Saving Energy, Improving System Longevity & Optimising Performance: how to achieve this complex balance when dealing with commercial heating systems

CIBSE  FERNOX
Commercial Heating: a changing environment

• There are currently many factors that affect the efficiency of a commercial heating system – not least regulations and improvements in design and control systems.
Commercial Heating: a changing environment

- Regulations / Guidelines
- Building Regulations
- Energy Related Products Directive - ERP
- Atmospheric boilers - Condensing boilers
- Zoning & controls
- Valves / TRVs
- Weather compensation / Overall design of the whole system
- Brand new systems versus refurbishment (practical and cost considerations)
- Primary / secondary systems
Commercial Heating: a changing environment

• These factors and considerations contribute to the final design efficiency of the whole heating system.

• As a water treatment company we do not really influence the original physical system.

• Starting with the correct and optimum system water condition and maintaining it, will significantly help to maintain the original design efficiency and reduce down time and repair costs—chemical & physical water treatment can help achieve this aim.

• On a new build or refurbished system it is critical and much easier to implement with advance planning—factor water treatment into the planning—Eliminate problems due to Corrosion / Corrosion products and Scaling.
Risk factors

• Commercial systems due to their very nature are often high profile, any failure / inefficiency affects many people and can have a critical impact e.g. hospitals, care homes, very cold locations & lost manufacturing time.

• Often systems may have to operate with minimal or no down time scheduled

• What can be done to claw back lost efficiency and keep the system running - by avoiding unplanned down time?
Light Commercial systems

- Scale
- Corrosion
- pH control
- Magnetite - product of corrosion
- Oxygen ingress
- Biological fouling / biologically induced corrosion
- Testing the system water
- Cleaning options
- Inhibition / protection
- Filtration: a cleaning method
Scale

- Scale causes heat transfer issues, it precipitates out on hot surfaces - typically heat exchangers, reducing the heat transfer efficiency and may limit flow in critical areas.

- Sometimes the surface may get superheated and bubbles initiated on the heat exchanger’s surface become very large and create noise - overall efficiency is lost.

- Hard scale may break off in larger lumps and circulate around the system finally causing a problem in another area.
Scaling in 350 ppm hard water

350 ppm hardness WITH Protector F1

350 ppm hardness WITHOUT Protector F1
Scaling in 1000ppm hard water

1000 ppm hardness **WITH** Protector F1

1000 ppm hardness **WITHOUT** Protector F1
How Do Antiscalants Work?

- Antiscalant molecules bind and distort calcium carbonate and magnesium carbonate formations

- Less limescale is formed; and it’s less compact

- Antiscalants can help Ca and Mg ions remain in solution
How Do Acidic Cleaners Work?

- **Acid** dissolves limescale (CaCO₃/MgCO₃) by reacting with it and forming calcium/magnesium salts that are soluble in water.

- The system is then drained and the metal salts removed.

- Note safer acid based chemicals are ones using weaker organic acids for e.g. Citric Acid.
Corrosion in heating systems
The graph shows how corrosive water can be, especially for mild steel.
Inhibitor corrosion levels should comfortably surpass BuildCert limits.
In the case of accidental under dosing, good protection may still be provided.
However, concentration should be checked with a suitable test kit.
Corrosion in aqueous solution due to Flux residues

<table>
<thead>
<tr>
<th>FLUX</th>
<th>Water</th>
<th>Conditions</th>
<th>Copper</th>
<th>Brass</th>
<th>M. Steel</th>
<th>Aluminium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flux 1</td>
<td>Hard</td>
<td>Natural Aerated</td>
<td>0.0809</td>
<td>0.0204</td>
<td>0.4935</td>
<td>1.1924</td>
</tr>
<tr>
<td>Flux 2</td>
<td>Hard</td>
<td>Natural Aerated</td>
<td>0.0296</td>
<td>0.0357</td>
<td>0.4138</td>
<td>0.1534</td>
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<tr>
<td>Flux 3</td>
<td>Hard</td>
<td>Natural Aerated</td>
<td>0.0517</td>
<td>0.1526</td>
<td>1.1311</td>
<td>1.2255</td>
</tr>
<tr>
<td>Flux 4</td>
<td>Hard</td>
<td>Natural Aeration</td>
<td>0.2388</td>
<td>0.3010</td>
<td>1.2767</td>
<td>2.4600</td>
</tr>
<tr>
<td>BLANK</td>
<td>Hard</td>
<td>Natural Aerated</td>
<td>0.0084</td>
<td>0.0144</td>
<td>0.1962</td>
<td>0.1266</td>
</tr>
</tbody>
</table>

- Equivalent levels of flux were used
- Test shows that fluxes cause more corrosion than water (blank)
- Flux 2 has the lowest corrosion, particularly with aluminium – important as aluminium heat exchangers can be at risk of failure (due to corrosion) in modern condensing boilers
pH control & buffering

• Different metals are more robust in certain pH levels
• For example Aluminium tends to corrode in higher pH environments (Alkaline). Pitting can develop into full blown corrosion. Hence a maximum pH of around 8.5 should be maintained.
• However mild steel is generally more stable in a higher pH environment and with a lower pH - below the neutral point 7 corrosion can begin
• Fernox inhibitors are designed to control corrosion in the mid- neutral range so are ideal in mixed metal systems
• Extremes of pH –Low / High are to be avoided for all metals.
A graph to show buffering

-0.1M NaOH Used (mL) / +0.1 M HCl Used (mL)
Aluminium corrosion against pH

Limescale solubility against pH
Magnetite  - Magnetic Iron Oxide

• Magnetite is a corrosion product of steel
• Hydrogen gas is also given off
• Magnetite settles in low flow areas
• It blocks heat exchangers
• It can cause extensive damage to circulating pumps
• Valves of all descriptions can be damaged causing faulty operation / sticking
• Fine / smaller water ways in condensing boilers are susceptible to blocking
• Magnetite combined with scale (baked on) is very hard to remove and can be abrasive
Heat exchangers & Circulation pumps

- Heat exchangers can make great filters!
- The waterways are small to ensure efficient heat transfer
- Magnetite in a system can block/partially block these waterways
- Reduces heat transfer efficiency
- Reduces flow - potential pressure drop issue
- Pumps can be affected by magnetite blocking small waterways around magnetic rotors/cores
Magnetite in a circulating pump
Heat Exchangers

- The small waterways which give a good heat transfer efficiency can be blocked by magnetite.
The impact of magnetite

• Magnetite is generally abrasive and in areas of high flow, where there are bends in pipework, erosion can be accelerated
• Fernox conducted a study on magnetite generation. It was found that magnetite in suspension accelerated the corrosion rate.
• Often metals can form a relatively stable oxide which slows down further corrosion. If this layer is eroded then a new surface is laid bare to corrode at a faster rate.
• Therefore eliminating the magnetite stops wear / blockages but also slows down corrosion hence the use of a filter is highly recommended.
Oxygen ingress

• We have discussed how magnetite causes many problems all of which can reduce the efficiency of the system and cause premature breakdown

• Oxygen ingress is to be avoided as this aids corrosion

• The colour of the water and corrosion product is predominantly rusty red
Biological fouling

- Mains water should be free from contaminants but borehole water may require pre-treatment for use

- Common problems are caused by:
  - Sulphate reducing bacteria (SRB)
  - Nitrite reducing bacteria
  - Pseudomonads

- Factors promoting growth of bacteria and MIC
  - pH: 6-9 is favoured which is also the range needed for corrosion protection
  - Temperature: 15-40 C – underfloor heating, summer shut down, stagnation
  - Nutrients: Some chemical inhibitors (i.e., nitrite, nitrate, phosphate) can promote growth
  - Dirt and debris reduce the effectiveness of biocides
Biological Induced corrosion

Corrosion by SRB’s:

- Oxygen depletion corrosion – differential oxygen content between the area below biofilm and the surroundings leads to electrolytic corrosion in depleted regions
- SRB’s reduce sulphate from the fill water to metal sulphides as corrosion products
- Essential nutrients for SRB’s include sulphate, phosphorous nitrate. Limiting nutrients can help control MIC

Nitrate/Nitrite reducing bacteria:

- Metabolism of NO₂/ NO₃ by bacteria may result in formation of corrosion causing ammonia (NH₃)
- Ammonia may attack copper and cause stress corrosion cracking of brass
Biocide

- Prevents **bacterial contamination** in heating systems and chilled water systems.

- Prevents reoccurrence of jelly-like deposits (fungal) in cisterns.

- Spot corrosion can take place under biological fouling.

- Eliminates gas produced by fermentation.

- Must be used in conjunction with inhibitors.

- Leave in the system permanently.

- Repeat applications may be required.
Standards underpinning commercial system maintenance

- EN14868:2005 – defines corrosion risks
- VDI 3035:2005 – scale & corrosion control (G)
- BSRIA BG50/2013 – WT for closed systems
- BS 8552:2012 – sampling & testing
Testing the system water

• There is a need to check the state of the system
• What is the water quality like? The pH - dissolved solids and suspended particles (debris)
• This is easily done with a professional sampling method - the water can be analysed using a System Water Health Check
• A full report is given explaining the system water quality
• Actions can be taken if the system water is not good enough
• A free test kit will be given to all delegates to use on a system of your choice
Action time after the System Health Check

• So what actions can be taken to restore design efficiency.

• In the Domestic Heating arena Fernox has shown that on sludged systems having a loss in efficiency, by thoroughly cleaning and flushing the system, and adding an inhibitor to stop further corrosion, the efficiency was significantly improved /restored close to its original state.

• In many ways, a parallel can be drawn to Light commercial systems.
Table 2 Recommended minimum standards for efficiency, system circulation, hot water storage, system preparation and commissioning for gas-fired wet central heating systems (continued)

<table>
<thead>
<tr>
<th>Minimum standard</th>
<th>Supplementary information</th>
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<tbody>
<tr>
<td>4.0 System preparation and water treatment</td>
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<tr>
<td>a. Central heating systems should be thoroughly cleaned and flushed out before installing a new boiler.</td>
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<tr>
<td>b. During final filling of the system, a chemical water treatment inhibitor meeting the manufacturer’s specification or other appropriate standard should be added to the primary circuit to control corrosion and the formation of scale and sludge.</td>
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<tr>
<td>c. Installers should also refer to the boiler manufacturer’s installation instructions for appropriate treatment products and special requirements for individual boiler models.</td>
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<tr>
<td>d. Where the mains total water hardness exceeds 200 parts per million, provision should be made to treat the feed water to water heaters and the hot water circuit of combination boilers to reduce the rate of accumulation of limescale.</td>
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<tr>
<td>e. For solar thermal systems, see Section 11.</td>
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</tbody>
</table>

Inhibitors should be BuildCert approved or equivalent.

Limescale can be controlled by the use of chemical limescale inhibitors, combined corrosion and limescale inhibitors, polyphosphate dosing, electrolytic scale reducers or water softeners. The relevant standard for water treatment is BS 7593:2006 Code of practice for treatment of water in domestic hot water central heating systems. BS 7593 notes that “naturally soft waters of low alkalinity or those supplied via a base-exchange resin softener have an increased potential for corrosion, and, if they are used in any central heating system, a corrosion inhibitor specifically formulated for the purpose should be added and properly maintained.” Manufacturers should be consulted for advice, paying particular attention to dosage levels.

Special radiator valves are available that will seal off the radiator as well as the heating circuit to prevent loss of inhibitor when removing a radiator for service or maintenance. A filter can also be fitted to the central heating circuit to help maintain the efficiency and reliability of the system.

Commercial Chemicals - Cleaners

• Pre-commission cleaning prior to inhibitor addition

• Contain corrosion and scale inhibitors, detergents, solubilising, dispersing and chelating agents

• Can be left in systems for up to 7 days (for heavily-contaminated systems)

• Work best in systems that can be fully drained

• Non-toxic, non-acidic and environmentally friendly
  (Discharge to drain – without neutralizer)

• Compatible with all common commercial metals and materials
How Do Detergent Cleaners Work?

- **Hydrophobic** (water-fearing) tails of detergents bind to debris/contaminants in water system.

- The detergents form a **micelle** (circle) around the contaminant.

- With the aid of the **hydrophilic** (water-loving) head, the contaminant is suspended/dissolved in the water and can be disposed of.
Corrosion Inhibitors / Protectors

• Multi-protection inhibition package comprising of inhibitors specialising in individual metals found in heating systems.

• Built-in pH buffering control – to combat rises in pH through corrosion

• Forms protective films and passive layers over heating system metals

• Antiscalant to disrupt and prevent limescale formation

• In-pack anti-microbial protection to keep the product sterile whilst on the shelf.

• Stop corrosion in the system by using an inhibitor
How Do Inhibitors Work?

• **Anodic inhibitors** – React with metal ions on the anode and create an insoluble protective film e.g. nitrates, molybdates.

• **Cathodic inhibitors** – Metals in the water react with water and form deposits on the cathode metal surface.

• **Organic inhibitors** – Absorb onto metal surfaces and provide a hydrophobic, protective film over the metal.
Antifreeze Protectors

- Combined antifreeze and inhibitor
- BuildCert, Kiwa, Belgaqua approvals
- Minimum of 25% concentration to standard inhibition protection. (Fernox)
- Frost protection levels:
  - 25% concentration, -11°C
  - 30% concentration, -15°C
  - 35% concentration, -18°C
  - 40% concentration, -22°C
- Most products are available in a range of sizes
- Know which glycol - understand disposal requirements
- Understand minimum dose to ensure corrosion protection
Filters

- There are a number of different types of filters available
- Some are just magnetic
- Some use mesh and settlement techniques
- Fernox has determined that Magnetic and Hydrocyclonic works well together giving a fast collection capability for both magnetic and non magnetic debris –this combination also gives a simplified cleaning method
- The installation of a filter device is strongly recommended particularly in an existing system where new equipment is to be installed.
Magnetic & Hydrocyclonic
Magnetic & Hydrocyclonic

Simulation Modelling
System status unknown

Check the quality of the system water using a comprehensive water test

Test confirms system is heavily contaminated and the water is in poor condition

Add a commercial cleaner - bring up to temperature and allow the cleaner to circulate

Test confirms system is clean and inhibitor levels are correct

NO ACTION

Fit a suitable filter

Dose the system with an inhibition product

Drain and flush the system

Test confirms system is clean and inhibitor levels are correct

How to clean up the system?

Test confirms system is lightly contaminated but the amount of down time the system can have is limited.

Fit a suitable filter
Refurbished system

Add a commercial cleaner - bring up to temperature and allow the cleaner to circulate

System breakdown
System with limited downtime

Fit a suitable filter

Dose the system with an inhibition product

Drain and flush the system
Maintaining & restoring energy efficiency

Summary

• Prevention better than cure
• Protect the system from the start
• Tools to understand what you have - System Health Checks
• Clean the system the best you can
• Ensure Inhibitor products are used
• Biocides as required
• Install a filter to catch any remaining debris
Thank you

ANY QUESTIONS?