

**CSCA 1<sup>st</sup> Technical Round Table Meeting,  
Tuesday 27th November 2018**



**Held at Fazeley**

**Topic:  
Oxygen & Corrosion in Closed Heating/Cooling Water Systems**

Present:  
John Smith (Chair) (JSS)  
Phillip Munn (PM)  
Alan Edwards (AJE)

Dannielle Tudor (CSCA Secretariat)

Apologies:  
Matt Morse

Circulation:  
CSCA Management Committee

**Topic for Discussion:**

- Oxygen and Corrosion in Closed Water Systems.

**Question (to PM):** Do you accept that in the presence of a high level of dissolved oxygen as (for example) in evaporative cooling towers circuits, chemical corrosion inhibitors successfully minimise corrosion on metal surfaces, by imparting an inhibitor film which acts by shielding the metal from the oxygenated water.

**Answer (by PM):** Yes

**Question (to PM):** Then why are you so concerned about excluding oxygen from closed water systems?

**Answer (by PM):** Because a properly designed closed water system will operate with low levels of dissolved oxygen to the extent that corrosion will be minimal, even without the addition of a chemical corrosion inhibitor.

**Question (to PM):** What do you mean by 'low levels'?

**Answer (by PM):** Typically, less than 100ppb, preferably less than 50ppb.

**Question (to PM):** Are such low levels practical?

**Answer (by PM):** Absolutely, and quite typical.

**Question (to PM):** In that case, are you saying that there is no need to apply a chemical corrosion inhibitor when the system water oxygen levels are low?

**Answer (by PM):** In theory there should be no need for chemicals, but I would say that there is a good case for their inclusion as part of the routine treatment programme, as a 'belt and braces'. However, if inadequately monitored, chemicals can cause problems due to the potential for them to be bio-degraded or if the concentration fall below critical levels to maintain passivation

**Question (to PM):** For example?

**Answer:** For example; the use of nitrate, a widely used components of many inhibitor formulations, can stimulate the development of nitrate -reducing bacteria (NRBs) which tend to reduce the nitrate to ammonia. (inhibitors containing nitrates should only be contemplated when aluminium is present, as they are ineffective with steel)

Ammonia will attack copper; dissolved copper can migrate and plate out onto steel or aluminium, creating a galvanic corrosion cell, to the detriment of either the steel or the aluminium. This process can be particularly severe in the case of copper/aluminium.

**JSS Comment:** Agreed Nitrate is specific for Aluminium, however Nitrite a commonly used inhibitor can also provide for NRB development. (PM Agreed)

**Question (to PM):** What would you say is a 'significant' level of ammonia in this context?

**Answer (by PM):** I don't know for sure but my guess is anything above around 5ppm as NH<sub>3</sub>-N.

**JSS Comment:** If we are going to reference a figure we need to explain where it comes from. Is there any reference to NH<sub>3</sub>/NH<sub>4</sub> levels anywhere i.e. ASTM G37, ISBN: 978-1-62708-118-4. Phil do you have access to these?

**PM Comment:** These both pertain to SCC of brasses. I agree that SCC of brasses is not likely to occur until much higher levels of ammonia are reached. My concern is more with the corrosion of copper which does not have any significant adverse effect on copper pipework but indirectly causes corrosion of more active metals, esp. aluminium.

AJE Comment: Yes – it would be useful to know if any authoritative guides give a lower figure than 40 ppm.

**Statement:** - but the BSRIA BG50 guide indicates that “up to 40ppm of ammonia” can be tolerated (BG50 page 72; note 25)

**Statement (by PM):** I find that figure surprisingly high as in my experience copper corrosion has occurred at much lower ammonia levels – I have in fact said as much to BSRIA and I’m sure the point will be addressed/amended in the forthcoming revision of BG50.

To give more detail - Ammonia will react with copper to form the cupro-ammonium complex, even in the absence of oxygen. This complex will break down and result in electro deposition of metallic copper on aluminium and steel. This in turn results in localised galvanic corrosion occurring between the copper cathode and aluminium anode causing localised pitting attack. In a closed system, copper ions will continually be removed from the water by electrodeposition and then replaced by further action of ammonia on copper pipework. The ammonia continues to be produced by the action of NRB on nitrite/nitrate. Therefore, the whole process is cyclic.

One could certainly argue about the amount of ammonia needed to kick start this process. However, ammonia is never a good thing to have in a closed system and we should be seeking to avoid having it in any amount in the first place. Therefore, if nitrate/nitrite inhibitors are used, one should regularly monitor for NRB and treat with biocides if necessary.

**JSS Comment:** Do not wait until bacteria proliferate, add biocide with initial fill & inhibitor to minimise bio problems. Once commenced it can be more difficult to control.  
(PM Agreed)

**Question (to PM):** As things are not always perfect it may well occur that some system waters will be carrying higher levels of dissolved oxygen -induced corrosion. In such cases would the diligent application of a chemical inhibitor be expected to minimise corrosion.

**Answer (by PM):** Yes, but that should not provide an excuse to not investigate and eliminate the source of the oxygen ingress.

**Statement (by PM):** To be honest, in my experience many of the failures that occur in closed water systems are due to inadequate protection in the early life of the system. This is particularly the case with systems fabricated of thin-walled carbon steel pipework.

**Discussion:** Of this point produced the following scenario:

1. Thin-walled carbon steel is typically supplied with an inner protective coating of an elasto-polymeric material. This protective coating is classed as ‘temporary’ and is designed to protect the metal during transit to the construction site.
2. The system is initially filled with water in order to allow hydraulic pressure testing. Typically, this water is then left in the system until pre-commission cleaning is applied – a period of

(possibly) several weeks or even months.

3. During this wet/static period unless the fill water has been adequately dosed with an effective chemical corrosion inhibitor then the 'protective coating' begins to deteriorate. PM remarked that in laboratory simulations of these conditions active corrosion sites can appear after only a day or so.
4. This evidences that at these 'weak points' corrosion processes can be initiated prior to the pre-commission clean.
5. Applying the 'classical' pre-commission clean typically involves a cleaning stage which may be a simple flushing but normally employs an 'aggressive' cleaning agent, which causes further deterioration of the protective coating, but which may not passivate the corrosion sites.
6. Following the chemical cleaning stage of a conventional pre-commission cleaning operation the system is subjected to extensive flushing to remove debris. This flushing is typically carried out with untreated mains water, which (of course) is well oxygenated.

Stage 6 thereby provides the conditions which can cause further development of these active corrosion sites.

7. Finally, the routine inhibitor treatment is applied but this will not necessarily passivate the corrosion sites or clean off the corrosion nodules beneath which microbiologically-induced corrosion (MIC) may have started, leading eventually to perforation of the pipework ('pin-holing').

**Question (to PM):** Given the above scenario, how would you recommend that such systems be cleaned?

**Answer (by PM):** Well obviously, the fill water used for hydraulic pressure testing should be treated both with a chemical corrosion inhibitor and a biocide and these chemicals should be maintained at active levels during the subsequent idle period. Secondly; consider that it may not always be necessary to employ an aggressive chemical cleaner – a simple mild dispersant at the chemical cleaning stage would be less likely to affect the 'temporary' protective coating. Note that the worst one could do would be to fill a system with untreated water and then leave it drained down for a considerable time. This would create a metal/water/air interface where pitting attack would occur.

**Post meeting comment (AJE/JSS) –** The existence of the protective coating in the initially supplied pipework presents a potential hazard; as follows:

If the coating was to be 'quite durable' (and heat -stable if used in hot water systems) then it should only be necessary to water flush at the pre-commission cleaning stage. However, as the coating is designed to provide only 'temporary protection' it can be argued that a cleaning agent which would be 'aggressive' enough to strip it completely would be beneficial, in that it could produce an even clean metal surface without the same potential for localised corrosion attack.

The probability is that even with an 'aggressive' chemical cleaning agent the protective coating would be removed only gradually, leaving the potential for anodic/cathodic areas to be established. Under these circumstances it becomes important to a) exclude oxygen as far as is practicable and b) apply a supplementary inhibitor /biocide programme and monitor the water quality regularly, adjusting as required to maintain the specified water analysis.

**Conclusion:** The main points of agreement were:

- If dissolved oxygen levels can be maintained at (say) less than 100 ppb corrosion of system metallurgy would be so minimal that a supplementary chemical corrosion inhibitor should not be required.

- However, in view of the fact that chemical inhibitor films will successfully minimise corrosion, even in the presence of oxygen, their use is justifiable as an additional precaution. Also, the use of a biocide is justifiable in order to minimise the potential for the creation of biofilms which would otherwise interfere with the action of chemical corrosion inhibitor films, or initiate MIC.
- The presence of the 'temporary protective coating' within new thin-walled carbon steel pipework is a cause for concern. Discussion with the pipework suppliers may be useful.