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Functional Testing and Evaluation of the Advanced Crystallisation Process (ACP)™ Scale Inhibitor Unit

This independent test report was prepared by Department of Chemistry, University of Surrey.

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Introduction

1.1 The build-up of limescale (calcium carbonate, $CaCO_3$) deposits is estimated to cost the UK economy millions of pounds per year in increased energy bills as scaled surfaces have lower thermal conductivity and so take more energy to heat. Research (e.g. Glater et al, 1980) has shown 1mm of scale will result in an increase in energy costs of 7.5% while 25mm of scale reduces heat transfer by up to 95%. In addition increased appliance maintenance, equipment replacement and the cost of regular descaling and cleaning are estimated to exceed USD25 billion worldwide.

1.2 Currently scale is mainly treated with chemical inhibitors or by softening the water with ion exchange systems. Both can have damaging effects on the environment.

1.3 Addition of chemical inhibitors is an effective method for controlling scaling but this is best suited to enclosed systems (such as central heating). The use of metal cations such as copper and zinc is also well reported (e.g. Coetzee et al., 1998; Ghizellaoui et al., 2007) with zinc being the more effective. Zinc cations, as Zn2+, are thought to nucleate CaCO3 in the bulk of the liquid rather than at the surface. They also promote the formation of aragonite, a softer form of CaCO3 than calcite. Zinc ions are also known to disrupt and slow the formation of CaCO3.

1.4 This report details the results of the fuctional tests conducted on the ACP unit. Such tests were undertaken to asses the performance of the ACP device in reducing scale build up in heated water systems.

Method

2.1 The ACP unit (as supplied) was connected to a potable water supply at the University of Surrey, Guildford. Water was then passed through the unit for 48 hours in order to thoroughly clean it before a sample of 20 litres was taken for testing.

2.2 A 3kW domestic immersion heater element (supplied by RS Components Ltd, Corby, UK) was placed in the 20L sample of treated water and operated to maintain a water temperature of 75°C for 6 continuous hours. This was to simulate the conditions within heated water systems.

2.3 The resultant build-up of $CaCO_3$ scale on the heater was dissolved in 50mL of 0.5M nitric acid (HNO_3, supplied in concentrated form by Fisher Scientific, Loughborough, UK and diluted with ultrapure (18.2MΩ) water). This solution was then analysed by an Agilent Technologies 7700 ICP-MS to determine calcium content.

2.4 A 20L sample of untreated water was treated and analysed in the same way (using a second immersion heater element) to provide a control sample comparison.

2.5 The water quality of the potable source is shown in Table 1.

Table 1: Potable Water Source Parameters (Thames Water Quality Report for GU2 7XH)

Property	**Value**
pH	7.3
Hardness as $CaCO_3$	251 mgl^{-1}
Zinc concentration	0 mgl^{-1}

2.6 The test unit under evaluation was an Advanced Crystallisation Process (ACP)™ 20. The unit was installed vertically on the test rig and the outside case was connected to earth as per the manufacturer's instruction.

Results

3.1 During the test, scale formed on the heater elements for both samples. The quantitative evaluation of Ca for both the treated and untreated/control samples is shown in Table 2

Table 2: Calcium concentrations

Sample name	**Concentration ^{44}Ca (mgl^{-1})**
Detection Limit	*0.001*
SRM 1640*	5.630 ± 0.024
Control (untreated water)	**1481**
ACP treated water	**271.7**

*NIST Standard Reference Material; reference value: 5.516 ± 0.021 mg/l Ca (n=2)

Conclusions

4.1 The ACP unit works as an electrolytic scale inhibitor (ESI). It operates by virtue of the electrolytic action between brass and zinc to dose zinc ions as Zn^{2+} into the water stream. These have the effect of reducing calcite scale build-up.

4.2 During the analysis measured calcium could only come from the scale dissolved from the element. It can be concluded therefore that treatment with the ACP unit prevents over 80% of scale formation. This potentially represents in excess of a 5 fold reduction in scale build up within heated water systems.

Appendices

5.1 Photograph of ACP unit below. Water enters at the bottom (capped end). The unit is earthed when in use.

5.2 Photograph of immersion heater element test rig set up. The element is immersed in 20L of potable water and operated at 75°C for 6 hours, the element has an integral thermostat to regulate heating.