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Removal and/or prevention of limescale in plumbing tubes by a radio-frequency alternating electric field inductance device

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ABSTRACT

Fouling problems due to limescale formation are of major concern to many industries. Deterioration of heat transfer equipment performance and substantial increase of pressure drop across piping systems comprise the main problems, resulting in high machinery-maintenance cost and decreased productivity. Limescale removal techniques, like scraping, hydro-blasting, and the use of aggressive chemicals, shorten the life of pipes and machinery. Furthermore, limescale prevention techniques in industrial scale, like ion-exchange or reverse osmosis, require expensive equipment and heavy maintenance. In this paper, an electronic antifouling device is presented which, not only prevents limescale formation, but also removes existing scale in plumbing tubes, at insignificant energy consumption. Induction of a Radio-Frequency Alternating Electric Field (RFAEF) in water at a specific range of frequency and antenna voltage, along with its distinct sinewave waveform, changes the way minerals precipitate, minimizing hard-lime scale by producing instead a non-adherent mineral powder in the bulk water. Moreover, the unsaturated solution that is created, along with enhanced carbon dioxide production, dissolves gradually the existing scale in plumbing tubes. Furthermore, the RFAEF inductance device demonstrates a major improvement over other pulsed-power systems, proving this electronic antifouling technique suitable for both hard and soft waters, as well as for large-scale applications.

1. Introduction

Scale is the well-known crusty chalky build up that forms when hard water is being processed in heat transfer equipment, such as, heat exchangers, condensers, evaporators, cooling towers, boilers, pipe walls, as well as, household appliances. Scale composition differs from application to application depending on the mineral content of the utilized water. The most common component of scale though is calcium carbonate ($CaCO_3$), which occurs naturally as an ingredient of chalk, limestone, and marble. When hard water is pumped into heat transfer equipment, calcium and bicarbonate ions precipitate due to the changes in solubility, forming hard deposits (limescale) on the heat transfer surfaces, clogging pipes and manifolds (Reaction (1)); a phenomenon traditionally called “fouling” [1–3].

$$Ca^{2+} + 2HCO_3^{-} \rightleftarrows CaCO_{3(s)} + H_2O + CO_{2(g)} \quad (1)$$

Fouling problems are of major concern to many industries using water and heat. Examples include petroleum, food, marine, mining, air compressor, and air separation industries. Once scale forms on a heat transfer surface, at least two major problems associated with the scale occur. The first problem is the deterioration of the heat transfer equipment performance due to the much lower thermal conductivity of scale compared to that of pipe materials [4–6]. The second major problem is that a small change in tube diameter, substantially increases the pressure drop across the water piping system [7]. Scale creates also secondary problems of a big concern such as, rust accumulation leading to corrosion, increased growth of bacteria in drinking water [8,9], high machinery-maintenance cost, and decreased productivity due to increasing production downtime while equipment is repaired and maintained, equipment failure or even total damage [2,6]. Thus, it is self-evident that if one can reduce or prevent fouling in heat transfer equipment, the savings in energy, maintenance, and replacement of equipment will be truly significant.

Among the current techniques to prevent fouling is the use of scale-inhibiting chemicals, such as dispersing or chelating compounds that chemically grip dissolved cations, thus neutralizing them. Ion exchange and reverse osmosis are also used to reduce water hardness, alkalinity and silica level [2,3]. However, this equipment is expensive in industrial scale and requires heavy maintenance for proper operation. Furthermore, once fouling occurs in the piping system, scales need to be

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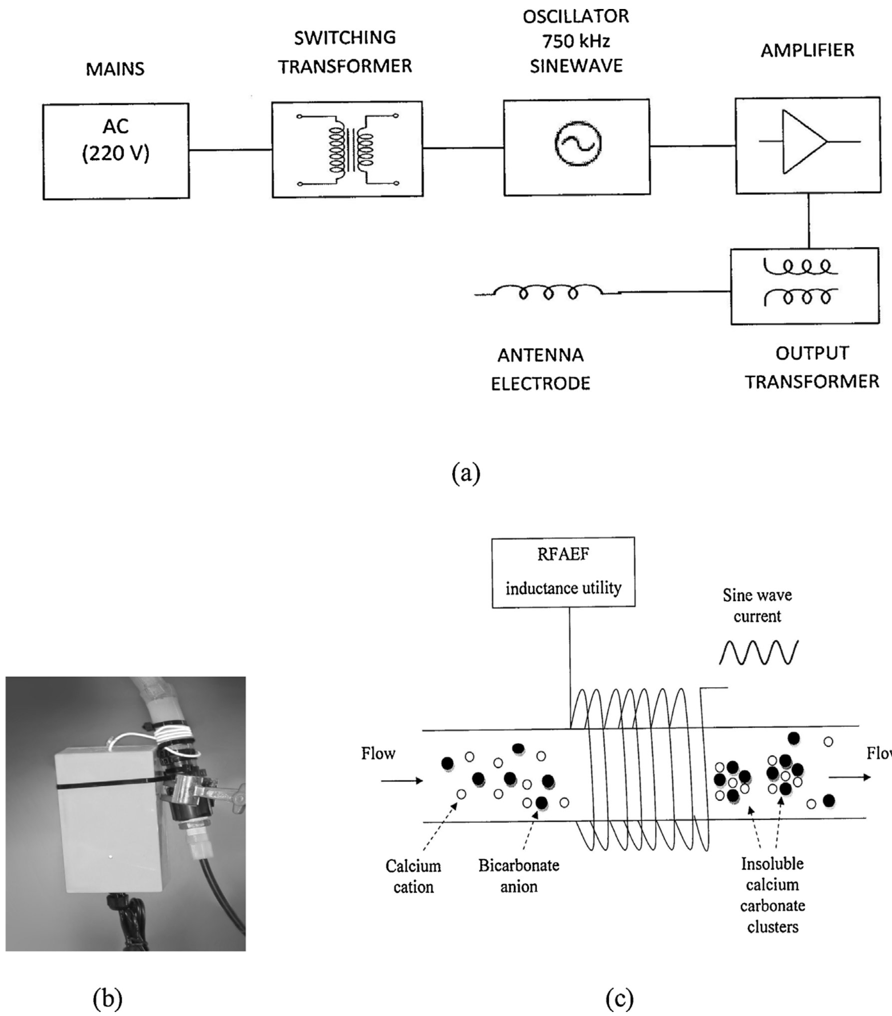

Fig. 1. (a) Block diagram, (b) photo, and (c) illustration of the operating principle of the RFAEF inductance utility.

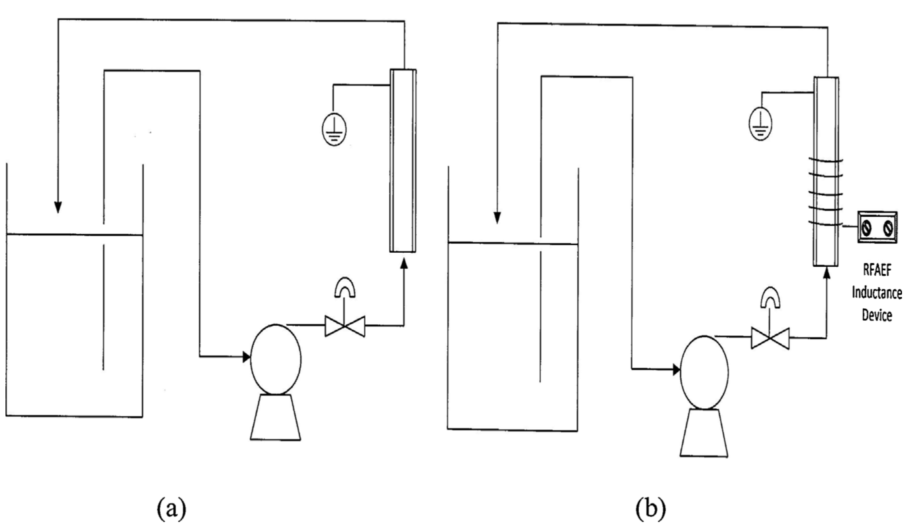

Fig. 2. Flowsheet of the experimental installations; (a) without the RFAEF inductance device, (b) with the RFAEF inductance device fit on the plumbing tube.

Table 1
Scale prevention experiment – water characteristics.

pH	Alkalinity (mg/L $CaCO_3$)	Total Hardness (mg/L $CaCO_3$)	Conductivity (μS/cm)
8.4	600	600	2,030

removed by using several cleaning techniques, like, aggressive acidic chemicals, scraping, hydro-blasting, sand blasting, or the use of metal or nylon brushes. The latter operations incur downtime and repair costs, while they also shorten the life of the pipes and the machinery. Moreover, all the above scale-removing techniques pose danger on both human health and the environment with accidental spills, or accumulated chemical residues over a long period of time [10,11]. Thus, there is an increasing need for a new, environmentally safe and economically