Water Treatment in Commercial Heating Systems

CIBSE South East

15th September 2021

CPD Overview

Section 1

- Why water treatment is so critical
- Industry guidelines

Section 2

- Corrosion in closed heating systems
- Costs of poor water treatment and case study

Section 3

- The Impact of limescale
- Scale in secondary hot water systems
- Treating limescale and case study

Section 4

- Key actions to takeaway today

Section 1

The need for treatment and industry guidelines

Why water treatment is so critical.

- System issues are caused by a combination of:
  - water impurities
  - heat
  - different metals
  - The introduction of dissolved oxygen
- In closed heating systems these chemical reactions lead primarily to corrosion.
- In ‘once through’ heating or domestic hot/cold water systems or leaking closed systems, limescale becomes a major problem.

Corrosion:

Limescale:

Consequences of poor water treatment

- Reduced efficiency
- Increased energy costs.
- Environmental penalties (CO_2 emissions).
- Failures outside of warranty - Boiler manufacturer's warranties are now up to 10 Years and are linked to water quality.

Consequences of poor water treatment

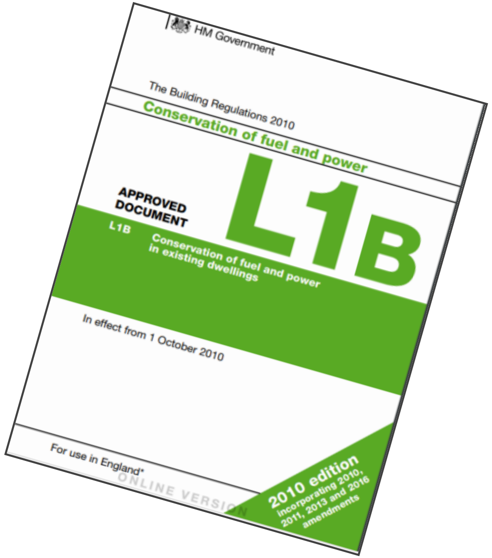
- Loss of efficiency
- System downtime.
- Complete boiler failure – even within just a few months of commissioning.
- Liability for remedial/replacement works and associated costs.
- Damage to reputation.

Industry Guidelines

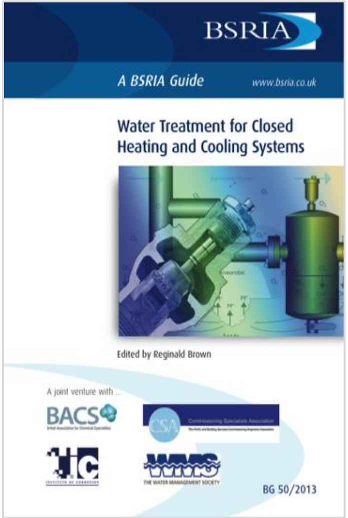
Water treatment guidelines in Part L

"Central heating systems should be thoroughly cleaned and flushed out before installing a new boiler."

"...a chemical water treatment formulation should be added to the primary circuit to control corrosion and the formation of scale and sludge."



Water treatment guidelines in BSRIA



"…cleaning is achieved through a process of flushing and chemical cleaning (where required) followed by the addition of biocides and inhibitors."

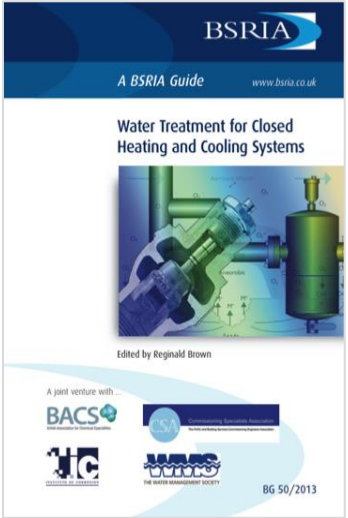
"The success of …cleaning is inferred from water samples that are analysed for a range of parameters including suspended solids, iron and bacteria."

BSRIA *Water Treatment for Closed Heating and Cooling Systems* (BG 50/2013)

BSRIA *Pre-Commission Cleaning of Pipework Systems* (BG 29/2020)

BS 8552:2012 *Sampling and monitoring of water from building services closed systems*

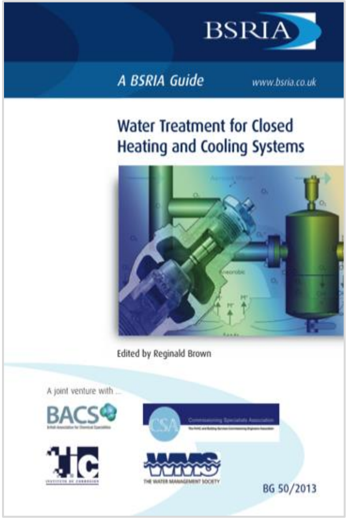
Summary of additional topics covered under BG29/2020



- Cleaning Precautions for thin-walled carbon steel.
  - Only chemicals recommended by the manufacturer to be used to clean the surfaces prior to application of Biocide and inhibitor

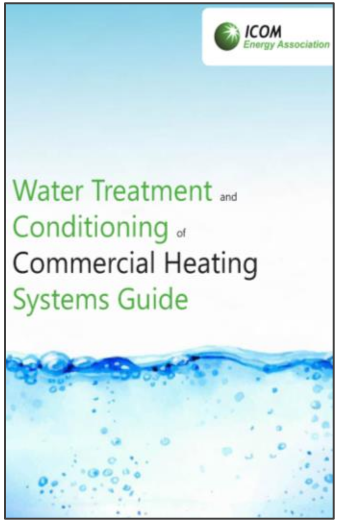
- Closed-loop Pre-treatment Cleaning (CPC).
  - Cleaning and biocide treatment in combination with filter to remove contaminants

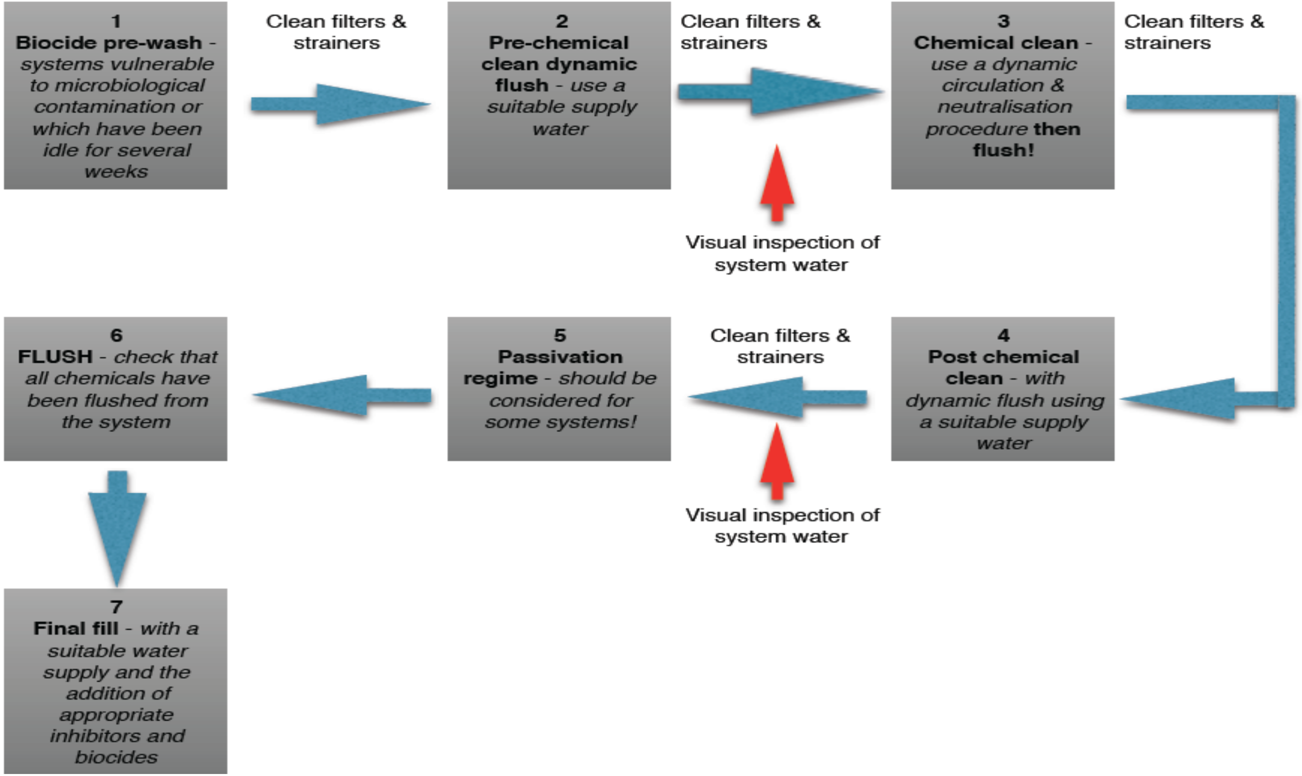
Summary of additional topics covered under BG29/2020 (Cont'd)



- Corrosion Monitoring
  - Technology can be used to Monitor system and provide a warning if corrosion rises above acceptable limits.
- Reference to VDI 2035
  - Reference made to the German standard and confirmation the measures to achieve and maintain compliance fall outside the scope of BG29

Water treatment guidelines in ICOM





Section 2

The impact of Corrosion

Corrosion: An Introduction

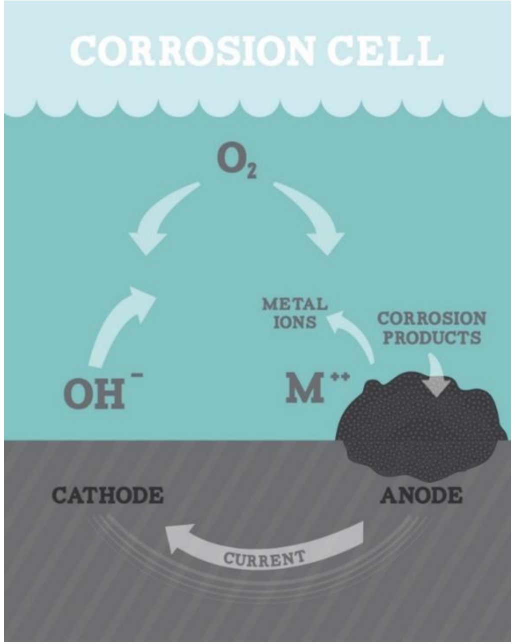
- Corrosion is the degradation of metal surfaces.

- It is a natural process of wastage which occurs when metal is exposed to a reactive environment.

- Water systems provide a highly reactive environment for most metals, unless treated.

What causes corrosion in closed heating systems?

- The primary cause of corrosion is the introduction of dissolved oxygen from raw water makeup.
- A corrosion cell arises when two metals with dissimilar compositions or microstructures come into contact in the presence of an electrolyte



How does corrosion affect metals in heating systems

Heating systems are composed of a wide variety of metals which will react with each other if not treated.

Heat exchangers:	*Aluminium, copper, steel.*
Boilers:	*Steel, cast iron, stainless steel.*
Pumps:	*Miscellaneous.*
Pipework:	*Copper, steel, carbon steel, plastic.*
Radiators:	*Steel, aluminium.*
Fittings/valves:	*Brass, bronze, cast and ductile iron, carbon and forged steel.*

Electrochemical table

Anodic

more easily corroded

Reactive

Magnesium
Zinc
Aluminium
Mild Steel
Cast Iron
Stainless Steel (active)
Lead
Brass
Copper
Bronze
Copper Nickel Alloys
Titanium
Silver
Stainless Steel (passive)
Gold

Nobel

more easily protected

Cathodic

Corrosion of mild steel and iron

- Mild steel and iron corrode rapidly in untreated/poorly treated systems.

- This often releases small flakes of rust into the water - particularly harmful in the area of pump shaft seals.

- Corrosion of mild steel radiators can sometimes be illustrated by pin-holing

Sludge in heating systems

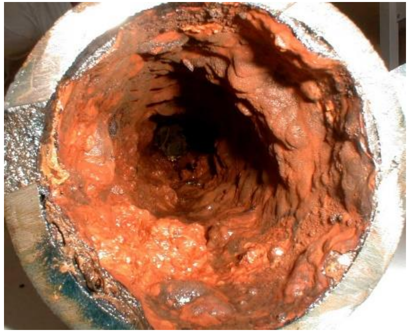
Oxide is approximately 5x heavier than system water, which leads to:

- Blockages in pumps, valves, radiators (see cold spot).
- Reduced water velocity.

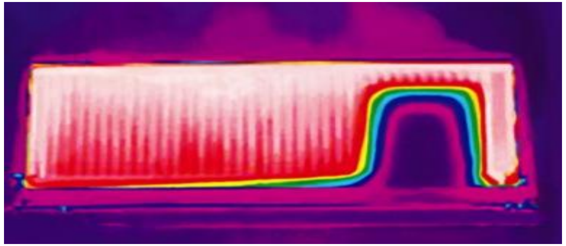
As a result:

- Pumps have to work harder, which causes higher energy consumption.
- Heat output reduces.

Blocked pipe:



Cold spot in radiator:



Baked on deposits in heating systems

Heavier black magnetite builds in the lowest points of a heating system (usually the boiler), forming a tough layer of baked on deposit.

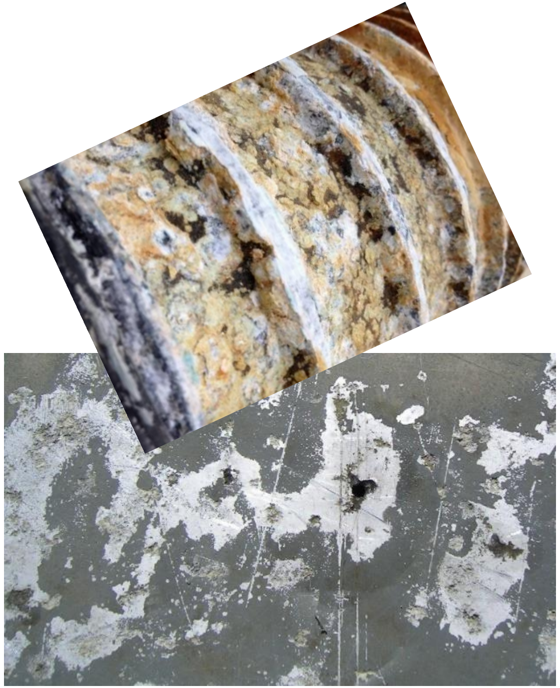
This can inhibit water flow, leading to:

- Blockages of the system.
- Over heated boiler.
- Cracked heat exchanger.

Effects of Aluminium Corrosion

Aluminium is an ideal choice for high efficiency heat exchangers.

- Its protective oxide layer is pH dependant
- If this layer is disrupted, corrosion occurs rapidly (aluminium has high anodic value).



Causes of disruption include:

- Base exchange softened water can lead to higher system water pH.
- Insufficient flushing of alkaline cleaners.
- Inhibitors that elevate pH values.

Effects of stainless steel corrosion

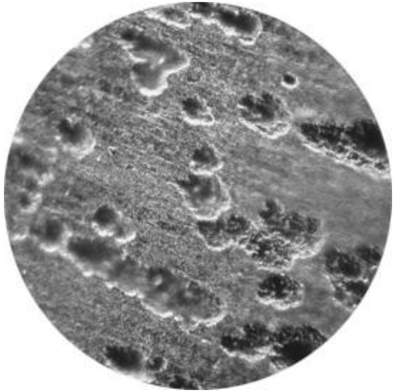
Alloying with chromium (11% minimum) to yield stainless steel, results in a chromium rich oxide layer that is:

- highly stable
- corrosion resistant.

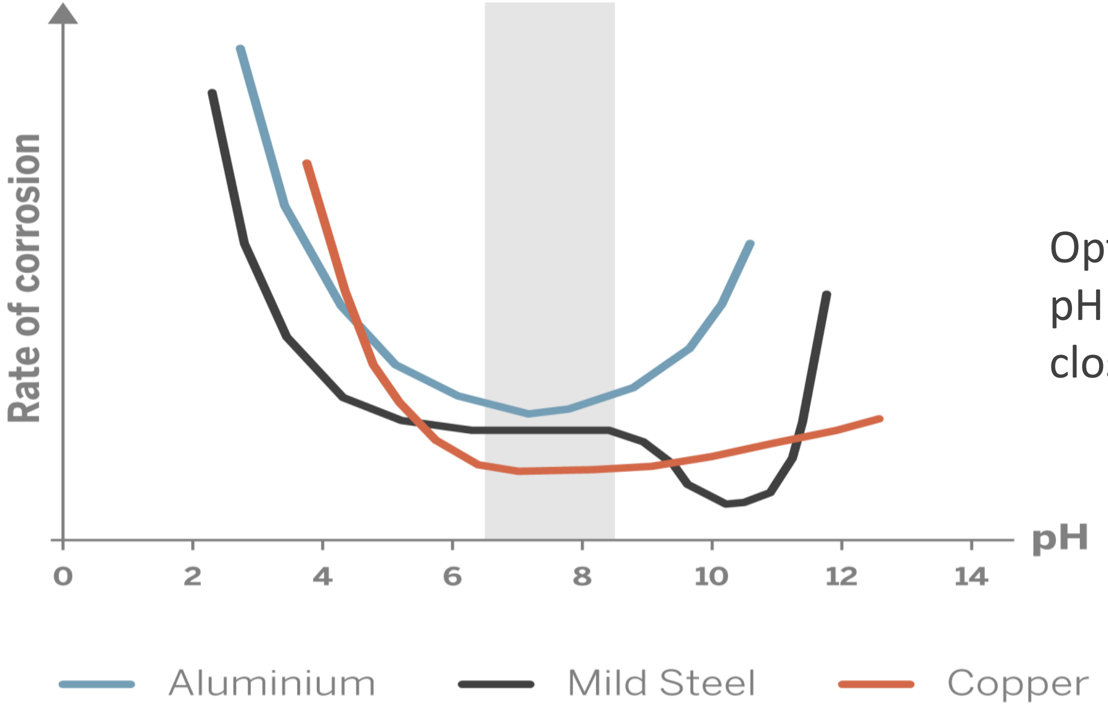
S/S is vulnerable to localised or pitting corrosion, due to aggressive constituents such as:

- chloride
- sulphate.

Corrosion of stainless steel:



pH vs. rate of corrosion



Optimum range of pH of water in a closed system.

The cost of poor water treatment

Basic cost implications of ineffective water treatment

COST OF REPLACEMENT	COST OF PREVENTION
Material and labour costs to replace this failed heat exchanger:	Cost for high-quality chemicals:
£3,500	**£300**

Cost of prevention is less than 10%

In the case of a failed heat exchanger in a 70kW boiler, one OEM quoted:

"for ease and expediency, the complete boiler would be replaced rather than just the heat exchanger ...."

Counting the cost of carbon from scale and sludge

There are government schemes related to energy consumption and CO_2 emissions of commercial buildings:

CRC
ErP
ESOS

The example opposite illustrates costs associated with a 500kW boiler at 85% design efficiency, with reduced performance of 10% due to system fouling.

FINANCIAL COST

Additional gas costs per annum*:

£7,000

ENVIRONMENTAL COST

Additional CO_2 emissions per annum**:

48,000 kg

*based on 3418 load hours with gas tariff at £0.035 per kW.
**1 kW of gas produces 0.185 kg of CO_2.

The Solution

Cleaning and flushing

New systems

- Flux residues
- Greases
- Installation debris
- Metal swarf
- Mineral oil

Existing systems

- Magnetite sludge
- Corrosion debris
- Limescale
- Slimes
- Bio-fouling

Adding correct inhibitor

Inhibitor provides protection to systems to prevent the build up of scale, sludge and corrosion.

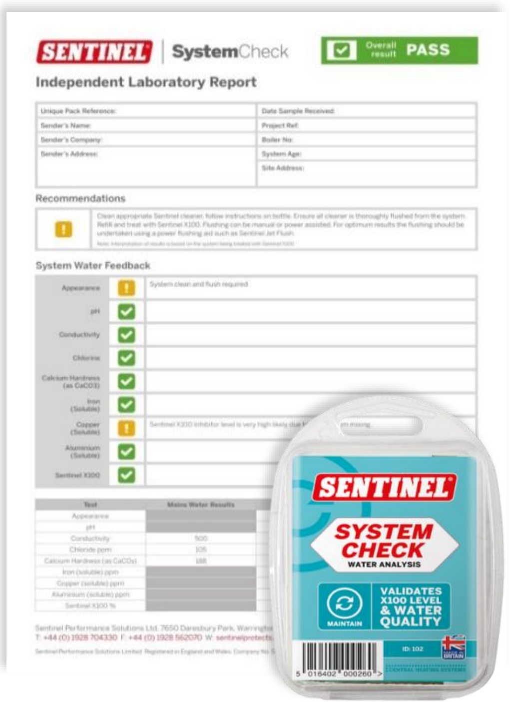
- Strength of pH buffer varies between brands considerably.
- OEMs do endorse select inhibitors in line with their warranties.
- Total system volume can be estimated using 12L per kW boiler output.
- Dosage varies depending on chemical used, typically a minimum 1% of system volume.

Application via dosing pot:

Monitoring – test kits

Test kits are available on the market and can be used to verify and certify the water treatment process.

- Monitor quality of system before treatment.
- Make recommendations from test results.
- Implement treatment.
- Use test kits for on-going monitoring PPM (Planned Preventative Maintenance).



Case study – Education Facility

Timeline of failure

- Brand new £250K traditional boiler / heating complex installed in education facility.
- Commissioned in the Autumn term.
- Heat exchanger fails in the following Spring.

Heat exchanger after a few months

Assessing the problem – test results

Water sample analysis

pH	9.6
Aluminium	20.1 ppm
Total hardness	20.0 ppm
Copper	1.5 ppm
Iron	0.14 ppm
Conductivity	1770 us

Deposit analysis

Aluminium	31%
Calcium	1.4%
Copper	11%
Iron	0.19%
Phosphorus	0.9%
Zinc	0.16%

Why did it fail?

Little or no pH buffer

Problem / Solution

The sample analysis revealed that:

- Ineffective flushing of cleaner was carried out.

Remedial recommendations:

- Replace heat exchanger.
- Flush and inhibit the system.
- Ongoing dosage monitoring.

1. Brand Y

mls/litre	pH
0.00	6.80
0.50	8.18
0.60	**8.44**
0.70	8.80
0.80	9.27
0.90	9.75
1.00	10.09

2. Sentinel X100

mls/itre	pH
0.00	6.82
2.00	7.35
3.00	7.55
4.00	7.76
5.00	7.94
6.00	8.11
7.00	8.32
8.00	**8.54**
9.00	8.78
10.00	9.04
11.00	9.31
12.00	9.63
13.00	10.03
14.00	10.59

1. Titration of 100mls of 1% v/v Brand Y with 0.1 M NaOH
2. Titration of 100mls of 1% v/v X100 with 0.1M NaOH

Tips for success – closed heating systems

Check existing water conditions

↓

Plan cleaning and subsequent treatment process

↓

Select appropriate products

↓

Verify water treatment product has been applied & dosed appropriately

↓

Test and monitor appropriate water conditions are in place on an ongoing basis (PPM)

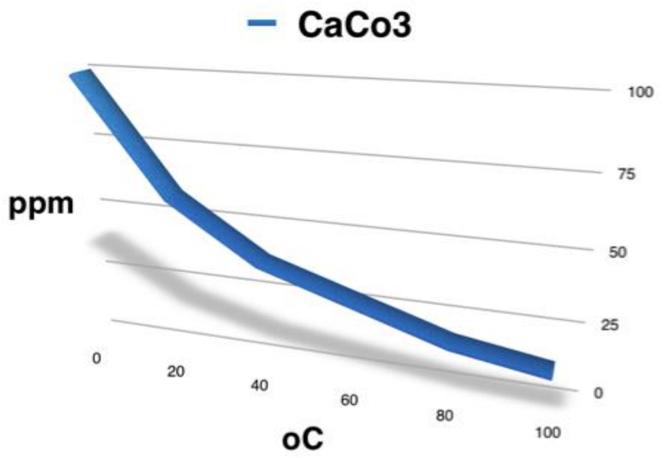
Section 3

The Impact of Limescale

What is limescale?

- Mains water contains varying levels of calcium salt.
- Calcium salts exhibit inverse solubility when water temperature rises.
- The carbonates are deposited as off-white solids on the inside surfaces of pipes and heat exchangers.

Solubility of Calcium Carbonate



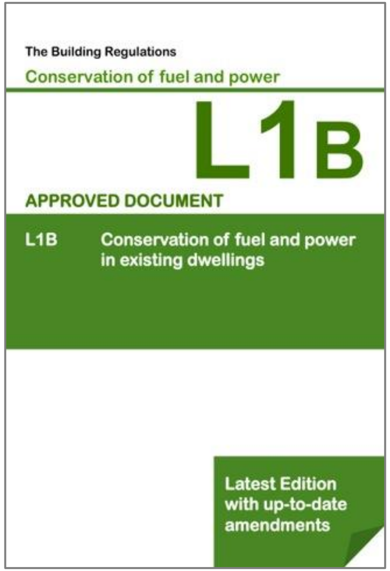
(heat)

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + CO_2 + H_2O$$

Water treatment guidelines – Part L / HSE

Part L:
"Where incoming mains water hardness exceeds 200ppm, provisions … should be made to treat the water" including, **electrolytic devices.**

HSE:
"In hard water areas… scale control should be considered and suitable measures implemented to control legionella risk."



The scale of the problem

Hard water affects more than 60% of England.

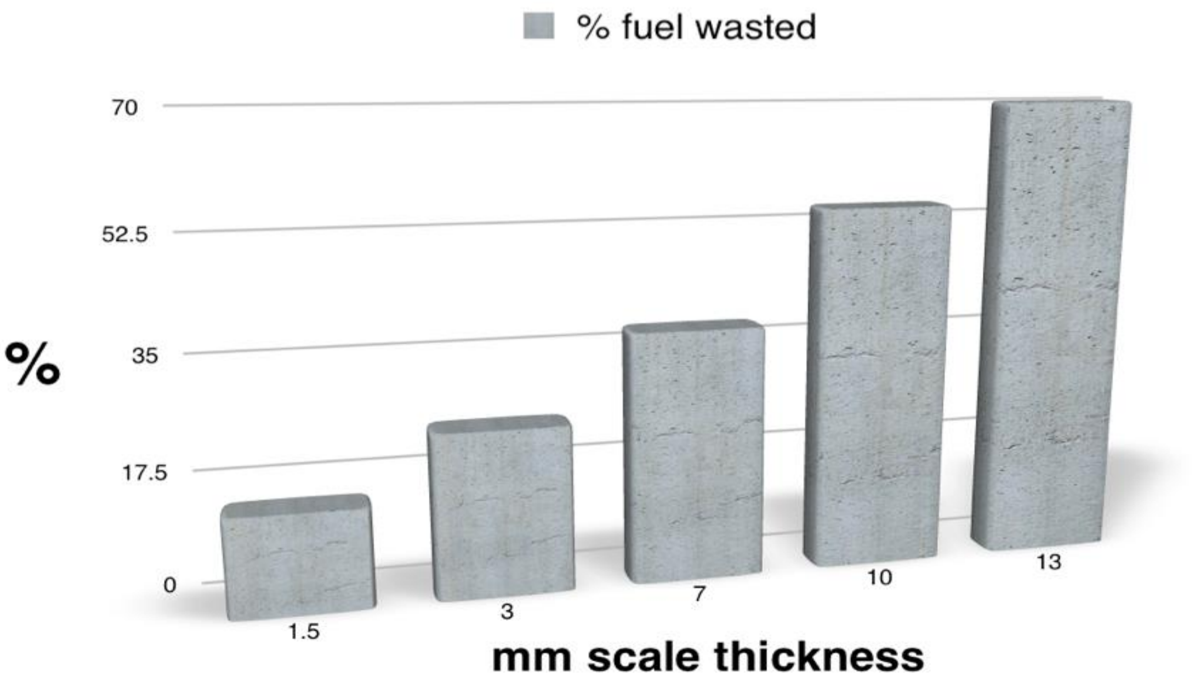
Most commercial buildings in the South, East and Midland areas of the UK will be subject to the detrimental effects of limescale if left untreated.

Soft to moderately soft
0-100mg/l as calcium carbonate equivalent

Slightly hard to moderately hard
100-200mg/l as calcium carbonate equivalent

Hard to very hard
> 200mg/l as calcium carbonate equivalent

Fuel wastage vs. scale thickness



How does limescale form in heating systems?

- Scale deposits can form initially during the first test firing of a new installation.
- Limescale builds significantly in ‘once through’ water heaters as these heat large quantities of fresh water.
- Scale also causes issues in closed heating systems if not properly controlled.

Limescale in calorifier:

Limescale in water heater:

How does limescale affect hot water systems?

- Impaired operation (especially in hot water cylinders/calorifiers).
- Reduced energy efficiency.
- Pumps have to work harder leading to increased energy consumption, reduced longevity.
- Heat exchanger failure due to overheating.
- System noise (kettling).
- On continuous flow water heaters, scale presence will result in immediate lockout

Limescale on heat exchanger

Limescale in water heater

Additional consequences of limescale

Limescale deposits accumulate quickly in appliances such as water heaters, immersion heaters and sanitary fittings.

Limescale accumulation could lead to:

- Downtime.
- Replacement costs.
- Unplanned maintenance/repairs.
- Costs associated with cleaning ‘visible’ limescale.

Limescale on appliances

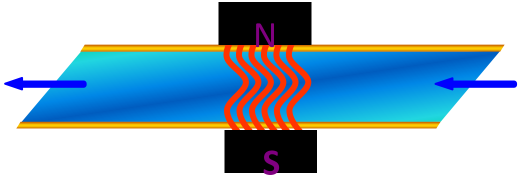
Treating limescale in secondary hot water

Temporary solutions to combat limescale

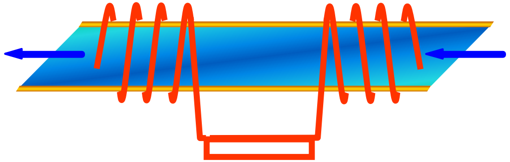
Include: **Magnetic, & H.F impulse field.**

- Condition water temporarily through ‘ionisation’.
- Ionisation is lost if water is stored or flows through directional changes in pipework.
- May require several devices upstream of each water heater / calorifier / plate heat exchanger to provide protection = additional cost.
- Require a positive LSI water chemistry
- These may not treat modern high efficiency water heaters

Magnetic

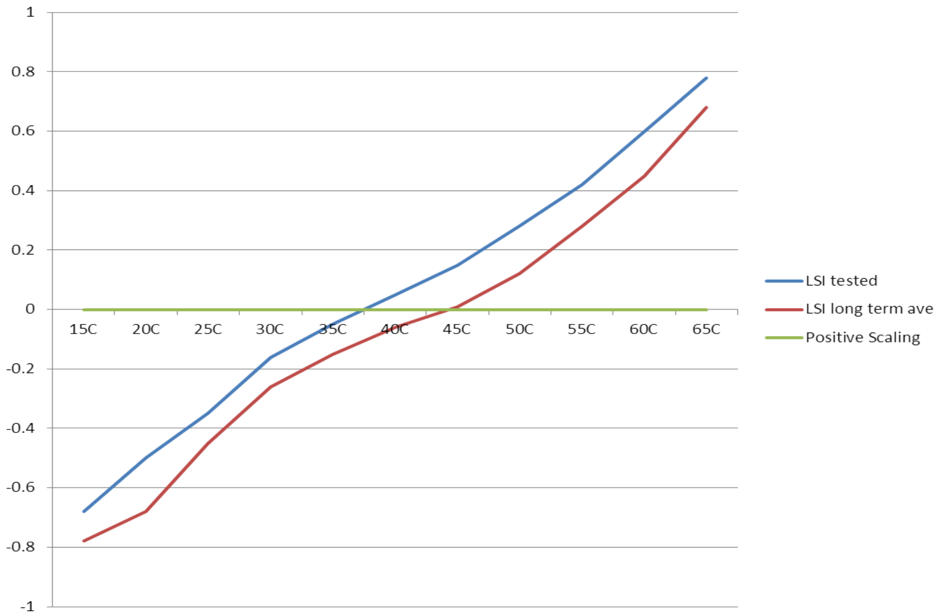


H.F. Impulse Field



LSI – Langelier Saturation Index

- LSI is a measure of a waters ability to dissolve or deposit calcium carbonate.
- Positive LSI is required for many conditioning devices, such as magnetic, electromagnetic and radiowaves, to control scale formation.
- The formula to calculate the LI uses:
  - pH
  - Alkalinity
  - Calcium concentration
  - Total Dissolved Solids
  - Water temperature



Only at +35 to 45 ^{0}C would some devices begin to prevent scale

Permanent solutions to combat limescale

Ion exchange water softener

- Proven effective.
- Requires regular salt top up (plus labour and H&S) = high costs.
- Regeneration takes 90 minutes.
- Water wasted during regeneration.
- Water is not potable.
- Disposability issues.
- Requires regular water testing.

Other methods

- Reverse osmosis
- CTU
- Point of use filters

Permanent solutions to combat limescale

KalGUARD

- WRAS approved – water is potable.
- Methodology recommended in Part L.
- Uniquely powered electrolytic system
- Zinc anode lasts 10/12 years.
- Requires no salt.
- Does not waste water.
- Non LSI dependant
- Permanent treatment i.e. does not decay in storage or pumping.
- As a result of the above a single KalGUARD can be installed on the MCWS as it enters the building.

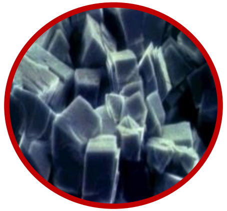
KalGUARD technology process

- KalGUARD delivers low levels of stable zinc into water electrolytically via a zinc anode and copper cathode.
- Zinc holds much of the calcium carbonate in solution, minimising formation of crystals.
- The calcium carbonate which does precipitate develops as soft non-deposit forming aragonite, instead of hard deposit-forming calcite.

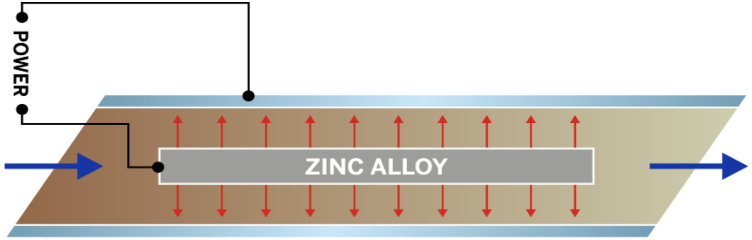
Untreated: Calcite deposit:

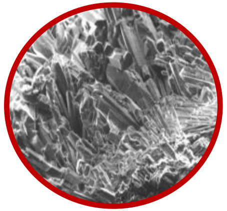
KalGUARD: treated water, no deposit.

KalGUARD technology process

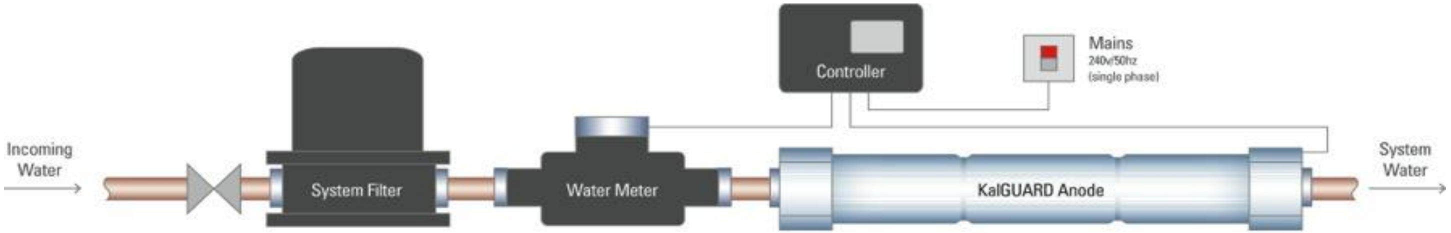


CALCITE
highly crystalline





ARAGONITE
more amorphous



Case study – Whitbread

Problem / Solution / Savings

Problem:

- Previously used ion exchange softeners to prevent limescale.
- Programme was not being monitored or managed correctly.
- Solution was ineffective.

Solution:

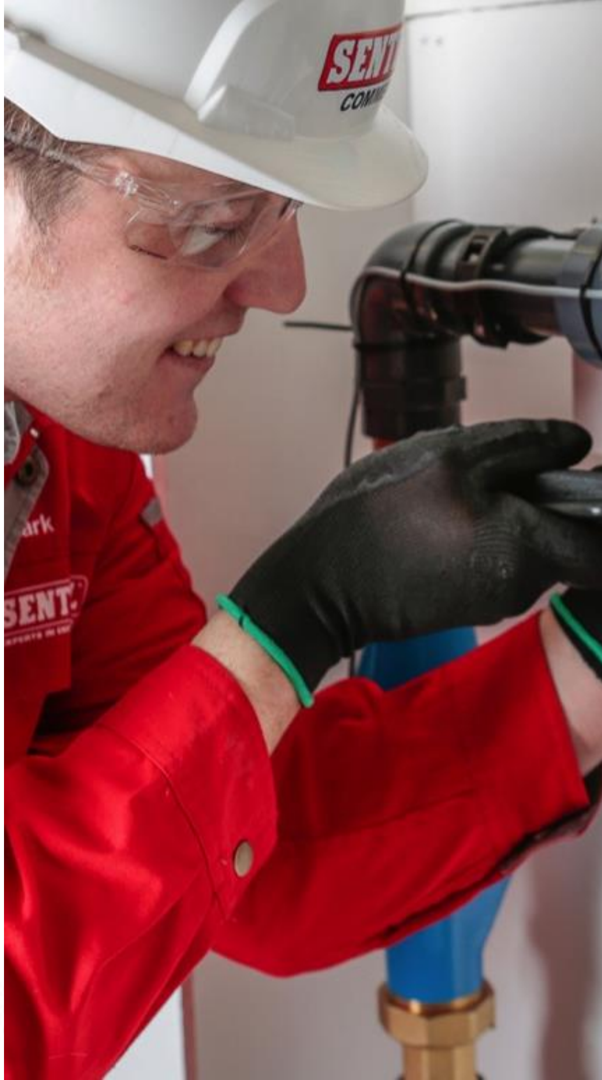
- Ion exchange softeners were switched with KalGUARD's for a trial period.
- KalGUARD systems have now been specified and installed in Premier Inn hotels for 10 years.

Savings achieved with KalGUARD:

Energy	£3,000,000
Asset life increased	£250,000
Salt NOT purchased	£700,000+
Reduced water heating servicing	£200,000
Room rate refunds	£500,000
Fewer plumber call-outs	£300,000
Total Saving	**£5,000,000+**

Section 4

Key actions to takeaway today



Design / site tips / taking control

Specification:

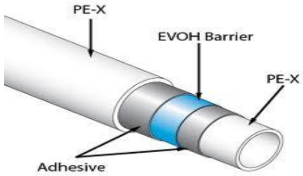
- Check hardness levels for limescale control & specify a proven technology.
- Refer to OEMs’ warranty requirements for chemical inhibitors and cleaners.

Water usage /make up to LTHW system:

- Fit a water meter to boiler make up line to enable make-up volumes to be monitored.

Corrosion risks:

- Ensure plastic pipe has oxygen barrier.



Testing/Monitoring:

- Use test kits to establish initial water conditions and to subsequently, check suitable protection remains in place.

Thank you
&
Any Questions

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Commercial