Are closed systems a 'closed book'?

Pre-commission cleaning of closed circuit pipework systems, and the subsequent monitoring of water quality, are essential in any building. Getting either wrong can mean disruption to occupants while systems are re-cleaned or, in the worst cases, complete closure of buildings while entire systems are ripped out and replaced due to early failure. However, according to Dr Pamela Simpson, a specialist in water microbiology who established water quality specialists, Whitewater Technologies, in 1998, and, Chris Parsloe, of Parsloe Consulting, although the risks associated with open systems (where the circulating water might come into contact with humans) are generally appreciated, there is less awareness of the problems that can affect closed systems.

A closed re-circulating pipework system is one which, as the name implies, is closed, i.e. the water in them is not exposed to the atmosphere, and is not significantly depleted due to evaporation or draw-off. The water is permanently enclosed, and typically spends all of its time being heated, cooled, and re-circulated, in the process of delivering heating or cooling. All systems serving terminal devices – from radiators to fan coil units or chilled beams – are examples of closed systems.

The potential problems start during construction. In large buildings, heating and cooling circuits can include pipes that are over a metre in diameter. In an ideal world, these pipes would be installed in a clean, debris-free condition, but in practice, nothing can be ruled out.

Hard hats, soft drink cans, plastic bags, and even dead foxes, have all been found inside systems. If left undetected when the pumps are switched on, such items can cause major damage to expensive boilers, chillers, and pumps. The smaller particles can be just as bad. Some modern control valves have clearances of less than half a millimetre. This means that sand, grit, jointing material, or welding slag, can cause blockages and consequent heating or cooling dead spots.

Tubercle formation within a closed hot and cold water system.

Danger not ended

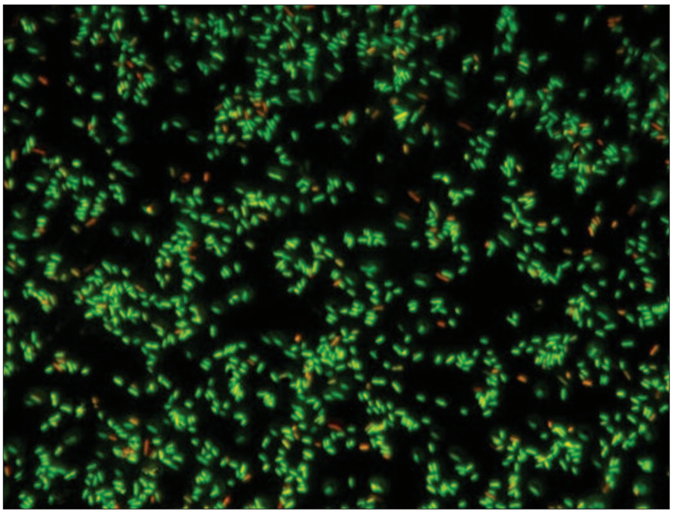
All of this debris should therefore be removed by dynamic flushing of the system during pre-commission cleaning. Successful removal of these items does not, however, end the danger.

Most closed re-circulating systems are constructed predominantly from carbon steel pipe. Carbon steel has the significant advantage of being both strong and cheap. However, as we should all remember from our school science days, in the presence of oxygen and water it will corrode rapidly, i.e. within hours. Our high strength steel is then replaced by low strength semi-soluble particles of soft brown rust or, if the supply of oxygen is limited, black magnetite. Thick-walled steel pipe has some tolerance built into it, and can survive for a while, but thin-walled steel has less.

Dynamic flushing of pipework involves circulating highly oxygenated water through the pipes at high velocity. Hence, as we are removing the problem of system debris, we are potentially encouraging corrosion. As a result, following the dynamic flush, some form of chemical clean is usually essential to remove corrosion products from the surfaces of steel pipes.

Corrosion process potentially controllable

In theory, once the system is put into operation, the corrosion process should be controllable. If there is no replacement of the water in the system, the oxygen in the water should gradually become depleted,



Pseudomonas spp biofilm development on surfaces of pipework.

Corrosion pits associated with microbially influenced corrosion.

thereby stifling the corrosion. Furthermore, corrosion inhibitor chemicals can be added to further reduce the rate of corrosion.

However, corrosion protection regimes can go wrong, and water quality monitoring is therefore essential. For example, whenever water is lost from a system – whether due to system modification, or when replacing a component – fresh oxygenated water is drawn in, while water containing valuable corrosion inhibitor is lost. This combination can be sufficient to initiate a burst of corrosion.

Furthermore, inhibitor levels can drop even without water being taken out of the system. The active ingredients of inhibitors can be used up in developing protective layers on pipes, or via reacting with oxygen in the water. However, even more shocking is the realisation that some inhibitors can provide a food source for bacteria – and not just any bacteria. The bacteria we can find in closed systems can initiate catastrophic damage on a scale equal to, or worse than, that caused by simple debris or oxygen-induced corrosion.

Many types of bacteria present

All natural sources of water (including mains water) contain many different types of bacteria, some of which may multiply and lead to problems within closed systems if they encounter suitable conditions for growth. Mild steel, stainless steel, and copper, are thought to be particularly prone to microbial-influenced corrosion (MIC). For MIC to occur, it is necessary for some types of bacterial species to colonise the metal surface. The extracellular material produced by rapidly multiplying aerobic bacteria species, e.g. *Pseudomonas spp*, develops into a biofilm (i.e. slime), which produces both aerobic and anaerobic zones.

The anaerobic conditions enable anaerobic bacteria such as sulphate-reducing bacteria (SRB) to multiply, and a potential difference is established between different areas of the metal surface. SRB metabolise naturally occurring sulphate in the water to produce sulphuric acid under bacterial clumps. This results in accelerated, localised pitting corrosion, and eventual perforation of the pipe. Corrosion by SRB can cause significant damage to surfaces, in particular where pipework may have bends, uneven surfaces, abrasions, or joints and welds.

Increasing electrolytic corrosion risk

Other bacteria of concern are nitrate/nitrite-reducing (NRB), and nitrite oxidising bacteria. These bacteria can cause rapid loss of nitrite-based corrosion inhibitor from the system, and thus increase the risk of electrolytic corrosion. Equally, the ammonia produced by some of these bacteria when metabolising nitrite can lead to stress corrosion cracking of brass fittings if present at significant levels.

During the pre-commission cleaning stage of any new build, it is important to prevent microbial presence wherever possible, and to avoid areas of low flow rate or deadlegs where bacteria can multiply, settle, and develop biofilms unhindered by circulating biocide chemicals.

> Some modern control valves have clearances of less than half a millimetre. This means that sand, grit, jointing material, or welding slag, can cause blockages and consequent heating or cooling dead spots

About the authors

Dr Pamela Simpson

Dr Pamela Simpson is a Chartered Fellow of the Society of Biology. She established Whitewater Technologies in 1998, before which she spent over eight years working in the speciality chemicals industry, initially as a technical and European director of the Industrial Biocides Division of a major chemicals manufacturing and processing company.

She has developed a broad knowledge of the application of microbial control techniques in product preservation and antimicrobial surface protection, process water control, and microbial issues within hot and cold closed systems for both healthcare new-builds and commercial premises. She is also an approved trainer for *Legionella* awareness courses for water treatment engineers.

Her recent work involved expert work for microbially-influenced corrosion in a range of commercial and healthcare buildings of hot and cold closed systems. She was on the Steering Group for the writing of BSRIA BG50/2013: *Water treatment for closed heating and cooling systems.*

Chris Parsloe

Chris Parsloe is joint author of the BSRIA guide, BG29/2012: *Pre-commission cleaning of water systems.* Whilst working at BSRIA, he was responsible for writing application guides on pipe system design, commissioning, and pre-commission cleaning. Having produced the first edition of the BSRIA pre-commission cleaning guide in 1989, he was the sole author of three subsequent revisions until 2001, when he left to start a new venture.

Drawing on input from experienced water treatment specialists, BSRIA guide BG29/2012 provides best practice recommendations on how to flush and clean chemically closed pipework systems. It also provides criteria for assessing the post-clean water quality.

Chris Parsloe's background is as a building services design engineer. He has a degree in Building (Engineering and Management), and is a Fellow of the CIBSE. In 2003 he set up his own consultancy, Parsloe Consulting Ltd. He is regularly involved in troubleshooting and expert witness work, and is a recognised authority on pipe system cleaning.

Under the 'banner', Parsloe-Simpson, he collaborates with Dr Pam Simpson, together with corrosion specialists and water treatment chemists, to offer a complete water quality consultancy and investigation service.

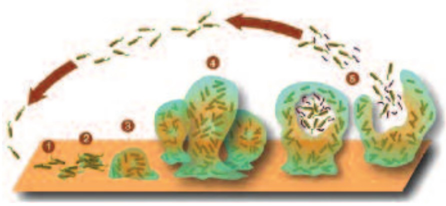
Biocide wash

For many systems, the precaution of a 'biocide wash' is included as part of the pre-commission cleaning process. This involves circulating a biofilm-disrupting chemical through the system to destroy any biofilms that may have developed during the construction process.

Bacteria-related problems, and their potential to incur major costs for the system owner, should never be forgotten or underestimated. As an overriding principle it should be remembered that it is much, much easier and cheaper to maintain microbiological control within a closed heating and cooling system than to clean up a badly fouled system containing biofilm.

Microbiological control can be achieved by:

- Ensuring that the system is free of suspended solids and debris which may be utilised by bacteria as an energy source.
- Carefully managing biocide dosing, and maintaining records of the treatment efficacy.
- Regularly monitoring and sampling the system water content in a correct fashion (refer to BS 8552:2012: *Sampling and monitoring of water from building services closed systems. Code of practice).*
- Maintaining good flow around the system to ensure that biocide treatments are properly circulated.



The formation process of a microbial biofilm.

Scale, biofilm, and corrosion deposits within pipework.

Corrosion pit and subsequent leaking pipework.

Using an appropriately qualified contractor

It can be seen that pre-commission cleaning and ongoing monitoring of water quality incur too many potential pitfalls to be left to installing or building maintenance contractors. It is usually essential that a properly qualified pre-commission cleaning or water treatment specialist contractor is involved in these activities. BSRIA Guides BG29/2012: *Pre-commission cleaning of water systems, and BG 50/2013: Water treatment for closed heating and cooling systems* provide an explanation of the procedures, tests, and monitoring regimes, that need to be adopted. However, proper implementation of this guidance requires an organisation that can draw on expertise across a range of specialisms, including pipe system design, pre-commission cleaning, water treatment chemistry, corrosion, and microbiology. This is essential if monitoring is to be carried out at appropriate intervals, and the results interpreted in a way that identifies potential risks as soon as they occur, so that any necessary remedial actions can be taken before things get out of hand. ✚

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