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Use of RF electric fields for simultaneous mineral and bio-fouling control in a heat exchanger☆

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ABSTRACT

The objective of the present study was to investigate the effectiveness of a physical water treatment (PWT) technology using oscillating RF (radio frequency) electric fields in water to mitigate both mineral and bio-fouling in a cooling water application. Heat transfer tests were conducted using a laboratory-scale cooling tower to determine fouling resistance over time, and bio-fouling tests were performed using a heterotrophic plate count method to measure colony forming units (CFU) values per milliliter of cooling water. The results indicated that the present PWT technology could provide an effective mineral fouling prevention by maintaining 90% of the peak heat transfer performance of a heat exchanger, while effectively controlling water-borne microbial organisms.

1. Introduction

Cooling-water systems are used throughout residential, commercial and industrial buildings. One of the drawbacks of water-cooling systems however is that mineral and bio-fouling tend to develop on and around heat transfer surfaces, which significantly reduces overall heat exchanger performance and increases the operational costs. It is therefore essential to prevent or control both mineral and bio-fouling on and around heat transfer surfaces. Currently, industry-standard practices for preventing mineral and bio-fouling call for the addition of scale-inhibiting chemicals and biocides to circulating cooling water [1,2]. The use of such chemicals contributes to fresh water pollution, a major environmental concern. Several physical water treatment (PWT) methods [3–11] have been introduced in recent years as alternatives to standard chemical water treatment; some of the best results have been documented using solenoid-type PWT technologies using oscillating fields. However, these PWT methods produce relatively weak oscillating magnetic and/or electrical fields due to limitations governed by the laws of physics [12]. Moreover, the effectiveness of such methods on bio-fouling control has not been clearly demonstrated.

The present study introduces a new PWT technology that utilizes two graphite electrode plates immersed in water at a cooling tower sump, applying RF electric fields directly in cooling water, rather than indirectly by means of a solenoid mechanism. The study examines the performance of the new PWT technology for both mineral- and bio-fouling controls. By applying RF electric fields directly in water, it was possible to vary both the strength and frequency of the electric fields over a wide range.

When circulating cooling water is exposed to the RF electric fields, particles of calcium salts have been shown to be produced in the water through the bulk precipitation mechanism [5,8]. Accordingly, the suspended particles tend to form particulate fouling rather than precipitation fouling. In cooling water applications, the particulate fouling often results in soft sludge coating on condenser tubes that can be easily removed by the flow velocity of moving water, thus preventing mineral fouling on the tubes. Previously, microbes have also been reported to be killed by pulse electric fields of in the MHz frequency range [13].

The objective of the present study was to investigate the efficacy of the present PWT method using RF electric fields in water on the prevention of both mineral and bio-fouling in a heat exchanger.

2. Experimental facility and method

The effectiveness of a new PWT technology using RF electric fields was studied in a heat-transfer fouling test (HTFT) setup with a laboratory-scale cooling tower. Fig. 1 shows the test facility, which consisted of a water circulating loop, the new PWT device (i.e., two electrode plates at the tower sump and a control unit), a cooling tower, a pump, a HTFT setup, a conductivity meter, and a floating-ball valve for make-up water. The HTFT system consisted of a water heater and a heat exchanger test section where scale accumulation took place on a copper tube surface. In addition, the HTFT system was equipped with a transparent outer shell through which the fouling process was monitored using a digital camera by directly observing the scale deposition during the fouling test. The HTFT system was also equipped with four temperature sensors for determination of the

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