as possible – **within 24 hours at most**

- Make sure the operator is aware of **issues relating to corrosion** such as unplanned room usage, maximum humidity and use of additives
- Refer to the **recommended test intervals as per BSRIA recommendations**
- **Arrange an appointment with the operator or maintenance manager** immediately after installation and commissioning



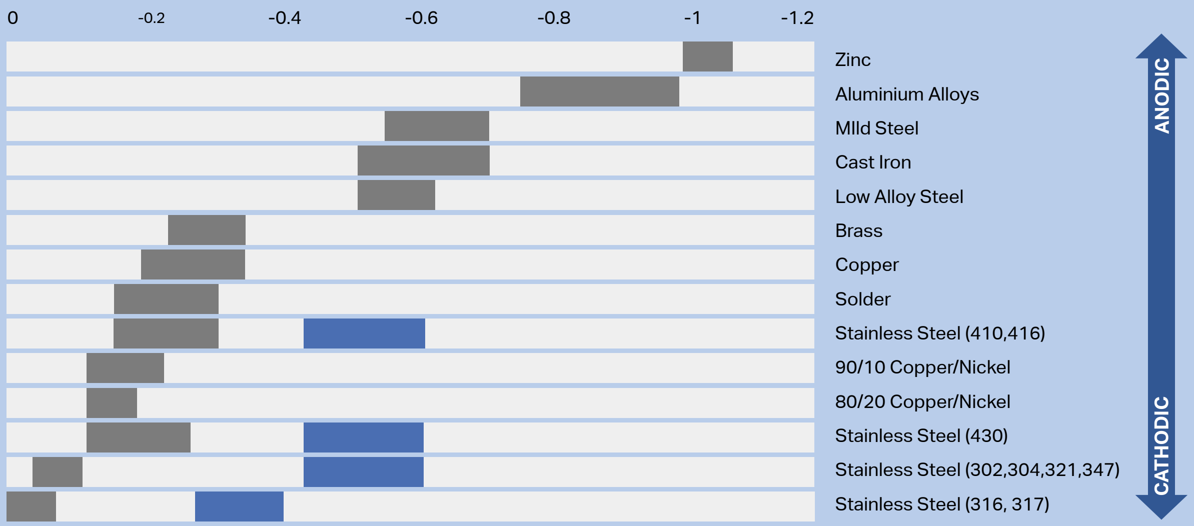
- **Follow manufacturer's guidelines** on suitability and dosage of water additives or inhibitors
- Ensure handover of mass loss corrosions device for peace of mind

RESISTING CHANGE

For some contractors and installers, particularly since the sharp 2016 fall in copper prices, switching materials has been perceived as the easiest and most convenient way to address any potential corrosion issues. However, basic corrosion science highlights a significant flaw with this approach.

In fact, switching material to stainless steel, or other tubes which meet the old British Standard BS 1387:1985, **will only move the problem within a system of mixed pipework materials**. Where it moves to will depend on the system and the materials used, using the galvanic scale below.

Figure 1.



→ THE SCIENCE BEHIND THE SWITCH

Remember, pipework corrosion is accelerated through the formation of a galvanic cell combined with oxygen, when two metals are physically connected and placed in an electrolyte such as water.

Figure 1. shows the cathodic potential of various metals when in seawater, with the most anodic (susceptible to corrosion) at the top and most cathodic (resistant to corrosion) at the bottom. The grey bars represent the 'normal' state of the metal, whilst blue bars show the anodic values of stainless steels when 'active' – i.e. the protective chromium oxide layer has been damaged.

Crucially, the greater the difference between two metals on this chart, the greater their tendency to want to react and the quicker corrosion will usually occur on the anode metal.

The ideal solution is to design a system using the same material throughout, but this is often not viable particularly in repair and retrofit situations. Alternatively, designers can either insulate dissimilar metals using coatings or plastic, or select metals close in the galvanic series as shown in Figure 1.

Simply switching carbon steel for stainless steel, as has often been the case in recent years, will only move the potential issue to the next anodic material.

For example:

- A carbon steel system with a high proportion of copper can lead to galvanic corrosion
- Because carbon steel is more anodic than copper, the corrosion will occur on the carbon steel
- Substituting carbon steel for another material such as stainless steel 316 will not eradicate the potential issue - it will move it to a different part of the system; and the most likely candidates will be components made of brass and/or copper
- The oxygen will simply react elsewhere, which can lead to corrosion of the most anodic material elsewhere in the system, for example valves, radiators, pumps, etc...

MASS LOSS **CORROSION CONTROLS**

The issue of corrosion has also highlighted the need for effective and ongoing controls, which should be included as part of any system design and not simply offered as a reactive measure.

Traditionally there have been two methods of monitoring the condition of a closed water system:

ULTRASONIC THICKNESS TESTS

- Can determine the current condition of the system but will only provide a snapshot
- Unlikely to find a problem before a major fail
- No opportunity to monitor entire system

MANUAL TESTING

- Offers a snapshot and is unlikely to record required levels of data
- Can be cost-prohibitive, particularly as it should be done several times every year
- Will usually only happen after an incident

In contrast, modern water monitoring devices offer greater visibility of the system with early warning detection of potential issues - all with greater flexibility and lower costs than previous systems.

- Devices sited throughout the system to monitor all materials
- Early warning detection system, reacting to changes in the water make up
- Changes activate an alarm on a downloadable dashboard
- Option of complex data or simple data
- Cost-effective and long lasting
- Devices can be removed and replaced without needing to drain down the system
- Meets the requirements of BG 29/2012 standards for water sampling

“The only way to give a full picture of the system during its use and monitor the development of potential problems is through continuous monitoring.”

Chris Thompson
Research Engineer, BSRIA

https://www.cibsejournal.com/cpd/modules/2018-10-pip/

CARBON STEEL
IN PRACTICE

OMAGH HOSPITAL

In June 2017, a new hospital opened its doors in the Northern Irish town of Omagh, providing a comprehensive range of healthcare services for local people. The new facility employs a mix of two- and three-storey elements, spanning a total floor pace of 28,000 m².

After the issues faced at the nearby Royal Victoria Hospital project (see right), it was crucial that the consultants involved with the Omagh Hospital build made the right decisions over closed system pipework.

Fortunately, contractors R&F Mechanical had worked closely with Geberit for many years. As a result, they had a good understanding of precision carbon steel, its properties and performance benefits. Crucially, they also knew how to store, install, commission and maintain the system to avoid any potential corrosion issues.

Geberit Mapress Carbon Steel was used in full across nine plant rooms, in varying diameter of 15mm – 108mm. In total, 50km of pipe and over 250,000 fittings were installed and at its busiest, 150 M&E installers were on site together, all of which had received training on Geberit Mapress Carbon Steel.

The system was handed over successfully with no concerns over corrosion.

> **"Twenty years into installing hospitals and we've never had an issue. Mapress Carbon Steel is our product of choice."**
>
> **William Flemming**
> R&F Mechanical

Omagh Hospital

→ A TALE OF TWO HOSPITALS


Belfast's Royal Victoria Hospital

The opening of a new critical care unit at Belfast's Royal Victoria Hospital was significantly delayed in 2012 after corrosion of pipework was detected in the new heating system during final checks.

The ensuing bad publicity caused a decline in the specification of press-fit precision carbon steel pipework in Northern Ireland and throughout the UK, despite the clear and demonstrable benefits when handled, installed, operated and maintained correctly.

In fact, at **Mater Hospital**, less than two miles away from the Royal Victoria, experts inspected a 12 year old press-fit system in the aftermath of the issues and all samples of polypropylene coated precision carbon pipework were found to be in a condition similar to when it was installed.


Mater Hospital

KEY TAKEAWAYS

- Despite rumours shared within the industry, precision carbon steel pipework offers a long and productive life when handled, installed, operated and maintained correctly in accordance with manufacturer and industry standards. It has simply been the easiest thing to blame for highlighting irregularities in systems that have failed when using it
- It is durable and cost effective, but system design must be taken into account to reduce the risk of corrosion (as with any metal pipes)
- Where corrosion of precision carbon steel has been in the system, installation or ongoing usage of that pipework was not correct in the first place
- Following a simple six-step process throughout the specification and installation process can help to prevent undesirable corrosion and ensure the long-lasting integrity of carbon steel
- Switching materials is not the issue - pipework corrosion is accelerated through the formation of a galvanic cell, when two metals are physically connected and placed in an electrolyte such as water. It will only move the issue elsewhere in the system
- Ongoing water monitoring should be included as part of any system design
- Modern water monitoring devices offer greater visibility of the system with early warning detection of potential issues - all with greater flexibility and lower costs than before.

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