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BULLETIN #3
CHILLER AND CLOSED-CIRCUIT BACTERIA AND BIOFILM CONSIDERATIONS- THE EFFECT, COST AND CONSEQUENCES

WHY ARE BACTERIA AND BIOFOULING AN ISSUE FOR CLOSED CIRCUITS?

This paper starts with direct quotes from two of the UK's leading organisations in construction and building services. These quotes send a real message as to why it is so vitally important that we can start to understand how critical control of bacteria and biofilm is in closed circuits:

BSRIA guide - Water Treatment for Closed Heating and Cooling Systems

"The treatment of water in modern closed heating and cooling systems is essential for the avoidance of microbiological fouling (biofouling), corrosion and scale. These problems can result in energy wastage, poor system performance, and the need for early replacement of plant and components. **The consequences of inappropriate or non-existent water treatment can sometimes be disastrous.**"

Indeed, during the late 1990s, some bacteria (particularly Pseudomonas) were linked to a series of damaging contamination problems. "It is much easier and more cost-effective to maintain microbiological control within a closed heating and cooling system than to clean up a badly fouled system containing the heavy build-up of biofilm". – BSRIA BG29/ 2012.

CIBSE in reference to the BSRIA guidance above goes on to state:

"The objectives of a water treatment programme are to maintain the **system efficiency and cleanliness and prolong system life**".

The symptoms of microbiological fouling included blockages at valves and strainers, sludge formation, and severe gassing affecting flow measurements and commissioning results.

We all have a level of understanding as to what bacteria are; that they are ubiquitous, and we typically associate such things with living creatures and the effect we associate they have on them. To start understanding how bacteria can compromise closed circuits, we first need to understand what bacteria are to then be able to control their behaviour.

Bacteria are microscopic single-celled organisms and as such can live without a host, they can generate energy and make their own food, move freely and have the ability to reproduce themselves (binary fission) capable of doubling every 20 minutes. This set of attributes and what is key here allows bacteria to live in a multitude of environments: soil, water, plants and other living beings. It should be noted here that less than 1% of bacteria cause diseases in humans.

We can split bacteria into two simple groups: Hereterotropic Bacteria and Autotrophic Bacteria.

HERETEROTROPIC BACTERIA

The group we need to focus on when considering controlling bacteriological activity is the Hereterotropic group as they include yeast, and moulds as well as bacteria in their categorisation. The main reason we need to consider this group primarily is their ability to use organic carbon as food (as opposed to autotrophs as they rely on sunlight for theirs (photosynthesis)). Finally, we do need to further understand how bacteria respirate as this is key in the creation of biofilm and the damaging effect they can bring.

Here we can split groups into Aerobic Bacteria (requiring oxygen presence) and Anaerobic Bacteria (absence of oxygen (Hererotrophic bacteria).

These two respiratory processes follow as aerobic bacteria (typically *pseudomonas) colonise pipework surfaces and proliferate those parts of the system where dissolved oxygen is found. Once *pseudomonas starts to cover an area of pipework depleted oxygen level manifests; anaerobic bacteria, (which include such influential bacteria as Nitrite Reducing Bacteria (NRB) and Sulphite Reducing Bacteria (SRB)) themselves become a threat to pipework infrastructure where they can thrive. These bacteria are further discussed below in the section Biofilm and Pipework Failure.

BIOFILM

We can now consider the behaviour of these bacteria in our closed system circuits. The most common process bacteria undertake is the production of biofilm. As we understand the ubiquitous nature of bacteria, we need to make assumptions that there is every likelihood that a number of bacteria are going to be introduced into our water systems including closed system circuits. Once introduced one of the most common bacteria that is likely to be introduced is a group of bacteria called Pseudomonads which are cited as initiating most biofilms identified within closed systems. There is no evidence to confirm that Pseudomonas is directly responsible for the issues listed in the sections below – other bacteria may be to blame. However, it has been found that where levels of Pseudomonas-like bacteria (pseudomonads) are high, the risk of these problems is increased. Pseudomonad levels are, therefore, increasingly used as an indicator of the biological quality of system water.

Such bacteria adhere to pipe walls and create a protective layer of 'slime' (Extracellular Polymeric Substances (EPSs) composed mainly of polysaccharides)) or biofilm as seen in Fig 1 below.

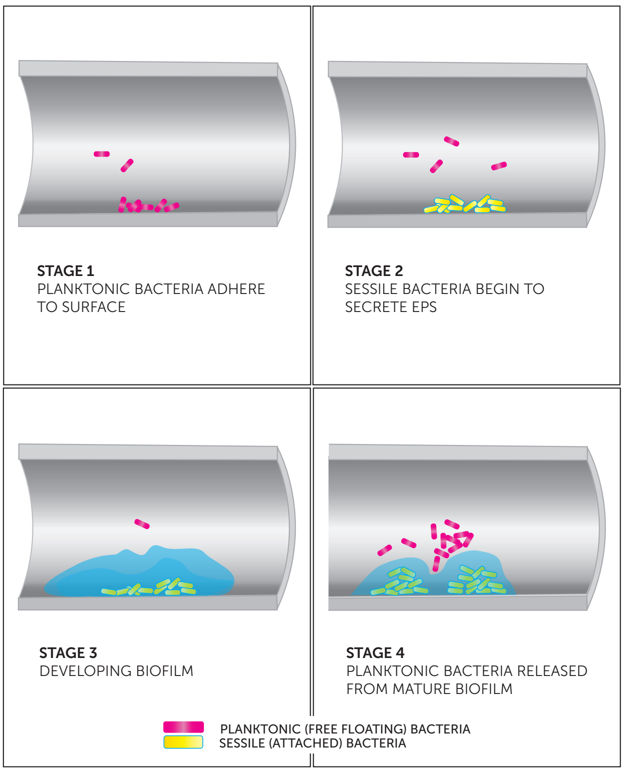

Fig 1

Note: Pseudomonads are more likely to grow in chilled water systems where no biocide has been dosed and can significantly reduce the efficiency of the cooling coil. Pseudomonads along with other species known as Psychrophiles actually prefer cooler waters at 0°C and below, hence here at ICS controlling and treating their presence we see as so important in the systems we manage. From the growth profile above (fig.2.) we can see the vast spread of bacteria groups and their various growth profile in different temperature settings. BSRIA BG 50/2021 states "All systems are therefore at risk of biofouling and should not be operated without the presence of a biocide".

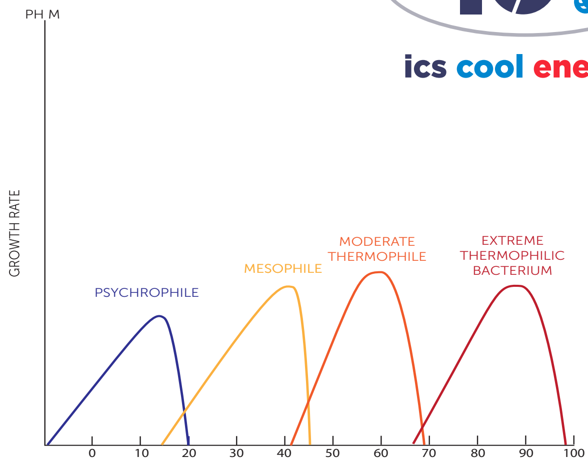

Fig 2

Such biofilms can harbour and allow to growth a multitude of numerous individual micro-organisms as well as capturing system debris. The challenge here is that Pseudomonads had been considered an aerobic organism, however, recent studies have shown that we are dealing with a highly adaptive bacteria that can also survive without the presence of oxygen. With a build-up of biofilm which can be rapid (given all the right conditions) we can expect a number of costly issues to occur:

1. REDUCTION IN EFFICIENCY

Biofilm is recognised as a thermal insulator; consider it similar to scale. However, the effect of biofilm versus scale is dramatic, having a fourfold increase; in simple terms 1 mm of biofilm is equivalent to having 4mm of scale on heat transfer surface, with that the impact of approximately 4mm of scale increases fuel costs up to circa 50%.

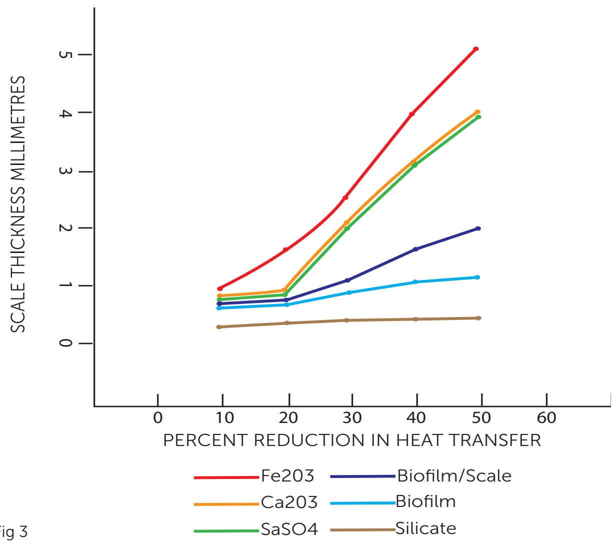

Fig 3

As with any insulation material present, when a process's basic function is to 'lose' heat, any disturbance to that process means a loss of performance and with that additional energy is needed to counter the thermal retention. This is why it is critical for the management of running an efficient system so that closed system circuits are protected from the formation and growth of biofilms and avoidable increases in energy costs. The illustration above (fig.3.) clearly highlights the significant impact the presence of biofilm has on the process of heat exchange against other recognised insulators.

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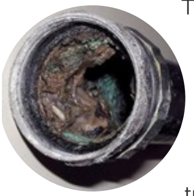
2. FLOW RESTRICTIONS



The formation of biofilms can become several millimetres thick and as a result (particularly in microbore pipework) significate compromise of flow rates; that is the ability to pass liquid in a system over a set period. This in turn affects the overall efficiency of a system and requires circulating pumps to increase their turnover (increasing energy costs) to be able to match the designed rates of flow. Further costly issues surrounding the impact on flow rates (due to biofilm ingress) are observed within strainers and control valves. Once biofilm(s) are allowed to become established within a closed system their removal is labour-intensive, time-consuming and costly.

Top: Established biofilm and trapped debris
Above: Restrictive effect of slime (biofilm) build up

3. BIOFILM AND PIPEWORK FAILURE

The three pathways that biofilm and associated bacteria are seen to manifest corrosion in closed systems, which then leads to reduced performance and often premature system failure are:

- As biofilm smothers the pipework surface, the creation of an aeration cell is established.
- Many of the biofilm-held bacteria secrete by-products (organic acids, hydrogen sulphide, ammonia etc) which then directly attack metal surfaces.
- Certain bacteria have a direct effect on chemical inhibitors and their stability, thus the inhibitor is nullified and with that dramatically reduces their protective function within the system.

4. SPECIFIC DETRIMENTAL BACTERIA

Nitrite Reducing Bacteria – Nitrite is the main component of one of the most commonly used corrosion inhibitors for closed systems found in the water treatment market. Nitrite-based inhibitors are seen as a cost-effective way to protect closed circuits from electrolytic corrosion. However, the presence of NRBs leads to the nitrite component being broken down as NRB uses nitrite as an energy source, digesting it using the various enzymes it possesses. Due to the susceptibility to NRBs, it is therefore vital that should nitrite be a component of the water treatment inhibitor chemistry programme both microbiological, as well as water chemistry are regularly tested. Note: Some species of Pseudomonads are classed as NRBs therefore among these as having the potential to break down nitrite chemistry.

Sulphite Reducing Bacteria – Unlike NRBs where the reduction of inhibitor chemistry is seen; SRBs metabolise sulphur found in water as their source of energy, and with that resulting hydrogen sulphide is produced in large quantities which in turn directly attacks iron, steel brass and copper. It's to be noted that the presence of SRBs will also have albeit to a lesser effect on nitrite levels should it be used to protect the system.

Above: Pitting effect of SRB on pipework

ICS Cool Energy has covered the biological and chemical processes in Bulletin #1 document: Chiller & Closed-Circuit Corrosion where the effect of biofilm build-up, NRB and SRB are discussed in relation to corrosion.

In summary the main problematic micro-organisms found in closed circuit systems are bacteria, which can lead to the rapid build-up of biofilms in pipework and on heat exchanger surfaces causing a reduction in efficiency, flow restrictions and under-deposit corrosion.

THE SOLUTION TO BACTERIA AND ASSOCIATED BIOFILM: TREATMENT AND TESTING

As this paper has highlighted the potentially damaging and costly presence of biofilm (and bacteria) in closed circuits if not addressed. Evaluating the status of both protective chemistry and microbiological presence is fundamental to help ensure we have clean, efficient and protected systems, anything other is going to be costly. This is why proactive testing and where required appropriate corrective treatment are undertaken.

ICS Cool Energy follows all the latest standards and guidance helping to ensure best practices are assured. These best practices include, but are not limited to:

- The regular screening for closed system bacteria that have a direct impact on system performance
- Understanding the water source makeup so that the selection of appropriate chemical inhibitors can be made
- Being able to offer a wide and varied range of biocides for a specific use, not only to help protect against microbiological attack (maintenance dose biocide) but should it be required applying a targeted biocidal flush (known as shock dosing) to help clear out established bacteria and biofilms.

The issues that this paper has emphasised can all be avoided by deploying the correct water monitoring schedule and chemical programme.

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