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November 24, 2009

Dear Ms. Wright,

I have completed my analysis of the copper pitting problem experienced by customers of Loudoun Water in your Raspberry Falls system. In this letter I briefly review the nature of the problem, develop a hypothesis regarding the cause(s), present results of a confirmation experiment, and make recommendations as to how the problem can be resolved. This letter references information I presented on this subject in your Loudoun Water office on September 23, 2009 (attached).

To summarize, the only copper tubing that experienced pinhole leaks to date in the homes of your Raspberry Falls customers are short copper sections entering and leaving the water heater (e.g., attached presentation slide 14, slide 15). A short section of copper is required by code and this fitting also provides a convienient transition to plastic CPVC pipe.

This fitting has a natural "crevice" at the CPVC/Copper junction. This crevice can serve to initiate localized corrosion and pinhole leak attack, because the crevice is removed from flow and can naturally become the anode in corrosion reactions (presentation slide 27-31). In a water that allows copper pitting corrosion to occur, pinholes would be expected to initiate and then propagate (grow) at the CPVC/Copper junction of this device. This can explain both the localization of corrosion in the depression near the CPVC/Copper junction and occurrence of leaks at this point of the device.

To verify this hypothesis we conducted an experiment using a sample of this fitting which was purchased at Ferguson's plumbing supply and received by us August 31, 2009. The experiment was started September 7th and ended October 5th 2009. A water was synthesized of pH 7.9, alkalinity 100 mg/L as $CaCO_3$ (added as $NaHCO_3$), 4 mg/L nitrate and 4 mg/L sulfate to roughly represent the water in your system. Water was recirculated through the fitting continuously using a pump at a 1.5 feet per second flow rate. Chlorine was added at a very high level of 10 mg/L to increase the likelihood that the water would propagate pinholes once they started, and to accelerate the corrosion reaction. On October 5th, 2009, a pinhole fully penetrated the wall of the test fitting at the exact location observed in the service failures in your system, thereby verifying the hypothesis that the crevice was initiating localized corrosion (Figure 1). On the basis of my analysis and experience, and data that you have collected to date, I predict that the rate of failure for this particular fitting in Raspberry Falls will approach 100% over the next 10 years.

Copper pinhole leaks require two factors: Initiation and Propagation. Step 1, the initiating factor, is inherent to the design of this fitting by virtue of the crevice. Step 2 requires the presence of a water that allows pits to grow once they have started. The specific factors that allow a potable water to support pit growth is a topic of current research. Without an initiation step or the presence of a water that allows pits to grow, leaks would not have occurred.

Solving these types of problems requires holistic consideration of costs:benefits, likelihood of success, and risks of failure. One possible solution is to dose an orthophosphate corrosion inhibitor, which has sometimes successfully stopped problems of this nature. In considering orthophosphate as a possible partial solution to the problem, I note the following:

1) There is no guarantee that orthophosphate will work to reduce the rate of copper pitting, or to stop pitting, in this water system. Based on my "gut" feeling and experience, I believe it is about 80% likely that dosing orthophosphate would dramatically reduce the rate of failures. But without additional testing there are no guarantees. Bench testing to see if orthophosphate would be effective in your system would cost approximately $40,000.
2) Orthophosphate costs money to put into the water at the potable water treatment plant and costs money to take out at the wastewater plant. There is also a cost associated with facilities, pumps and dosing of this chemical.
3) Orthophosphate has potential problems, in that it can sometimes serve as a nutrient for bacteria. However, these bacteria are considered harmless and I do not believe they pose a significant concern.

As a point of reference, about half of all utilities in the U.S. dose some form of phosphate corrosion inhibitors.

It was recently revealed that the same type of copper fitting occurs at multiple locations in Raspberry Falls homes. It is also my understanding that many of these fittings are behind walls and difficult to access and locate. In my opinion, this revelation tips the cost:benefit analysis in favor of dosing orthophosphate at a level of 1 mg/L as P. After 1 month, the dose can be reduced by 1/3 from this value to maintain benefits of corrosion control.

If you should have any questions about my analysis and opinions, feel free to contact me at (540) 231-7236.

Regards,

Marc Edwards

Marc Edwards
Charles Lunsford Professor of Civil Engineering

Attachments: Short-Bio, PowerPoint Presentation

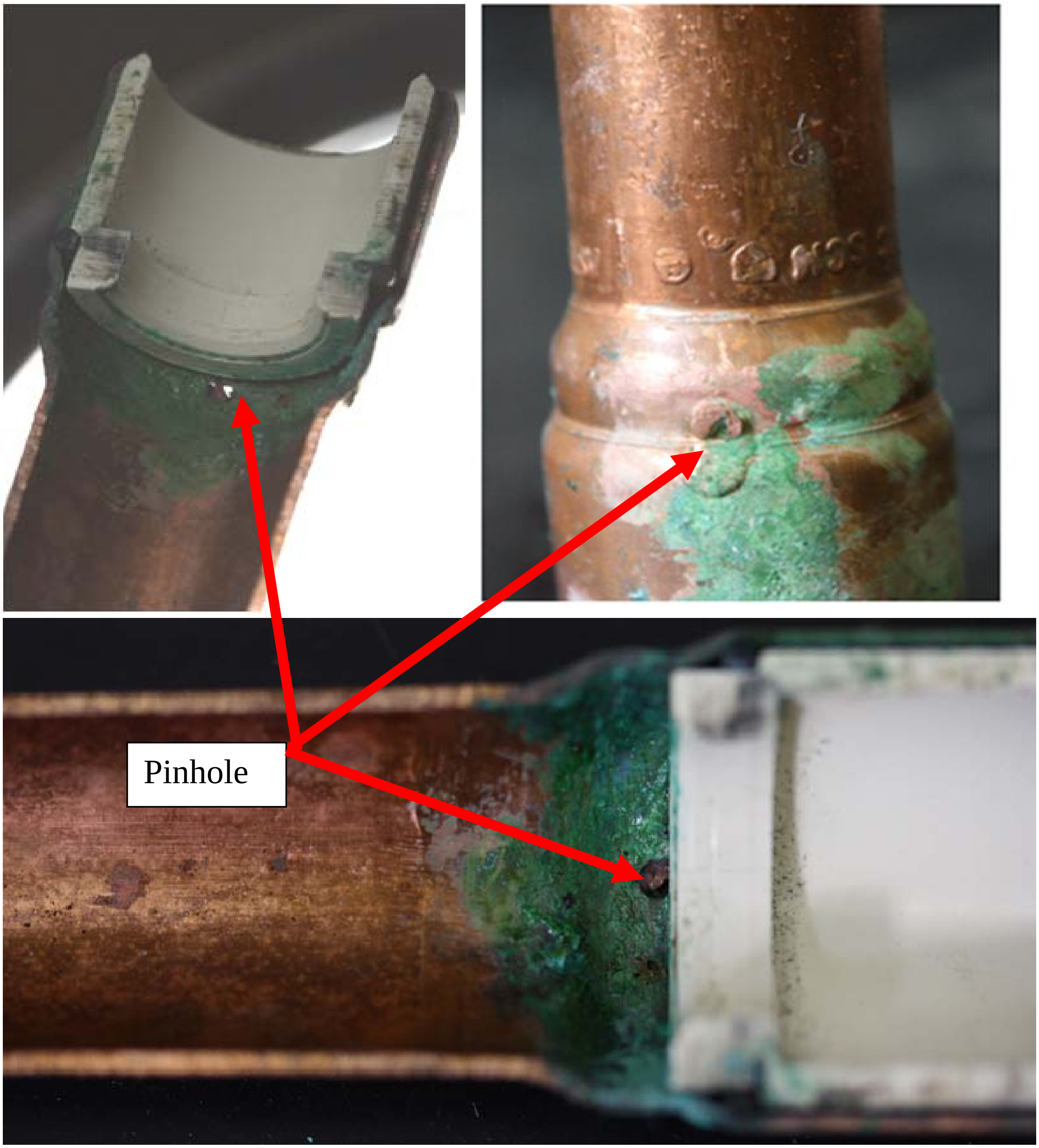

Figure 1. Perspectives on failure of the pipe fitting tested via experiment. The pinhole formed immediately adjacent to PVC/Cu Junction where crevice is formed and is visible with backlighting (upper left). The leak occurred in the same location as failures observed in practice (upper right). Interior view shows that corrosion activity is concentrated in depression near crevice (lower).

Marc Edwards received his bachelor's degree in Bio-Physics from SUNY Buffalo in 1986. He received his M.S. and Ph.D. in Environmental Engineering from the University of Washington, in 1988 and 1991, respectively. In 2004, Time Magazine dubbed Dr. Edwards "The Plumbing Professor" and listed him amongst the 4 most important "Innovators" in water from around the world. The White House awarded him a Presidential Faculty Fellowship in 1996. In 1994, 1995 and 2005, Edwards received the Outstanding Paper Award in the Journal of American Waterworks Association and he received the H.P. Eddy Medal in 1990 for best research publication by the Water Pollution Control Federation (currently Water Environment Federation). His M.S. Thesis and PhD Dissertation won national awards from the American Water Works Association (AWWA), the Association of Environmental Engineering and Science Professors and the Water Environment Federation. He was later awarded the Walter Huber Research Prize from the American Society of Civil Engineers (2003), State of Virginia Outstanding Faculty Award (2006), and a MacArthur Fellowship (2008-2012).

Edwards is currently the Charles Lunsford Professor of Civil Engineering at Virginia Tech, where he teaches courses in environmental engineering and applied aquatic chemistry. Since 1995, undergraduate and graduate students advised by Edwards have won 22 nationally recognized awards for their research work on corrosion and water treatment. Edwards has published more than 100 peer reviewed journal articles, made more than 100 national and international conference presentations on six continents, and has delivered dozens of keynote addresses. Edwards was president of the Association of Environmental and Engineering Science Professors and he testified to the United States Congress on the issue of lead in Washington DC drinking water. His research group is currently emphasizing research on internal corrosion processes in home plumbing-- a problem costing consumers in the U.S. billions of dollars each year and which also can endanger the safety of potable water. The National Science Foundation, individual water utilities and homeowners' groups, the AWWA Research Foundation, the United States Environmental Protection Agency (U.S. EPA), and the Copper Development Association have supported that research. His students' work has been featured in Time Magazine, Materials Performance, National Public Radio, Prism, Salon, Good Housekeeping, Environmental Science and Technology, Public Works, Earth and Sky, and in newspaper articles around the country.