Corrosion On a PVC Irrigation System

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A two and one-half inch ips male thread-to-tubing nipple.

ONE WOULD ordinarily think that copper fittings on an underground plastic piping system would not corrode; there is much experience to back this up. This was not the situation, however, in an automatic sprinkler system installed several years ago in the community center of a major city in Michigan where an abnormal situation resulted in leaking at the copper fittings.

The installation involved copper fittings in conjunction with automatic brass valves and plastic piping on the main and lateral runs. Back flow prevention was provided consisting of line size vacuum breakers on the discharge side of each zone control valve.

The underground specifications called for sizes two-inch and smaller being flexible, non-toxic plastic pipe made from 100 percent virgin polyethylene with a minimum 80 psi working pressure. All stainless steel clamps were to be used to secure the joints. Joints one inch to one and one-half inches and larger were to be double-clamped. All plastic pipe was to be continuously and permanently marked with the manufacturer's name, material, size and schedule or type; pipe conformed to PE 2306-Irrigation pipe. Sizes two and one-half inches and larger were to be virgin high-impact polyvinylchloride pipe with a minimum 125 psi test; pipe was to conform to ASTM C-178-60T. Pipe fittings were to be either copper pipe with wrought solder fittings or flexible polyethelene fittings on automatic drain and underground branch line only. PVC solvent weld fittings were also allowed.

Other details of the manual valves, remote control valves, automatic controllers, valve boxes, drains, and so on, are not germane to the ensuing problem.

At the time the investigation started, the system was approximately a year old, and was buried in soil not considered overly aggressive. However, in a short period of operation, leakage was found at several of the copper fittings on the underground systems. City officials and others involved in the problem immediately began to look for such things as electrolysis, stray currents from nearby radio transmitters or unusual soil conditions. The water used for sprinkling was city water.

When the investigation of the cause of corrosion started, three threaded copper adaptor pieces were received. The pieces may be described as follows:

- Small piece, two and one-half inch ips male thread-to-tubing nipple with a short length of two and one-half inch copper tubing attached by a soldered joint.
- Medium piece, two two-inch ips male thread-to-tubing nipples joined together to a short length of two inch copper tubing by soldered joints.
- Large piece, two-inch ips male thread-to-tubing nipple soldered to a piece of two-inch tubing, in turn soldered to a two-inch to one and one-half inch reducing bushing, soldered to a piece of one and one-half inch tubing.

The small piece showed attack at only one area in the threads; this was located three threads back and was slightly oval in shape. Sand was present in the threads on most of the piece, indicating that no more than three threads had been properly engaged.

The medium piece showed the largest amount of attack. There was a large section chewed out of the threads on one end with the adjacent threads attached. The octagonal shanks of the fitting were worn smooth right down to the solder in one area. The other threaded end was perfect, with the first four threads clean and shiny showing full engagement; the remaining six threads had a visible trace of a blue compound plus very definite grains of sand in many of these threads. On the attached end, from the color of the threads and the location of the sand in the threads, it was very evident that no more than two threads had been fully engaged.

The large piece had been coated after removal with a blue PVC joints cement over a large part of the threads. Thus, the presence of sand and gradations in color would not be clearly differentiated. However, the location of attack was, at one

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point, in the threaded portions of the nipples.

Metallurgical examination was carried out by removing sections from both small and large pieces. The microstructure was normal for drawn copper fittings with no signs of metallurgical contaminants such as copper oxide. The structure of the attacked areas was the same as the unattacked. There was no sign of pitting, stress corrosion, intergranular corrosion attack, and so on. Chemical analyses were not run since metallographic examinations showed no abnormal phases nor were specifications on the copper fittings spelled out to allow any comparison.

Examination at low magnifications (three to 15 times) clearly showed the nature of the attack. The medium piece showed the greatest attack and the clearest differentiation of the mechanism. The maximum attack in the threads started at the inner end of the thread and progressed back six threads at one location. The attack was characterized by overlapping shallow depressions in both the root and the top of the threads as well as along the sides of the thread. There was a definite clockwise orientation to the attack in the direction of the right-hand thread. This was characteristic of the attack on all threaded joints. Downstream of the attack area there was no attack. The hole in the medium piece, which was elongated transversely to the length of the tubing and nipples, was in direct line with the eroded portion of the shank of the two nipples.

There was no sign of attack on the interior of the tubing or fitting and the hole clearly proceeded from the inside outward. The surface of the tubing and the nipples showed an exceptionally smooth wear pattern and with no grooves or scratch marks. Obviously, the copper wall of the tubing had been worn by external erosion of escaping water to the point where it could no longer withstand the internal pressure; the tubing then ruptured.

Dr. Mars Fontana of The Ohio State University, the senior author of "Corrosion Engineering" (McGraw Hill, 1967), lists eight forms of corrosion and the factors causing each type of corrosion on copper. Two additional types of corrosion have been added since they are corrosion caused by environmental conditions.

Examination of the pieces and description of the corrosion allows the conclusion to be drawn that the corrosion was NOT:

1. Uniform—The attack would not have been uniquely located in just a part of the threads if the soil were corrosive and would have been found inside the tubing if the water were corrosive.

2) Galvanic—So far as is known, copper nipples were not in contact with cast iron or passive stainless steel or graphite; in addition, attack would have appeared entirely around the threads.

3) Crevice—Again, the attack would have appeared entirely around the threads in all crevice areas and not just a small area.

4) Fitting—The attack would have been more evenly spread over the threaded area without the unique orientation found.

5) Intergranular—No attack was seen at grain boundaries on metallurgical examination.

6) Selective leaching—No such attack was seen on metallurgical examination nor was there a second element present in the copper for such an attack.

7) Stress—Metallurgical examinations showed no stress corrosion

This is the medium piece — a two inch ips male thread-to-tubing nipples joined together to a short length of two inch copper tubing by soldered joints.

cracking (the pieces were in the annealed condition).

8) Soil—Attack would have been on the exterior of the copper pieces and not uniquely in the threads.

9) Stray current—Attack would have been localized on certain portions of the exterior and not in the threads.

The corrosion of the copper fittings is traced to cavitation corrosion in the threads, followed by erosion-corrosion of the exterior of the shank of the two nipples and the tubing joining the nipples ("medium" piece).

The fact that sand and blue "thread cement" were still visible on all but the first two or three starting threads of the nipples establishes that there were insufficient threads in contact. The on-off operation of the sprinkler system with the fluctuating pressure from zero to full line would then cause cavitation to progress along a path of seepage of water to the exterior. This would account for the clockwise orientation of the attack and the roughened appearance of the attack.

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In the case of the medium piece, when water wore a big enough path through the threads, its jet action then caused erosion of the shank and the tubing joining the nipples. When the tubing was worn down to a thickness less than 1/64 of an inch, rupture of the tubing occurred due to insufficient wall thickness to resist pressure. Reference to the "Piping Handbook" indicates that joint sealants such as litharge and glycerine or glypton are preferred for tight joints. In addition, the Handbook points out that for two-inch pipe size, five threads should be engaged for a hand-tight connection. For two and one-half inch pipe size, approximately five and one-half threads should be used. The Handbook further states that Teflon thread lubricant should be used in assembling threaded PVC plastic piping. This obviously applies to joints that may have to be disassembled subsequently, since threaded joints of PVC pipe may be permanently joined using a thread cement such as PVC cement. This material uses a solvent such as tetrahydrofuran. This solvent is often pigmented blue.

It is therefore the obvious conclusion that someone assembling the copper fittings to the mating PVC threaded pipe used the blue PVC cement as the thread sealant. PVC cement is just that — an excellent cement and solvent for PVC but certainly not a thread sealant. Perhaps the convenience of the PVC cement being available in a can with a half-inch wide brush and applicator was too tempting to certain of the trades, and this cement was used rather than the conventional joint sealants, such as litharge or glycerine or preferably Teflon tape.

The purpose of this paper has been to make available an analysis of a mistake of others so that personnel in the business of installation of underground sprinkler systems would not fall into the same trap that was earlier committed. Proper materials require proper sealants and proper assembly, and no short-cuts. □

TABLE I

Form of Corrosion	Characteristic Appearance	Typical Conditions Causing Attack on Copper
Uniform	Thinning of entire area	Nitric acid, conc. HCl, oxidizing solutions, etc.
Galvanic	Localized attack where dissimilar metals are in contact (copper is usually cathodic or unattacked).	Graphite (or graphitic structure) in a highly conductive solution, such as salt water
Crevice	Attack within a restricted area	Metal-ion or oxygen concentration cells, mainly on metals that depend on oxide or passive films for resistance (not generally true of copper).
Pitting	Localized holes	Oxidizing solutions on partially protected surface (imperfect scale deposit).
Intergranular	Attack at metal grain boundaries	Excess copper oxide eutectic at at grain boundaries
Selective Leaching (Dezincification)	Removal of 1 element of alloy	Un-alloyed copper is immune.
Erosion	Mechanical wear	Water & brine at high velocities, esp. oxygen-saturated fluids
Cavitation	Considerably roughened	Water at high velocities or pulsating pressures
Stress	Cracking by combination of stress and corrodant	Ammonia complexes or mercury in water or air
Soil*	Thinning and/or pitting	Rifle peat soil (pH 2.6), cinders (pH 7.6) and Sharkey clay (pH 6.8)
Stray Current	Localized exterior attack	Electrolytic current from an external source, cathodic to copper.

*Data from "Underground Corrosion", M. Rtmanoff, NBS Circular 579; (1957) Pages 19, 20, 83, 84, 85


This is the two-inch ips male thread-to-tubing nipple soldered to a piece of two-inch tubing, in turn soldered to a two-inch to one and one-half inch reducing bushing, soldered to a piece of one and one-half inch tubing.