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Examples of Stress Corrosion Cracking in Copper Piping for Heating and Cooling Systems

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Copper piping systems are used to transport heating and cooling water in high rise buildings. Stress corrosion cracking has been identified as a failure mechanism normally occurring in the infancy of the life of the systems. Examples and characteristics of the material and crack morphology are presented.

Within the first 2 years of operation, a high rise building had reported 3 incidents of leaking copper pipes in the fan coil system. These 1" diameter copper pipes were insulated with a black foam. In several areas, nylon wire wraps (or zip-ties) were found. Some of those areas contained water which was apparently dammed in the annular space between the insulation and the copper tube. In the areas of the leaks, the pipe had a black appearance in contrast to the typical clean copper color. There were also isolated areas of greenish deposits, but these green deposits did not appear to be directly related to the failures. The observed cracks were predominantly longitudinal with only short isolated transverse cracks connecting adjacent longitudinal cracks. Visual and low power microscopy indicated only short cracks on the inside of tubes where longer cracks were found on the outside.

The copper tube material was specified as ASTM B88 grade C12200, type L. The chemical properties and hardness values (66 HR30T) were typical of C12200. The hardness was relatively high, though no maximum hardness was specified. Residual stress measurements indicated values in the 20,000 to 25,000 psi range in the circumferential direction. The microstructure consisted of alpha grains which were elongated typical of a cold worked product. In the cracked areas, brittle intergranular cracks were observed with branching characteristic of Stress Corrosion Cracking.

Analysis of corrosion deposits by x-ray diffraction, found copper oxide and copper carbonate as primary constituents. No significant nitrate compounds were detected. Analysis was performed on air and water found in the annular space between the pipe and insulation. Ammonia was indicated in both cases.

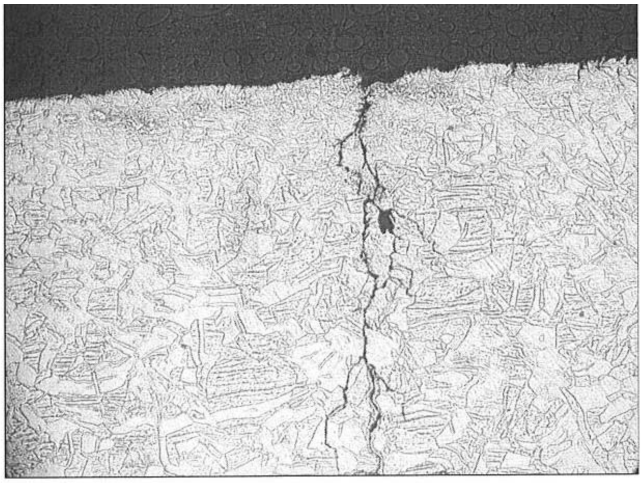
Based on the testing of the fractured and other samples of the copper piping samples, it appears that the cracking was due to SCC of the copper tube due to the combination of high residual stress in the copper tubes and the release of ammonia from the insulation. The presence of water in the annular space between the tube and insulation significantly contributed to the failure in that the water promoted release of ammonia and corrosion of the copper. The water may have been introduced by rain or snow events during construction when the piping system was being built. Heat from brazing operations was also a potential contributor to the release of ammonia.

Figure 1 – To the right is a sample of cracked copper tubing and the black foam insulation which had been on the outside.

Figure 2- An illustration of the cracks observed on the outside of the tubing is shown in the photograph to the right.

Figure 3 - the image at the right shows the typical microstructure of cold worked alpha grains. Original magnification was 100X, etch ammonium hydroxide and hydrogen peroxide.

Figure 4 – A typical example of the cracking observed in a section from the copper tube. Original magnification was 100X, etch ammonium hydroxide and hydrogen peroxide.



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