Groove Mechanical Connectors Show Better Erosion/Corrosion Resistance with Copper Piping than Sweated Joints

INTRODUCTION

Grooved mechanical pipe connectors have been successfully utilized in piping systems of ductile iron, steel and aluminum for more than 50 years. The flexibility and ease of fabrication offered by grooved mechanical pipe connectors is unmatched in welded, threaded, or flanged systems. Recent concerns regarding the potential health hazards associated with leaded solder joints in potable water systems have demonstrated the need for an alternative joining technique for copper piping in medium to large potable water distribution systems. The normally thin wall and high ductility of copper piping make a mechanical connector with a rolled-in groove a very likely candidate. This rolled-in groove, while providing the necessary geometry to physically hold the piping connection together, also would form a very similar shape or protrusion into the flow stream inside the pipe. Recognizing that this roll groove would alter the flow pattern, Victaulic contracted with the LaQue Center for Corrosion Technology, Inc. (LaQue Center) to conduct a series of tests to evaluate what effect, if any, this protrusion might have on the flow stream pattern and, consequently, the historically low corrosion rate of copper piping in potable water systems.

TEST PROCEDURE

In order to evaluate any effects this rolled-in groove may have on the erosion/corrosion behavior of copper piping, two identically configured test systems utilizing actual piping components were set up at the LaQue Center at Wrightsville Beach, NC. These systems, shown in Figure 1, included straight couplings, 90° elbows, and branch tee runs using $2^1/_2$" L grade copper pipe. Lead solder joints were also included to provide control data.

The first system was operated at 6 ft./sec. with once-through ambient temperature natural seawater to provide short term indications of any problem areas. Considering the aggressiveness of this environment, attack at any substantial flow disturbance was anticipated and would quickly identify any problem areas. This system was set up outdoors on the bulkhead adjacent to Banks Channel and operated for 60 days with an interim inspection conducted at 30 days.

The second system was operated with potable water at 150°F/ +66°C. The potable water was taken from the Wrightsville Beach municipal water system and fed to the test system at a rate to allow for a complete exchange of water every 24 hours. Flow through the test piping was maintained at 6 ft./sec. to duplicate the highest velocity condition anticipated in actual service. The test duration for this system was scheduled for six months with monthly inspections.

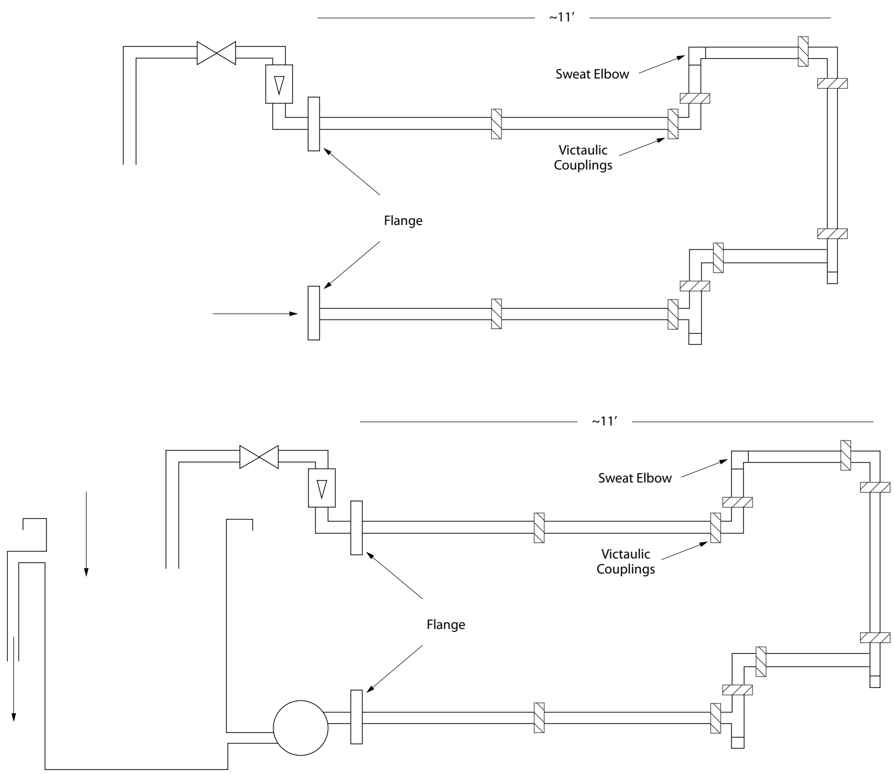

Figure 1
Schematic view of the piping test loops: (top) seawater and (bottom) freshwater.

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RESULTS AND DISCUSSION

Accelerated Natural Seawater Tests

After 30 days of operation, the seawater test system was partially disassembled to allow visual inspections and photographing. As anticipated, there was a substantial green cupric hydroxychloride film in place on all of the inside diameter of the test sections except at the increased turbulence areas associated with the elbows, tees and roll grooves. The appearance of the test sections is shown in Figure 2-3.

Figure 2
Appearance of copper pipe at upstream roll groove after 30 days in natural seawater.

Figure 3
Appearance of copper pipe at downstream roll groove after 30 days in natural seawater.

Following the 30 day inspection, the system was assembled and operated for another 30 days. After 60 days, testing was terminated according to schedule and the system was completely disassembled and split longitudinally to allow more detailed visual inspections, photographing, and measurements of attack. Figures 6 – 11 show the appearance of the test sections after the operation in natural seawater for 60 days.

Figure 4
Overall view of the seawater test loop after cross-sectioning.

Figure 5
Appearance at roll grooved area after 60 days in natural seawater (flow - left to right).

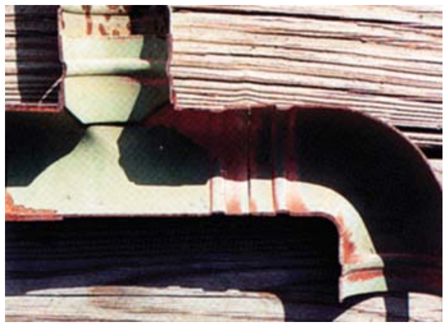


Figure 6
Appearance of the inside of the tee/elbow combination after 60 days in natural seawater (flow – left to right).

Figure 7
Appearance at roll grooved tee after 60 days in natural seawater (flow – left to right).

Figure 8
Appearance of sweat elbow and roll grooved elbow after 60 days in natural seawater (flow – left to right).

Only one site of measurable localized attack, as shown in Figure 9, was found. This localized erosion corrosion, measuring 10 to 15 mils in depth, resulted from excess solder deposits left on the inside diameter from the sweating operation.

Figure 9
Close-up appearances of sweat elbow after 60 davs in natural seawater. The depth of attack is approximately 10-15 mils (flow – left to right).

Overall, the slight erosion corrosion patterns observed at the roll grooves were comparable to those observed at the higher turbulence areas around the tees and elbows. Even in these areas, however, no measurable depth of attack was noted. In looking at the outside of the system, there was no evidence of accelerated corrosion of the metal couplings, even though they had been exposed to a very aggressive marine atmosphere. Atmospheric corrosion of the copper pipe was minimal, as would be expected, with no signs of any preferential attack at any of the couplings or sweated joints.

Elevated Temperature Potable Water Tests

As in the seawater test system, the potable water system was partially disassembled and inspected after 30 days of testing. Photographs taken during this inspection are shown in Figures 10 – 11. This inspection indicated that there was no visible attack and that an adherent corrosion product film was in place.

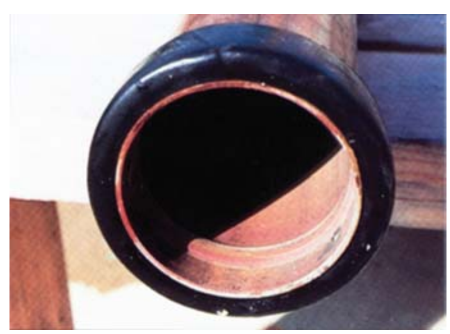


Figure 10
Appearance of copper pipe at upstream roll groove after 30 days in potable water at 150°F/+66°C.

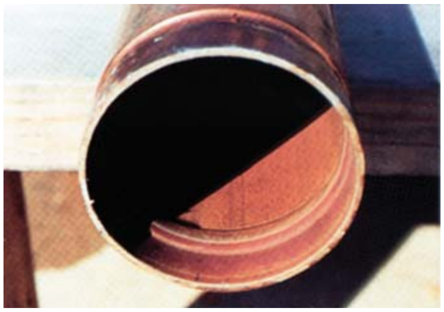


Figure 11
Appearance of copper pipe at downstream roll groove after 30 days in potable water at 150°F/+66°C.

The next inspection of this system was performed at 60 days and the photographs in Figures 12 – 14 show that little, if any, change had taken place since the 30 day inspection.

This system was shut down at two other times during the remainder of the scheduled six month test period and visually inspected. On each occasion, no signs of accelerated corrosion were seen and the system was reassembled and restarted.

Figure 12
Appearance of copper pipe at upstream roll groove after 60 days in potable water at 150°F/+66°C.

Figure 13
Appearance of copper pipe at downstream roll groove after 60 days in potable water at 150°F/+66°C.

Figure 14
Appearance of roll grooved area in tee/elbow combination after 60 days in potable water at 150°F/+66°C.

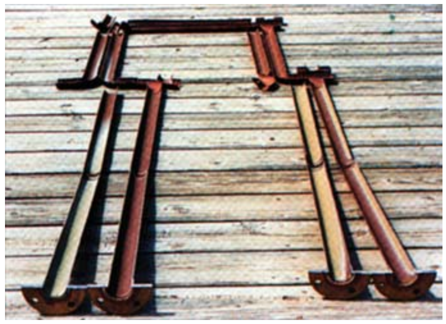


Figure 15
Overall appearance after six months operation at 6 ft./sec. in 150°F/+66°C potable water.

At the conclusion of the six month test period, the system was shut down, disassembled, and the test sections were split longitudinally. The overall appearance of the inside diameter of the system is shown in Figure 15. Close-up photographs of the higher turbulence areas are shown in Figures 16 – 19. As can be seen in these photographs, there are no signs of any attack associated with the roll grooves.

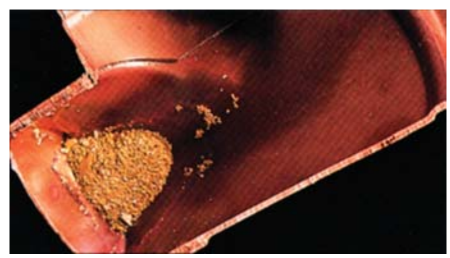
Figure 16
Typical appearance of roll grooved area in copper pipe after six months' exposure to 6 ft./sec. potable water at 150°F/+66°C.

Figure 17
Appearance of roll grooved elbow after six months' exposure to 6 ft./sec. potable water at 150°F/+66°C.

Figure 18
Appearance of sweat elbow after six months' exposure to 6 ft./sec. potable water at 1 50°F/+66°C.

Figure 19
Close-up of sweat elbow after six months' exposure to potable water at 150°F/+66°C.

The fully developed corrosion product film was affected at only one place. This location, as shown in Figure 20, was at the bottom of the sweated cap on one of the tees. This area was the low point within the test piping section of the system and apparently the highly abrasive carbonate material precipitated from the potable water collected in this location was continually swirled. This swirling action kept the copper from developing its naturally protective film (or continually abraded it away) and caused the accelerated corrosion observed here. The carbonate material found in this system is typical of heated Wrightsville Beach municipal water and is due to the high (650 - 750 ppm) total dissolved solids content. The depth of this attack is aproximately five mils.



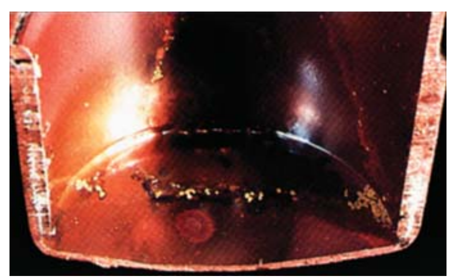


Figure 20
Appearance of attack caused by carbonate material in bottom of sweated tee cap (depth of attack five mils).

Figure 21
Appearance of corrosion product buildup on exterior surface of sweated joint after approximatley six months.

Upon inspection of the outer surfaces of this system, there was only one location that displayed signs of localized corrosion. This attack, shown in Figure 21, was apparently caused by the acid based flux used in the sweating operation.

CONCLUSIONS

In review of these tests, the aggressive 60-day exposure in natural seawater revealed that effects of the increased turbulence caused by the introduction of roll grooves for the Victaulic piping method were no more than those caused by the tees and elbows in the system, which are the same as for sweated piping systems. It was shown that turbulence risers caused by excess solder in sweated joints could prevent the establishment and retention of the corrosion product film necessary for the low corrosion rates normally exhibited by copper piping systems.

Results of the six-month potable water test, while not being anywhere near the expected life of an actual copper piping system, demonstrated that the roll grooves had no adverse effects on the formation and retention of a protective corrosion product film. This protective film uniformly covered the whole of the interior piping system and was the same for Victaulic joints as for the sweated joints. Based upon these test results, the Victaulic piping system should perform equally with a sweated piping system under the same conditions.

The 60-day seawater test was conducted on an open pier and the six-month potable water test in a well-ventilated building adjacent to the pier. In neither test was there any indication of preferential exterior corrosion of either the pipe or the coupling at the joints, even though they are of dissimilar materials (copper pipe and ductile iron couplings) and were constantly exposed to atmospheric moisture. A similar Victaulic piping system would show the same lack of preferential corrosion at the joints, especially since interior building piping is typically subject to a less aggressive atmospheric environment than experienced in these tests.