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Analysis of pitting corrosion failure of copper tubes in an apartment fire sprinkler system

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ABSTRACT

Microscopical and structural analyses as well as visual inspection of copper tubes were used to investigate the cause of pitting corrosion failure of copper tubes in the wet pipe sprinkler system. Chemical analysis of the water in the copper tubing and XRF/XRD analysis of its sediments were also used to obtain hints on what was happening in the copper tubing during the progress of the pitting corrosion. It was found from the failed copper tube that a significant amount of pressurized air was present over the water in the copper tubing during operation and a series of corrosion pits were aligned adjacent to the water/air line. The waterline localized corrosion, a type of differential oxygen concentration cell corrosion, induced by pressurized air over the water in the copper tubing was identified as the cause of the pitting corrosion failure. A state of a very low oxygen concentration was maintained under the envelope of a dense layer of malachite, the corrosion byproduct, which was evidenced by the formation of Cu_2O crystalline particles inside the corrosion pit. CuO particles observed on the inside surface of the copper tube do not seem to help prevent local as well as general corrosion. Accelerated pitting corrosion of the copper tube in the wet fire sprinkler system was simulated using a differential aeration cell. Finally, measures for stopping or delaying the pitting corrosion of the copper tube in the wet sprinkler system are suggested.

1. Introduction

Fire sprinkler systems are now extensively used worldwide at commercial buildings as well as homes, schools and apartment buildings for fire protection. In 2011 Wales, UK became the first country in the world where fire sprinklers are compulsory in all new homes [1]. In South Korea, high rise apartment buildings with more than 11 floors have been enforced to install fire sprinkler systems since 2009 [2].

Depending on whether the water distribution pipes are filled with water or not, a fire sprinkler system is classified as the wet pipe fire sprinkler system or the dry pipe fire sprinkler system [3]. The wet pipe fire sprinkler systems are installed more often than the dry pipe fire sprinkler systems because they are more reliable, simpler, and more cost effective both in installation and maintenance. Fig. 1 is a schematic diagram of a typical wet pipe sprinkler system. It consists of sprinkler heads connected to a water distribution piping system and a water supply system. The water distribution pipes of the wet fire sprinkler system

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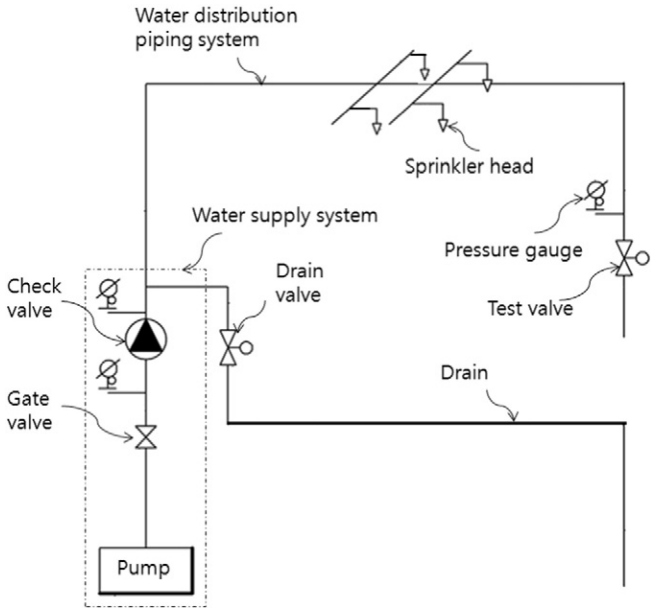

Fig. 1. Schematic diagram of a typical wet pipe fire sprinkler system.

are always filled with water up to the sprinkler heads so that they are quick to react when sprinkler heads become open by the heat of fire.

Either metallic or PVC tubes have been used for the water distribution pipes of the wet pipe fire sprinkler systems. Some construction companies in Korea chose to use copper tubes for the wet sprinkler systems of the apartment buildings constructed during the period of 2009 to 2013. This decision was made on the basis of better corrosion resistance and easier installation of copper tubes compared to steel tubes. Actually, in Europe and North America, copper tubes accounted for more than 80% of all tubes installed in water service [4]. Even though copper tubing was expected to give better performance in the wet fire sprinkler systems as well, many apartment buildings with copper tubes installed in their fire sprinkler systems have suffered from severe water leakage from the copper tubes starting from the year 2011 to the present time because of pitting corrosion of copper tubes. In this study the cause of the pitting corrosion failure of copper tubes in the wet pipe sprinkler system was identified through microscopical, structural and chemical analysis of copper tubes with pitting failure, the water and its sediments from several apartment sprinkler systems in an apartment complex. Accelerated pitting corrosion of the copper tube in the wet fire sprinkler system was simulated using a differential aeration cell. Finally, measures for stopping or delaying pitting corrosion of the copper tube in the wet sprinkler system are suggested.

2. Experimental procedures

2.1. Visual inspection of the copper tubes with water leakage

Copper tubes removed from an apartment fire sprinkler system of an apartment complex due to water leakage were cut longitudinally into halves for visual inspection. Pictures of the pitting corrosion area were taken by a digital camera and the positions of pitting corrosion were located relative to the water/air line.

2.2. Microscopical and structural analyses of corrosion pits

The morphological images and the compositions of the materials in the pitting corrosion area of the copper tubes were obtained by a scanning electron microscope (SEM) equipped with an energy dispersive X-ray spectroscope (EDS). Powder X-ray diffractometer (XRD) and micro-XRD were also used to identify the materials in the pitting corrosion area.

2.3. Analysis of the water and its sediments in the copper tubes of the sprinkler system

The chemical compositions of the water samples collected from the fire sprinkler systems of the apartment complex were analyzed by atomic absorption spectrometry (AAS), inductively coupled plasma optical emission spectrometry (ICP-OES) and ion chromatography (IC). Sediments from the water samples were analyzed by X-ray fluorescence spectroscopy (XRF) and powder XRD.