The effectiveness of a magnetic physical water treatment device on scaling in domestic hot-water storage tanks

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Abstract

In this paper the effectiveness of a permanent magnet for the prevention of scale was investigated. Experiments were conducted on two electrically heated domestic hot-water storage tanks. Ten experiments were conducted, each over a period of 28 d in which 8 000 ℓ of water was heated to 75°C, while the quality of the feed water and mass precipitation of calcium were monitored. In four of the experiments reproducibility was investigated which was found to be good. In the other six experiments the effect of the permanent magnet was evaluated by commuting it between the two storage tanks. It was found that the permanent magnet was effective in suppressing the mass precipitation of scale in all six these experiments.

Keywords: physical water treatment, permanent magnet, hot water, storage tanks

Introduction

Scaling problems in a heating or cooling system can be recognised by one or more of the following symptoms: reduction in heat transfer rate, in which the formation of an insulating deposit on a heat transfer surface significantly reduces the cooling or heating efficiency of the equipment; reduced water flow, which results from a partial or complete blockage of pipelines, condenser tubes, or other openings. Even a small build-up of scale on a heat exchange surface reduces water flow. Scale may continue to build up in boilers until heat transfer is so low that the metal overheats, permitting the tubes to rupture under the operating pressure. Scale is usually found in water-handling equipment in which water is heated, i.e. hot-water storage tanks, boilers, etc.

The magnitude of this problem may be appreciated by considering that scaling can cause degradation, or complete failure in thermal and hydraulic performance which increases initial and operating costs (Chan and Ghassemi, 1991). In a fairly low-pressure boiler, only 0.6 mm of calcium sulphate scale on the tubes results in a 180°C temperature drop. The cost involved due to heat transfer inefficiency and the removal of scale, in Britain alone, is estimated at £1 billion per annum (Darvill, 1993). Poor conductivity of a 25 mm thick $CaCO_3$ scale layer can decrease the heat transfer by 95% (Glater et al., 1980), whereas a SiO_2 scale layer 0.5 mm thick results in a 90% decrease in heat transfer (Grutsch and McClintock, 1984).

The suggested mechanism by which scaling occurs is as follows: The calcium in the solution, is derived either from dissolution from natural resources, or from chemicals added during water treatment. The concentration of CO_2 dissolved in the water determines the dissolution of calcium carbonate. Calcium carbonate becomes less soluble at higher temperatures and on heating, CO_2 escapes favouring the bicarbonate decomposition reaction which causes calcium carbonate to precipitate. At a pH value of less than 8.8, the solubility of calcium carbonate increases with decreasing pH and decreases with rising temperature. If the pH is larger than 8.8, the solubility increases with increasing temperature and pH (Yacoby, 1995). Pure calcium carbonate is found in three general forms, i.e. vaterite, calcite, and aragonite with calcite being the major constituent in calcium carbonate scale. To try to prevent or minimise the formation of scale, different techniques have been developed. These techniques can be divided into the following groups: chemical, detonation-wave techniques, blow-down, and physical water treatment (PWT).

Since the first physical water treatment patent was registered in 1945 (Vermeiren, 1958), hundreds of these PWT devices have appeared on the market that are reported to reduce scale formation and blow-down requirements without chemical treatment. These devices include those based on permanent magnets, electromagnets, high frequency electric fields, high voltage electrostatic fields, ultrasonic treatment, flow restriction and catalytic conversion.

The efficiency of physical water treatment devices for the prevention of scale is a controversial subject. Busch et al. (1986), for example, surveyed approximately 60 papers on this subject. They have found that many contradictions exist in the claimed effects, and that even when performance is reported to be effective, the results are typically characterised by low reproducibility. Busch et al. (1986) state that "No agreement exists on optimum operating parameters that should be used in the installation of these devices, and in many cases, exact experimental conditions are not given, which makes valid inter-comparison of the results nearly impossible. Finally, many of the theories relating magnetic fields to scale formation involve unsubstantiated, pseudoscientific postulations of strange, mysterious effects of the magnetic field on the structure of water and dissolved minerals. All of these factors have created a great deal of scepticism with regard to this technology." In a review paper by Baker and Judd (1996) it was concluded that at that stage it was still not certain as to whether magnetic suppression of scaling was a *bona fide* phenomenon.

It is the purpose of this study to evaluate the effectiveness of a permanent magnet, as a physical water treatment device, for the

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