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Failure analysis of a hard-drawn water tube leakage caused by the synergistic actions of pitting corrosion and stress–corrosion cracking

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ABSTRACT

Unalloyed high purity copper, deoxidized with phosphorus is widely used in tubing and fittings for sanitary installations due to its ease of use and corrosion resistance properties. Certain factors related to installation operating conditions on the one hand, and improper design/installation features on the other hand, often lead to unexpected failures. The case examines a Cu-tube that failed in a pump station after 2–3 years in-service. The investigation findings suggest strongly that the failure was the result of a complex mechanism involving corrosion–erosion process, facilitated by stress–corrosion cracking mechanism. Stress–corrosion cracking referred as a delayed failure mechanism resulted from the synergistic effect of corrosive environment, susceptible material and externally applied or residual – due to the manufacturing process-stress. In case of hard-drawn tubes, the development of tensile (circumferential or hoop) stress field at the outer surface area after cold drawing, enhances the propensity for stress–corrosion cracking (SCC), especially under the presence of corrosive environment.

1. Introduction and background information

Deoxidized-high-phosphorus (DHP) copper tubes exhibit long-life service and, therefore, are extensively used in water, healthcare, heating and refrigerant facilities due to their exceptional functionality and serviceability: high thermal conductivity, heat transfer characteristics, formability, corrosion resistance and antibacterial properties. Characteristic failures of copper tubes may be attributed to localized – pitting corrosion [1], stress–corrosion cracking [2,3], intergranular corrosion [4,5], erosion–corrosion [6], fatigue [3] and/or corrosion fatigue and microbiologically influenced corrosion (MIC) [7], and, of course, the combination of the above mechanisms. The classification and evolution of pitting corrosion processes as well as the various corrosion product layers grown on metal surface are identified and thoroughly presented in [1]. However, design and installation deficiencies or aggressive environmental conditions (such as improper water chemistry or chemical substances that can cause severe chemical attack) are very important contributors of tube unexpected damage that leads to leakage.

Samples from a DHP copper water tube (nominal dimensions: 76 mm outer diameter × 2 mm wall thickness, hard-drawn temper) which experienced leakage during operation after 2–3 years in-service, were brought for failure investigation. Optical and scanning electron microscopy coupled with energy dispersive X-ray spectroscopy for local elemental analysis,

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