



BuildCert Chemical Inhibitor Approval Scheme (CIAS)

*Standard Specification for the Performance
of Chemical Inhibitors for Use in Domestic
Hot Water Central Heating Systems*

February 2017:

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Foreword

The UK Government has recognised that ‘heat’ is a major contributor to CO₂ emissions and is continually developing policies to progressively de-carbonise heat. Domestic boilers account for up to 80% of CO₂ emissions and installing energy efficient models alongside a time, temperature and zone control specification makes a vital contribution to CO₂ reduction. Maintaining heating system efficiency is equally important and the use of water treatment chemicals within new and existing central heating installations is a proven method of preventing efficiency degradation.

Through the inhibition of corrosion and scale, chemical inhibitors have been shown to maintain or improve the long-term energy efficiency of domestic central heating systems.

This Industry Standard Specification has been written with the UK’s energy commitment in mind. Inhibitors that meet the requirements of this standard will have been shown to both restrict the formation of Calcium-based scales (hereafter referred to as scale) and reduce metallic corrosion. The test protocol has been specifically designed to evaluate the performance of the inhibitors with metals typically found within modern SEDBUK A and B rated condensing boilers. They will also have been shown to be compatible with non-metallic components commonly found within a modern central heating system.

This 2017 amendment of the BuildCert standard specification clarifies the pass criteria of the ‘compatible with non-metallic materials’ test and ensures that the scaling tendency test, water sample preparation is further brought ‘under control’ to ensure consistency of results. This amendment, together with the introduction of the ‘embedded’ spreadsheet and associated instructional text, ensures that all of the required information is entered correctly and that the final test result and quality control assessment is reported in an acceptable and correct way.

General Requirements of an inhibitor

In order to meet the requirements of the CIAS Standard Specification, an inhibitor shall:

- Inhibit the corrosion of metals typically found within a modern central heating system.
- Not damage any plastic or rubber components typically found within a modern central heating system.
- Inhibit scale formation.¹

General Requirements of the CIAS Standard Specification

This Standard Specification is applicable to chemical water treatments designed to inhibit both corrosion and scale in the primary circuit of domestic wet central heating systems. Special consideration has been given to ensuring that test methods embodied in this Standard Specification are not exclusive on the basis of cost or equipment availability.

This Standard Specification will verify that the inhibitor:

- when used in accordance with the manufacturer’s recommendations, will inhibit the corrosion of metals specific to modern condensing boilers and other system components under controlled laboratory conditions.
- will inhibit the formation of scale under controlled laboratory conditions.
- will be compatible with, and not adversely affect, the properties of commonly used non-metallic component materials of central heating systems under controlled laboratory conditions.

¹The building regulations focus on maximising energy efficiency in the home. Prevention of scale within a central heating system is an important element in ensuring that the energy efficiency of the system is maintained, and consequently the ability of an inhibitor to also prevent scale formation is important.

Scope

This Standard Specification specifies the minimum performance requirements of chemical inhibitors for reducing corrosion and scale formation in vented and sealed domestic hot water central heating systems, installed in accordance with BS 5449 and meeting the requirements of Part L of the Building Regulations for England and Wales, 2010 and revisions 2013 and 2016.

Introduction

The performance of the chemical inhibitor is evaluated in three stages:

- A short-term laboratory evaluation performed in conventional glassware, to determine the corrosion rate and pitting of standard metal coupons in inhibitor solutions at the manufacturer's recommended strength.
- A short-term laboratory evaluation performed in conventional glassware, to determine the tendency of the inhibited solution to form scale.
- An evaluation of the effect of the inhibitor on non-metallic materials.

The metals used in the tests are representative of the range of alloys found within domestic central heating systems. Consideration has been given to those metals found within modern condensing boilers. The metals are in the form of standard coupons, which are prepared by and obtained from a specialist supplier.

Section 1 describes the procedure for determining the general corrosion rates and propensity for pitting of mild steel, copper, extruded aluminium, brass and stainless steel under a variety of conditions in a glassware test. General corrosion rates and pitting density are determined at the manufacturer's recommended inhibitor concentration in both a standard hard and a standard soft water. Absolute corrosion rates are determined using mass-loss from coupons in the uncoupled condition.

Section 2 describes the procedure for determining the extent of scaling on stainless steel heat exchanger surfaces in a glassware test at the manufacturer's recommended inhibitor concentration in the standard hard water.

Section 3 describes a test for determining the compatibility of inhibitors with commonly used non-metallic materials. Accelerated testing is undertaken in laboratory glassware tests at double the manufacturer's recommended strength in the standard soft water.

Standard Test Waters

Standard Hard and Soft waters are used throughout the test protocols to ensure consistency of results, and are prepared from defined commercial bottled waters. Full details of the standard test waters are given in Appendix 1.

Approved Laboratories

Testing to this standard specification can only be undertaken using BuildCert approved laboratories.

Section 1. Corrosion Rate Determination

1.1 Apparatus

See Figure 1 for a diagram of the glassware assembly.

1.1.1 Test vessels

One litre glass test vessels, equipped with a multi-socket flanged lid, through which equipment may be attached by means of conical; ground glass fittings.²⁾ The use of specially prepared polypropylene lids with ports has been found to be particularly suitable for this purpose. The vessels may be equipped with glass jackets to enable heating of contents by circulating heating water, from an external water bath through the jacket.

1.1.2 Gas Sparger

When air sparging is required, a silicon sintered glass frit shall be used of nominal porosity >40 to <60 micron (ACE, Corning & Kimble rating C).

1.1.3 Air-cooled Condenser

Used to minimize the loss of test solution by evaporation.

1.1.4 Centrally Mounted Stirrer Motor, Shaft and Coupon Assembly

Metallic test coupons are mounted as described below and the coupon assembly shall be attached to a glass or PTFE coated shaft that shall be rotated in a central position in the test solution at 200 r.p.m. \pm 10 r.p.m.

1.1.5 Water Bath

Capable of controlling the temperature of the test solutions to $82^{\circ}\text{C} \pm 2^{\circ}\text{C}$. When turned off, the water bath shall cool the test solutions from 82°C to $35^{\circ}\text{C} \pm 2^{\circ}\text{C}$ in 2 hours and when turned on again at the start of the on-cycle, it shall be capable of raising the temperature back to 82°C within 1 hour³⁾. For test vessels which have a water jacket, the water bath should be capable of also pumping and circulating its heated water through the four vessel jackets. Temperature-programmable circulating water baths with cooling as well as heating capability have been proven to be the best way of obtaining a correct temperature profile.

1.1.6 Timer

A 24 hour, 230-240 volts AC timer (not required when using a temperature-programmable water bath).

1.1.7 Gas Flow Meters

One gas flow meter per test vessel under forced aeration, capable of measuring air flow from 50ml per minute to 200ml per minute.

1.2 Preparation of Test Solutions

Prepare test solutions by diluting the product to the manufacturer's recommended solution strength in the modified standard hard water and in the modified standard soft water as specified in Appendix 1. If the product comprises more than one component, these components shall be mixed in accordance with the manufacturer's instructions. Test solutions should be mixed immediately before use.

²⁾If the glass vessels have not previously been used, they should be pre-conditioned by filling with water and heating to a temperature of 80°C for two weeks. This procedure is intended to reduce the possibility of corrosion inhibition by silica leaching from the glass.

³⁾Alternatively, temperature control may be achieved by the use of thermostatically controlled stainless steel immersion heaters or by the use of a water jacket or heater/mantle around each cell.

1.3 Test Specimens

1.3.1 Coupon Type

The grade of metal to be used shall be as specified in the following table

| Metal | Specification | Density, ρ (g cm ⁻³) | Measurements (mm) |
|-----------------|--------------------------|---------------------------------------|-------------------|
| Mild Steel (2x) | EN 10130:1999 Grade DC01 | 7.86 | 50 x 25 x 1.5 |
| Copper | CW024A | 8.94 | 50 x 25 x 1.6 |
| Aluminium | 6063 | 2.70 | 50 x 25 x 1.6 |
| Brass | CW505L | 8.52 | 50 x 25 x 1.6 |
| Stainless steel | 1.4307 (304S11) | 7.94 | 50 x 25 x 1.5 |

Table 1. Test coupons for corrosion testing

The coupons shall have central holes 7.5 mm in diameter. Coupons shall have a bead-blasted finish using glass beads of between 100 μ m and 150 μ m at 4 bar from a distance of between 15 cm and 20 cm and be stamped with an identification mark.

Use only coupons which are free from coarse scratches, corrosion, pits, rolled-in laminations, gross blow holes or any other defects which could affect the visual assessment of the coupon after completion of the test.

1.3.2 Preparation of Test Coupons

Rinse the coupons thoroughly with demineralised water, then with methanol or acetone, and dry in warm air. Store the coupons for a minimum of 30 minutes in a desiccator before weighing to the nearest 0.1 mg at ambient temperature. At all times handle the clean coupons only with forceps or clean, grease-free cotton gloves.

If not required immediately, store the coupons in a desiccator.

1.3.3 Assembly of Coupons

Assemble the coupons by use of the central holes on a threaded brass bar attached to a rotating rod, with a PTFE insulating sleeve and brass nuts. Separate the coupons from each other by cylindrical PTFE spacers, each 6 mm long, so that they are not coupled to any other metal. There should be two mild steel coupons and one each of the other metals and the order of the coupons on the assembly should be as depicted in Figure 1.

1.4 Procedure

Perform a series of tests, with the parameters given in Table 2. All tests are to be undertaken using manufacturer's recommended inhibitor concentration.

| Test | Aeration/Deaeration | Water (Appendix 1) |
|------|---------------------|------------------------------|
| 1 | Air sparging | Modified Standard Soft Water |
| 2 | Air sparging | Modified Standard Hard Water |
| 3 | Natural aeration | Modified Standard Soft Water |
| 4 | Natural aeration | Modified Standard Hard Water |

Table 2. Test parameters for corrosion tests

Mount the coupon bundle on a central rotation shaft in each test vessel. The test vessel shall contain 1000 ml \pm 10 ml of the required inhibitor solution. Ensure that the bundle is spatially arranged with the long side of the coupons vertical such that it is half way between the bottom of the flask and the surface of the solution. As far as is possible, it should be arranged such that the circular solution flow is maximised through the bundle (see Figure 1).

Measure and record the pH of the solution in each of the test vessels.

Attach the lid, the air condenser and the gas sparger (if required). The gas sparge outlet should be positioned as near to the bottom of the flask as possible. Ensure that the rotation shaft is positioned through the central outlet and attached to a suitable stirrer motor.

If the test vessels cannot be heated by circulating water through heating jackets, place them in a water bath fitted with a suitable thermostat. If the vessels each have a water jacket, connect them to the water bath in the appropriate manner.

Close any open sockets with ground glass stoppers.

Set the temperature control on the water bath so that the temperature is $82^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

Connect a water bath to a timer and set the timer to operate in a cycle of four hours on followed by four hours off. If using a temperature-programmable water bath/circulator, start the temperature programme.

Set the rotation speed of the overhead stirrers to $200 \text{ r.p.m} \pm 10 \text{ r.p.m}$. When gas sparging is used, immediately connect the gas diffuser/bubbler to an air supply and commence sparging at a rate of 100 ± 10 ml per minute.

Run each test for $348 \text{ hours} \pm 12 \text{ hours}$, regularly checking the gas supply and air flow rate (when air sparging is used). Make up any loss of liquid due to evaporation by adding demineralised water to the test vessel.

At the end of the test, measure and record the pH of the solution in each of the test vessels, remove the coupon bundle from the test vessel, dismantle it and rinse the coupons with demineralised water, then with methanol or acetone, and dry in warm air. Store the coupons in a desiccator until ready for inspection and cleaning.

All tests shall be carried out in duplicate. Should the air supply run out, or the heater or stirrer motor fail during the test, the test shall be re-run. If the variation in mass loss between the two coupons of any metal for any specific test is more than a factor of two, repeat the test for the whole coupon bundle to produce a third set of results. The overall result shall be determined from the coupon bundles giving the closest results.

1.5 Cleaning and Evaluation of Coupons

Clean the coupons and calculate the mass loss in accordance with ASTM G1-03 clause 7, with all weights being recorded to the nearest 0.1 mg. Before each weighing, rinse the coupons with demineralised water, then with methanol or acetone, and dry in warm air. Store in a desiccator for a minimum of 30 minutes. Perform consecutive cleaning procedures avoiding excess force until all corrosion products have been removed. The mechanical forces used for cleaning should be held as constant as possible. Continue cleaning until at least three consecutive measurements are within 1.0 mg of the previous measurement. Correct the mass loss due to the removal of metal in the cleaning process. This is most easily achieved by plotting weight loss against the number of equal cleaning cycles (see ASTM G1-03). A straight line (calculated by linear regression) through the final cleaning cycle measurements (i.e. only those that differ by no more than 1.0 mg from its previous measurement) should be subtended to the origin to determine the corrected mass loss.

1.6 Expression of Results

1.6.1. General Corrosion Rate

The corrosion rate C , expressed in mm/year is given by the equation:

$$\text{Corrosion rate } C = \frac{\text{Corrected weight loss (mg)} \times K}{\text{Exposure Time (hours)}}$$

Where the factor K incorporates coupon density, area and units.

Factor K for the respective test coupon metals shall be taken from Table 3.

| Metal Coupon | Factor K |
|-----------------|----------|
| Mild steel | 0.4171 |
| Copper | 0.3644 |
| Aluminium | 1.2066 |
| Brass | 0.3824 |
| Stainless steel | 0.4129 |

Table 3. Factor K values for each type of metal test coupon

The result shall be given as a mean corrosion rate for each of the metals.

1.6.2. Pitting Density

Pitting density shall be evaluated by visual examination of the coupon surface under ordinary light, with the use of a low-power magnifying glass, to determine the extent of corrosion and the apparent location of pits. A photographic record of both sides of each test coupon before and after cleaning shall be provided with the Test Report.

The method for determining pitting density is given in BS EN 11463; the Characteristics of Pits are defined as the measurement of the diameter, the depth and the density. Use of a digital indicator or micrometer with a fine tip with a resolution of 0.05 mm has been found to be most suitable.

1.7 Pass Criterion

1.7.1 Absolute Corrosion Rate

The absolute corrosion rate of the metals shall not exceed those specified in Table 4.

| Metal | Corrosion Rate mm/year | | | |
|--------------------|--|--|--|--|
| | Modified Standard Hard Water, air sparging | Modified Standard Hard Water, natural aeration | Modified Standard Soft Water, air sparging | Modified Standard Soft Water, natural aeration |
| Mild steel | 0.040 | 0.040 | 0.040 | 0.040 |
| Copper | 0.005 | 0.005 | 0.005 | 0.005 |
| Extruded Aluminium | 0.100 | 0.100 | 0.100 | 0.100 |
| Brass | 0.005 | 0.005 | 0.005 | 0.005 |
| Stainless steel | 0.002 | 0.002 | 0.002 | 0.002 |

Table 4. Maximum corrosion rates for metal coupons

1.7.2 Pitting Density

Pitting density shall not exceed $1.5 \times 10^3/m^2$ for any metal. This equates to no more than an average of four pits on the coupons of any metal.

The method for pit identification and recording is taken from BS EN ISO 11463:2008 (Corrosion of Metals and Alloys – Evaluation of Pitting Corrosion).

In addition to pit density, a single pit in excess of a pit depth of 0.4mm or greater than $0.5mm^2$ in size would result in pitting failure even if the pit density measurement is not exceeded.

N.B. For clarity, localised attack will be considered to have occurred if a pit with a depth of 0.1mm or greater is found on the faces of the coupon clear of edges, punch-marks and mounting surfaces.

Section 2. Scaling Tendency

The scaling tendency test shall be carried out so as to obtain six experimental results. This can be achieved **either** as a single batch of 6 tests (requiring 8 litres of test water), **or** as a combination of two batches of 3 tests (requiring 2 * 4 litres of test water), depending upon the equipment available. All test solutions and results shall be traceable to individual test cells.

The scaling test shall be undertaken (in) at an ambient temperature of $20 \pm 5^\circ\text{C}$.

2.1 Apparatus

2.1.1 Heater Sheaths

The alloy used to make the heater sheaths shall be of austenitic stainless steel of grade 1.4301, conforming to BS EN 10083 - 3. Each heater sheath consists of a tube with a closed end and threaded at the other end, with dimensions as shown in Figure 2. The tube shall be formed by drilling to 6.4 mm diameter and then reaming to 6.53 mm. The external surface shall be ground before each test with 400 grade silicon carbide paper.

2.1.2 Heating Elements

Stainless steel heating elements consist of 230-240 volts AC, (150 W \pm 10 W) cartridge heaters, of 6.5 mm diameter, heated length of 30 mm at the bottom end and total length of 300 mm.

2.1.3 Assembly of Heater Sheaths

The heater sheaths shall be attached to a PTFE holder with heating elements inserted through the PTFE holder and heater sheaths until in contact with the closed end of the hole in the heater sheath (see Figure 3). A fluorocarbon 'O' ring, internal diameter 2.90 mm and thickness 1.78 mm shall be placed within the 'O' ring groove of the heater sheath. Before screwing the heater sheath into position on the holder, the heated length of the heating element may be brushed with a heat release agent.

2.1.4 Conditioning of New Equipment

New glassware should be conditioned at 95°C in demineralised water for a period of 48 hours prior to undertaking scaling tests.

2.2 Test Solutions

Prepare test water by adding the required amount of inhibitor solution, in order to obtain the manufacturer's recommended concentration, into a (2 litre) suitable volumetric flask and make up to the mark with the standard hard test water (Appendix 1). Each batch of 3 test cells will require the preparation of 4 litres of test solution (2*2 litres) in order to provide sufficient volume for samples for the determination of the initial calcium concentration (*CI*). New, unopened bottles of water shall be used; all 6 test solutions shall be from the same production batch, and the Batch number shall be recorded on the Scaling Tendency Calculation Spreadsheet. Test solutions shall be mixed immediately before use.

Record the dosage rate (%) on the Scaling Tendency Calculation Spreadsheet.

If the volume is to be determined by weight then the specific density shall be established at the ambient temperature of the laboratory at the time of the preparation of the aliquots.

For example: For a 1% solution dilute 20 ± 0.5 ml of inhibitor to 2000 ± 5 ml
 For a 4% solution dilute 80 ± 2.0 ml of inhibitor to 2000 ± 5 ml

Solution *CI*:

Take 100 ± 2.0 ml from each of the 2 litre aliquots of the prepared test solutions into a series of labelled plastic sample bottles containing 2.0 ± 0.2 ml of 4 Molar hydrochloric acid.

Retain these samples for the determination of calcium (Initial concentration = *CI*).

The remaining test solution shall be used to fill the three test cells (see 2.3.2) in the most convenient manner. Each 4 litres of test solution shall be traceable to a batch of 3 test cells as defined on the Scaling Tendency Calculation Spreadsheet.

Evian raw water sample (standard hard test water):

Take two 100 ± 2.0 ml aliquots of raw Evian water into labelled plastic sample bottles containing 2.0 ± 0.2 ml of 4 Molar hydrochloric acid, and retain these for calcium determination (Analysis Result 1 and 2)

2.3 Procedure

2.3.1 Immediately before testing, rinse the heater sheaths with demineralised water, then with methanol or acetone, and dry in warm air. Place the heater sheath assembly into a 1 litre glass test vessel, so that it is positioned centrally in the test vessel with the bottom of the heater sheath five centimetres from the test vessel bottom. The test vessel shall be equipped with a thermocouple or platinum resistance thermometer to control the temperature of the test solution to $82 \pm 2^\circ\text{C}$. A magnetic stirrer shall be used to stir the solution during the test.

2.3.2 Fill the test vessel with 1000 ± 10 ml of the test solution and, in order to minimise the loss of water by evaporation, fit to the test vessel an air-condenser or pressure release device to ensure that the vessel is not exposed to excessive pressure if it is fully sealed.

2.3.3 Turn on the heating element and set the magnetic stirrer to 200 ± 20 rpm. Adjust the temperature control, so that the required temperature is maintained. Continue the test for 168 ± 2 hours maintaining the level of solution throughout the test by the addition of demineralised water every 2 days as a minimum.

It is important that the volume of liquid at the end of the test is the same as at the start of the test (1000 ± 10 ml). If the heater fails during the test, the test shall be repeated using a fresh test solution.

2.3.4 At the end of the test, allow the test solution to stand for at least 30 minutes to allow any scale that may have spalled from the heater sheaths to settle to the bottom of the test vessel.

2.3.5 Carefully pipette 100 ± 2.0 ml from just below the surface of each of the final test solutions into a series of labelled plastic sample bottles containing 2.0 ± 0.2 ml of 4 Molar hydrochloric acid. Retain these samples for the determination of calcium (Final concentration C2).

2.3.6 Photograph each of the heater sheaths so that a visual record of adhered scale (scaling) is obtained.

2.3.7 Carefully unscrew each heater sheath from its heater sheath assembly. Should any material be dislodged then this should be collected.

2.3.8 Dissolve the adhered scale from each sheath, or any other component used within the test with an appearance of scale, by dipping the sheath/component into individual suitable beakers containing 20 ± 1 ml of 4 Molar hydrochloric acid. Retain these solutions.

2.3.9 Rinse the heater sheaths in individual beakers containing 100 ± 2 ml of demineralised water and retain these solutions.

2.3.10 Pour the solution obtained in step 2.3.9 into the relevant test vessel in order to dissolve any solid material that may have been produced during the test. Wash this beaker several times with the rinsing solution obtained in step 2.3.10 and therefore eventually adding all of this solution into the test vessel. Add any dislodged material recovered in stage 2.3.7 to the test vessel.

The total volume of liquid in the test vessel should now be 1020 ml.

2.3.11 Mix the solutions in the test vessels thoroughly, check that all solid material is dissolved and pipette 100 ± 2.0 ml of each of these solutions into labelled, (unpreserved) plastic sample bottles. Retain these samples for the determination of calcium (Concentration C3).

2.3.12 The Calcium content of all of the (18) liquid samples (4*C1 samples, 6*C2 sample, 6*C3 samples and 2* Evian raw water samples) shall be determined by a UKAS accredited laboratory being accredited for the determination of calcium in potable, environmental or other water.

Analysis may be carried out using atomic absorption spectroscopy, inductively-coupled plasma analysis or other appropriate validated method.

The (18) liquid samples shall be submitted to the laboratory for analysis at the same time.

2.3.13 Open the Scaling Tendency Calculation Spreadsheet in Appendix 2 by double-clicking on it. Enter all of the required information and analytical results for each test replicate into the appropriate spreadsheet cells that are shaded in pale blue (the spreadsheet is password protected so that only these cells can be edited).

Ensure that the *C1* results are entered into the correct locations in the spreadsheet so that they are traceable to each batch of 3 test cells.

When all of the data has been entered click in the main document to close the spreadsheet and all of the required calculations will be performed by the spreadsheet.

2.4 Pass Criteria

The scaling tendency of the inhibited solution is taken as the mean difference in Calcium concentration of the solutions before and after testing in six replicate tests.

The spreadsheet will calculate the % Calcium ion change for each replicate, and the arithmetic mean of the six replicates (*M6*). The Excel function *TRIMMEAN* is used to discard the two values furthest from (*M6*) and calculate the arithmetic mean of the remaining four results (*M4*).

The inhibitor will have passed the scaling tendency test if the mean reduction in Calcium ion concentration (*M4*) is no more than 15% at the completion of the test,

$$\text{that is if } \frac{(C1 - C2) * 100}{(C1)} \leq 15$$

The spreadsheet will display a PASS or FAIL notification.

2.5 Calcium Balance

The use of a Calcium Balance will highlight any anomalous results. The assumption is that the total amount of calcium within the test does not change.

The initial amount of calcium present in solution is obtained from analysis of portions of the test solution prepared for the tests (Section 2.2) (*C1* (mg)). The analysis of the Evian raw water shall be within $\pm 10\%$ of the calcium concentration given on the batch of water used, (see the Scaling Tendency Calculation Spreadsheet).

The final amount of calcium present in solution is obtained from analysis of the test solution at the end of the test (Section 2.3.5) (*C2* (mg)).

Note that *C1* and *C2* analysis results are reported as mg/l, but as the volume of test solution is 1 litre, *C1* and *C2* will be the mass of calcium present.

The weight of deposit produced during the test will be the material adhering to the heater sheaths plus the spalled solid material solubilised in stage 2.3.11.

The amount of material solubilised in stage 2.3.11 is determined by the difference in the calcium concentrations in the final test solution (*C2*) and the total calcium concentration (*C3*).

The amount of calcium in solution at the start of the test should equal the amount of calcium present in solution at the end of the test plus the amount of calcium present as solid material.

i.e. $(C1 * 1.02)$ should equal $((C3 * 1.02) + (C2 * 1.02 * 0.1))$

(The factor 1.02 is derived from the dilution effect of the 4M hydrochloric acid added to each sample)

$$\text{Therefore } C1 = C3 + 0.1 * (C2)$$

The Scaling Tendency Calculation Spreadsheet also has inbuilt 'quality' checks to help identify anomalous results:

- i) The analysis results obtained from the determination of calcium in the Evian raw water samples are compared to the expected value as recorded on the bottle.
- ii) The average *C1* analysis result is compared to the Evian water analysis result.

Section 3. Compatibility with non-metallic materials

The compatibility of an inhibitor with elastomeric materials commonly used within a central heating system is assessed by measuring the percentage volume change on immersion, using double the manufacturer's recommended inhibitor strength, for a minimum period of 336 hours at $82^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

3.1 Test solutions

Test solutions shall be made using double the manufacturer's recommended concentration of the inhibitor in the standard soft test water (Appendix 1).

3.2 Procedure

Testing is carried out on duplicate test samples of 2 cm x 2 cm x 2 mm, cut from sheets of typical elastomeric materials as defined in Table 5. Rinse the test samples in demineralised water, oven dry and allow to cool to room temperature.

Measure the mass of each of the test specimens using a wet balance, capable of measuring to ± 0.1 mg on suspended objects. The addition of a small amount of surfactant to the water will prevent the adhesion of air bubbles onto the surface of the elastomeric materials and therefore aids sinking. Test specimens may have a small hole at one end to allow suspension in the water.

Weigh each test piece in air to the nearest 0.1 mg (m_0). Then reweigh each test piece in distilled water at the standard laboratory temperature ($m_{0,w}$).

Place each of the test specimens in a 100 ml screw-top jar filled with the test solution. Separate jars shall be used for each of the different specimens in order to avoid any risk of cross contamination as a result of leaching. Specimens can be suspended in the test solutions by use of nylon filament threaded through the small hole and a small hole in the lid of the jar. This ensures that the specimen does not lie flat on the bottom of the jar. Tests shall be undertaken in duplicate.

Place the screw-top jars containing the components into an oven set at $82^{\circ}\text{C} \pm 2^{\circ}\text{C}$. After a minimum period of 336 hours, remove the samples, rinse in demineralised water, dry in warm air, and allow to cool to room temperature. Re-weigh the samples.

Control tests should be run using identical elastomeric materials immersed for a minimum period of 336 hours at $82^{\circ}\text{C} \pm 2^{\circ}\text{C}$ in soft test water alone. The results obtained under immersion in the inhibitor solutions are compared with those obtained under the control test conditions.

3.3 Non-metallic materials to be tested

Fresh (i.e. newly prepared) samples of elastomeric materials should be obtained from specialist suppliers and stored in a cool dark place prior to use. Only samples manufactured less than two years prior to the test can be used.

| Material | Reference ⁵ |
|-------------------------|------------------------|
| EPDM 70, sulphur-cured | 5073B / 032 |
| EPDM 70, peroxide-cured | 5073B / 003 |
| EPDM 70, resin-cured | 5373B / 001 |
| NBR 70, peroxide-cured | 4073B / 074 |

Table 5. Non-Metallics to be tested by Immersion

⁵Supplier Reference, Clwyd Compounders Ltd., Garden Industrial Estate, Ruabon, Wrexham, LL14 6RG

3.4 Expression of Results

After immersion, weigh each test piece in air (m_i) and then reweigh in distilled water ($m_{i,w}$). Test pieces and water shall be at the standard laboratory temperature.

Calculate the percentage change in volume ΔV_{100} using the following equation.

$$\Delta V_{100} = \left[\frac{m_i - m_{i,w}}{m_o - m_{o,w}} \right] - 1 \times 100$$

where

m_o is the initial mass of the test piece;

m_i is the mass of the test piece after immersion;

$m_{o,w}$ is the initial mass of the test piece in water (plus sinker if used);

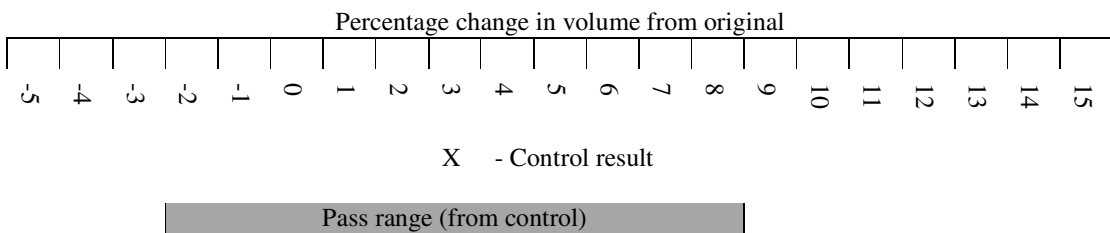
$m_{i,w}$ is the mass of the test piece after immersion in water (plus sinker if used).

3.5 Pass Criteria

An inhibitor will be deemed to have passed the test if the volume of the sample placed in the inhibitor is not more than 5% greater than the volume of the sample placed in soft test water, and the volume of the test sample placed in the inhibitor is not less than both 5% of the volume of the sample placed in soft test water and the volume of the sample piece prior to the test.

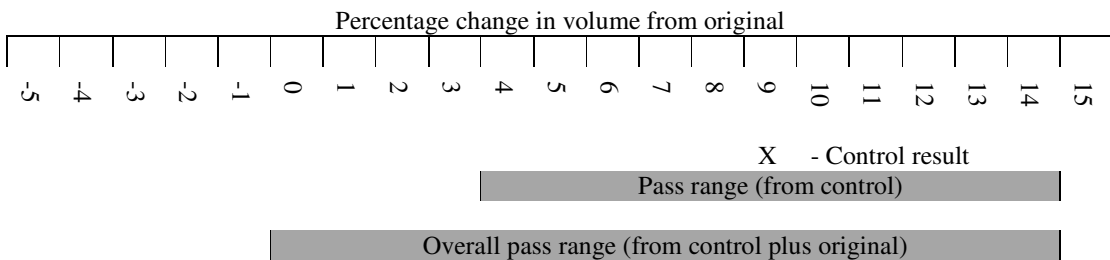
Example one:

If the volume of the sample placed in soft water increased in volume by 3% then the test sample would be deemed to have passed if its change in volume was between -2% and +8% from the original size.



Example two:

If the volume of the sample placed in soft water increased in volume by 9% then the test sample would be deemed to have passed if its change in volume was between 0% and +14% from the original size.



3.6 Visual Inspection

Each of the elastomeric materials tested shall be examined under a low-power optical microscope and photographed. An inhibitor shall be deemed to have failed the test if there is any visible sign of deterioration over and above that found on the corresponding sample immersed in the standard soft water.

Section 4. Reporting

A company confidential report shall be issued using the template provided in Appendix 2

FIGURE 1. Diagram of Glassware assembly

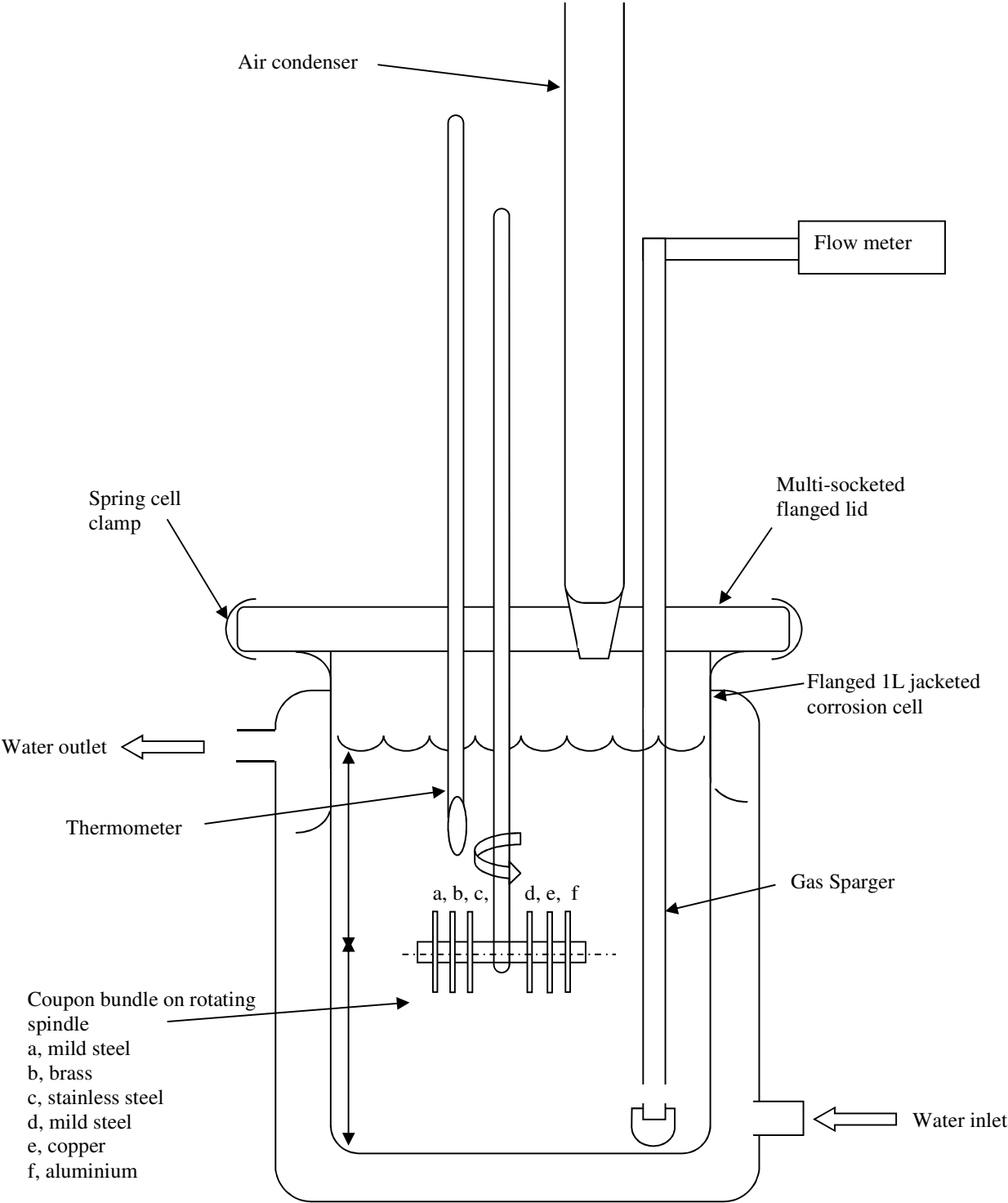


FIGURE 2. Diagram of Stainless Steel Heater Sheath

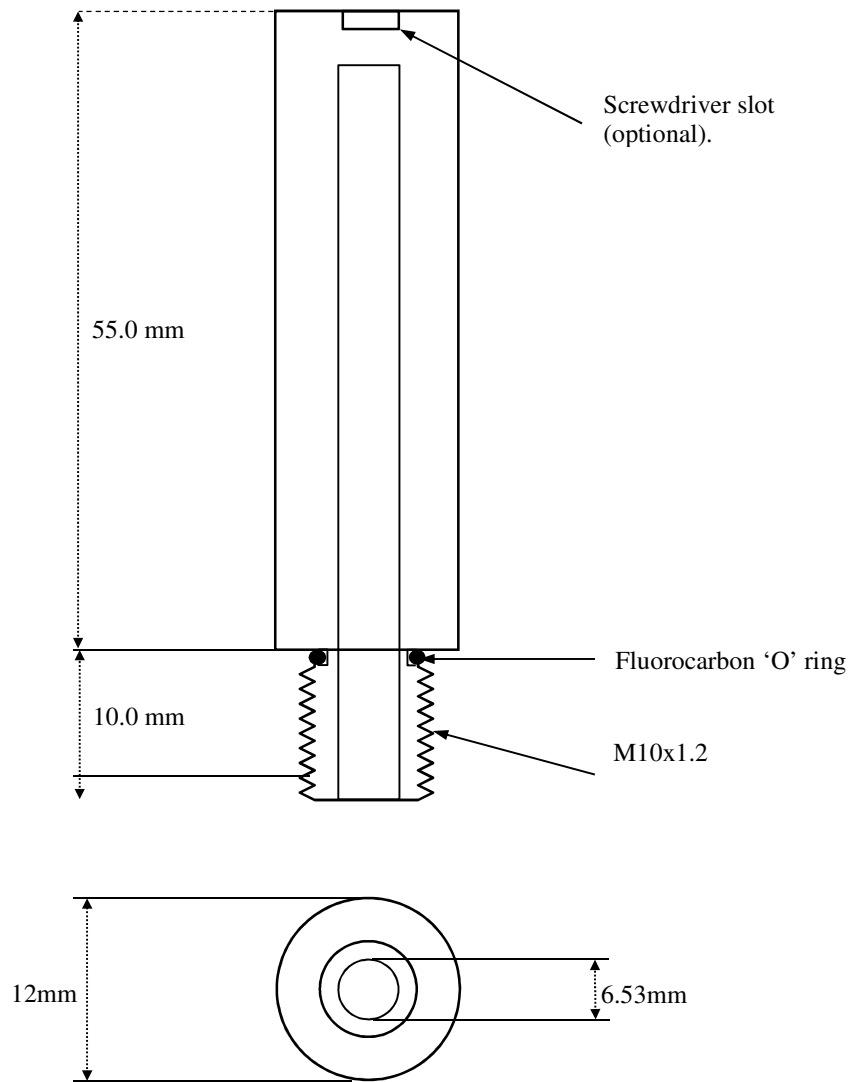
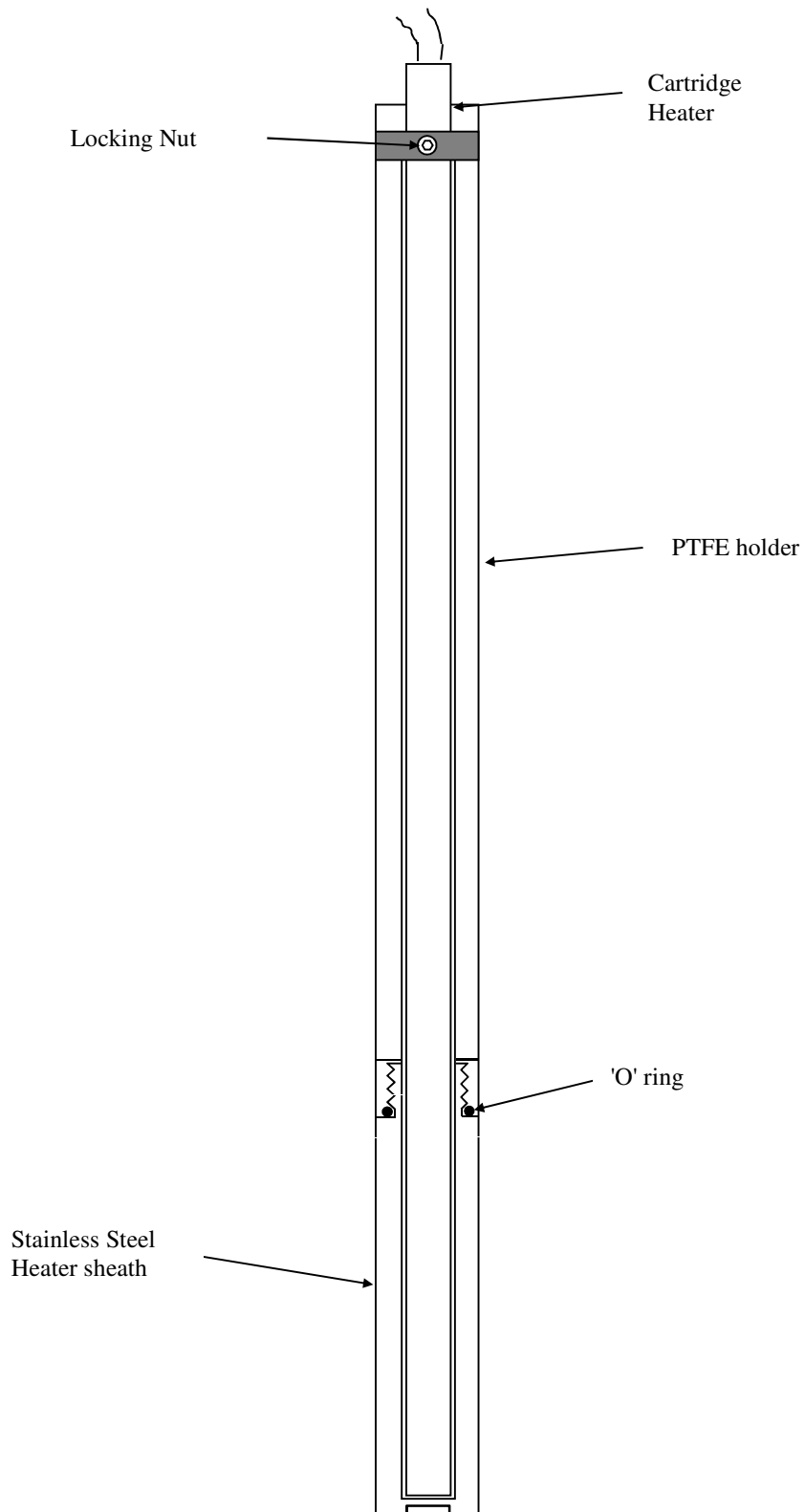


FIGURE 3: Diagram of Heater Sheath Assembly



Appendix 1: Standard Hard and Soft Test Waters

A.1 Preparation of Standard Test Waters

The standard hard and soft waters used throughout the CIAS test procedures shall be based on bottled, still mineral water and conform to the hardness specification outlined in Table 7. Test waters for the Corrosion Rate Determination require the addition of chloride and sulphate salts as detailed.

A.1.1 Standard Hard Water

The standard hard water shall be Evian bottled water. Fresh unopened bottles of water shall be used for each test and the batch numbers for the bottles used shall be documented to ensure traceability.

A.1.2 Standard Soft Water

The standard soft water shall be Aqua-Pura bottled water. Fresh unopened bottles of water shall be used for each test and the batch numbers for the bottles used shall be documented to ensure traceability.

Table 6 details recent published compositional analysis information for the two bottled waters (Evian and Aqua-Pura) which are used in the CIAS testing procedures.

| Water | Chloride | Sulphate | Total Hardness | Carbonate Hardness |
|-----------|--------------------|--------------------|--------------------------------------|--------------------------------------|
| | mg L ⁻¹ | mg L ⁻¹ | mg L ⁻¹ CaCO ₃ | mg L ⁻¹ CaCO ₃ |
| Evian | 9 | 13 | 310 | 287 |
| Aqua-Pura | 11 | 8 | 49 | 18 |

Table 6. Compositional analysis of bottled mineral waters used in CIAS testing

A.2 Preparation of Modified Standard Test Waters for use in Section 1. Corrosion Rate Determination.

The standard hard and soft waters need to be modified by the addition of chloride and sulphate salts so that the corrosion rates of the bottled waters are increased and that they conform to the specification outlined in Table 7.

| Parameter | Hard water | Soft water |
|--|------------|------------|
| Total hardness (mg L ⁻¹ CaCO ₃) | 310 ± 20 | 50 ± 10 |
| Carbonate hardness (mg L ⁻¹ CaCO ₃) | 290 ± 20 | 20 ± 10 |
| Chloride (mg L ⁻¹) [for corrosion rate test] | 60 ± 10 | 60 ± 10 |
| Sulphate (mg L ⁻¹) [for corrosion rate test] | 60 ± 10 | 15 ± 5 |

Table 7. Composition of test waters

Analytical grade sodium chloride and anhydrous sodium sulphate (both previously dried at 105°C ± 5°C) shall be added to adjust the composition as detailed below. All chemical additions shall be fully documented and traceable. Record the composition data for chloride, sulphate, total hardness and calcium hardness (alkalinity), from the bottled water label, with the preparation details for the chemical additions.

A.2.1 Modified Standard Hard Water

To prepare 2 litres (*):

Weigh out 0.1650 ± 0.0020 gm of sodium chloride and 0.1500 ± 0.0020 gm of anhydrous sodium sulphate and transfer to a 2 litre volumetric flask. Make up to the mark with standard hard water (Evian). If not used immediately, store in a polythene bottle at room temperature and use within 48 hours.

A.2.2 Modified Standard Soft Water

To prepare 2 litres (*):

Weigh out 0.1650 ± 0.0020 gm of sodium chloride and transfer to a 2 litre volumetric flask. Make up to the mark with standard soft water (Aqua Pura). If not used immediately, store in a polythene bottle at room temperature and use within 48 hours.

(*): Other volumes of modified test waters may be prepared as long as volumetric glassware (grade B or better) is used and weights are calculated on a pro-rata basis. All preparation details shall be fully documented and traceable.

Appendix 2: Inhibitor Evaluation Test Report

Assessment Laboratory Name:

Assessment Laboratory Address:

BuildCert Registration Number: BC

Customer Name:

Customer Address:

Procedure followed: BuildCert, CIAS Standard Specification for the Performance of Chemical Inhibitors for Use in Domestic Hot Water Central Heating Systems, February 2017

Product name:

Dosage rate:

Evaluation started:

Evaluation completed:

Evaluation carried out by:

Product Identification Code:

Summary

| | |
|-----------|-------|
| Pass | Fail |
| Comments: | |
| Assessor: | Date: |

Results Authorised by:

Position:

Signed:

Date of issue:

Note: These results relate only to the product named above. It should not be assumed that all products from this company meet all of the requirements of the BuildCert, CIAS Standard Specification for the Performance of Chemical Inhibitors for Use in Domestic Hot Water Central Heating Systems, November 2016.

Section 1. General corrosion rate

Batch reference and source/supplier of metal coupons:

Coupon Start Mass:

Coupon Finish Mass:

Water Source and Batch Numbers:

Test Start:

Test End:

Absolute Corrosion Rate:

| | Corrosion Rate measured, mm/year | | | | | | | |
|--------------------------|----------------------------------|--------------------|---------------------------------|--------------------|-----------------------------|--------------------|---------------------------------|--------------------|
| | Hard water, air sparging | | Hard water, natural aeration | | Soft water, air sparging | | Soft water, natural aeration | |
| Metal | Coupon bundle 1 | Coupon bundle 2 | Coupon bundle 1 | Coupon bundle 2 | Coupon bundle 1 | Coupon bundle 2 | Coupon bundle 1 | Coupon bundle 2 |
| Stainless steel | | | | | | | | |
| | Average: | | Average: | | Average: | | Average: | |
| Copper | | | | | | | | |
| | Average: | | Average: | | Average: | | Average: | |
| Extruded aluminium | | | | | | | | |
| | Average: | | Average: | | Average: | | Average: | |
| Brass | | | | | | | | |
| | Average: | | Average: | | Average: | | Average: | |
| Mild steel (1) (2) | | | | | | | | |
| | | | | | | | | |
| | Average: | | Average: | | Average: | | Average: | |

Pitting Density

| | Number of Pits | | | | | | | |
|--------------------------|-----------------------------|--------------------|---------------------------------|--------------------|-----------------------------|--------------------|---------------------------------|--------------------|
| | Hard water, air sparging | | Hard water, natural aeration | | Soft water, air sparging | | Soft water, natural aeration | |
| Metal | Coupon bundle 1 | Coupon bundle 2 | Coupon bundle 1 | Coupon bundle 2 | Coupon bundle 1 | Coupon bundle 2 | Coupon bundle 1 | Coupon bundle 2 |
| Stainless steel | | | | | | | | |
| | Average: | | Average: | | Average: | | Average: | |
| Copper | | | | | | | | |
| | Average: | | Average: | | Average: | | Average: | |
| Extruded aluminium | | | | | | | | |
| | Average: | | Average: | | Average: | | Average: | |
| Brass | | | | | | | | |
| | Average: | | Average: | | Average: | | Average: | |
| Mild steel (1) (2) | | | | | | | | |
| | | | | | | | | |
| | Average: | | Average: | | Average: | | Average: | |

Section 2. Scaling tendency

Laboratory reference of the Heater Sheath used:.....
 Sample chemical analysis results shall be appended in Annex A.
 Photographs shall be appended in Annex B

Test solutions prepared by: Weight. or Volume. [delete as appropriate.]
 Test Start Date:.....
 Test End Date:.....

| Sample Prep Dosage (%) | | | | | | | |
|---|----------------------|--------------------|-------------------------------|--|-------------------------|--|-----------------------------|
| Evian Water Batch Code | | | Evian Batch Ca Conc | | mg L ⁻¹ | | |
| Cell | <i>C1</i> | <i>C2</i> | <i>C3</i> | Calcium Ion Reduction <i>C1-C2</i> (Corrected) | % Calcium Ion Reduction | Balance <i>C3+0.1*(C2)</i> (Corrected) | Calcium Balance % Change |
| | Initial Calcium Conc | Final Calcium Conc | Total Calcium Conc | mg L ⁻¹ | % | mg L ⁻¹ | % |
| 1 | | | | #DIV/0! | #DIV/0! | 0.0 | #DIV/0! |
| 2 | | | | #DIV/0! | #DIV/0! | 0.0 | #DIV/0! |
| 3 | #DIV/0! | | | #DIV/0! | #DIV/0! | 0.0 | #DIV/0! |
| 4 | | | | #DIV/0! | #DIV/0! | 0.0 | #DIV/0! |
| 5 | | | | #DIV/0! | #DIV/0! | 0.0 | #DIV/0! |
| 6 | #DIV/0! | | | #DIV/0! | #DIV/0! | 0.0 | #DIV/0! |
| Average <i>C1</i> | | #DIV/0! | Arithmetic Mean (<i>M6</i>) | | #DIV/0! | | #DIV/0! |
| | | | Arithmetic Mean (<i>M4</i>) | | #DIV/0! | | |
| | | | | | #DIV/0! | | |
| | | | Analysis Result 1 | Analysis Result 2 | Average | Average <i>C1</i> Value (corrected) | Confidence % |
| Evian Raw Water (mg L ⁻¹ Ca) | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| Analysis QC Check | | #DIV/0! | | | #DIV/0! | | |

Comments or observations noted during the test:

Section 3. Compatibility with elastomeric materials

Batch reference and source/supplier of rubber:

Rubber Start Mass:

Rubber Finish Mass:

Test Start:

Test End:

| Elastomeric material | % change in volume of samples in control test (Standard Soft Water) | | % change in volume of samples in test solution, with inhibitor | | % change in volume – control vs. inhibitor | Visual inspection notes |
|-------------------------|---|-------|--|-------|--|-------------------------|
| | Set 1 | Set 2 | Set 1 | Set 2 | | |
| EPDM 70, sulphur-cured | | | | | | |
| | Average: | | Average: | | | |
| EPDM 70, peroxide-cured | | | | | | |
| | Average: | | Average: | | | |
| EPDM 70, resin- cured | | | | | | |
| | Average: | | Average: | | | |
| NBR 70, peroxide-cured | | | | | | |
| | Average: | | Average: | | | |

| | |
|----------------------------------|-------|
| Additional notes: | |
| Disruptions / equipment failure? | Date: |
| Detail: | |

Annex A: Sample chemical analysis results

Annex B: Photographs of the heater sheaths