Water Delivery Report 2008

The science behind water quality and pipe restoration

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The history of plumbing pipes in North America

During the 19th and early 20th century lead was used very widely in the major cities of the U.S. for water pipes because of its durability and malleability. It was also the major source of lead-related health problems in the years before the health hazards of ingesting lead were fully understood; among these were stillbirth and high rates of infant mortality[1]. Lead pipes were superceded by galvanized steel and copper, and copper pipes became the predominant material selected for domestic water service and distribution in residential construction after World War II. Copper still has over 80% market share for new indoor plumbing pipes[2] with galvanized pipes and plastics being alternatives. However, some old homes and particularly the service lines from the water mains to the homes still have lead pipes. For example, Providence Water in Rhode Island announced in May 2007 that some 25,000 of its total of 74,000 water connections are made of lead and will be replaced over a 15 year period.[3]

Why do plumbing systems fail?

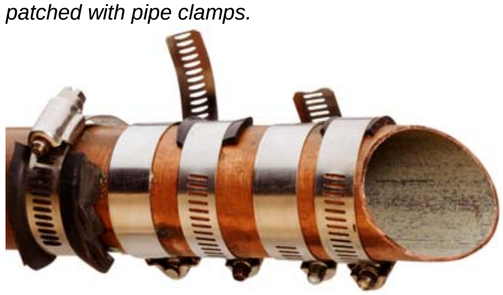
Water authorities are mandated by the Safe Water Drinking Act to measure the quality of water in customer's homes on a statistical basis. Unfortunately, this does not always protect the customer completely because each home or commercial building has its own unique plumbing installation. Even with a healthy source water, commercial and home plumbing systems can still fail prematurely or cause poor water quality.

No plumbing system that is in contact with water will last forever, but there is data to show that some copper systems are still in operation after 70 years from installation[2] while others have failed in only a few months[6]. Why this huge difference? The answer lies in a combination of factors:

- The design of the system
- The type and quality of the plumbing materials
- The quality of the installation procedure
- The source and composition of the water.

ABOVE: Galvanized steel pipe shows build of mineral and other deposits.

BELOW: Copper pipe with multiple pinhole leaks is patched with pipe clamps.



Design and quality

The World Health organization has stated that "the durability of a plumbing system is dependent on the quality of its component parts and the assembly skills of those who install it. No plumbing system, how ever well designed, can be expected to operate safely or hygienically if the products or materials used are unsatisfactory. The inverse is also true – if the best-quality products or materials are used but are installed incorrectly, the system will be a failure[4]. The use of undersized piping is a frequent cause of corrosion problems. Undersized piping creates high water velocities that can erode pipes or, more commonly, remove protective oxide coatings from the pipes. There is also much evidence that the excessive use of acidic flux in assembly of copper pipes is a major source of leaks[2].

Plumbing materials

Plumbing pipes found in existing buildings are likely to be lead, galvanized steel or copper.

Lead pipes

According to the Federal government,[5] “Lead is unusual among drinking water contaminants in that it seldom occurs naturally in water supplies like rivers and lakes. Lead enters drinking water primarily as a result of the corrosion, or wearing away, of materials containing lead in the water distribution system and household plumbing. These materials include lead-based solder used to join copper pipe, brass and chrome plated brass faucets, and in some cases, pipes made of lead that connect your house to the water main (service lines).” In 1986, Congress banned the use of lead solder containing greater than 0.2% lead, and restricted the lead content of faucets, pipes and other plumbing materials to 8.0%.” This so-called “lead-free” brass can still legally contain up to 8% lead and plumbing systems installed prior to 1986 can contain high levels of lead from both plumbing components and lead solder. The presence of lead in water from the tap is indicative of serious problems that must be corrected for health reasons.

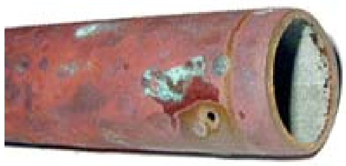
Galvanized pipes

Galvanizing of steel pipes involves the application of molten zinc to pre-formed steel pipes to provide a corrosion resistant coating. However many galvanized pipes in old buildings were manufactured using zinc that probably contained high levels of lead, which is a common impurity in the zinc. It was not until 1986 that the Wheatland Tube Company became the first galvanized pipe manufacturer to be certified to ANSI/NSF Standard 61 for its hot dip galvanized pipe. Galvanized pipes are still common in older homes and many commercial buildings. Galvanized pipes will corrode over time, as indicated by the following symptoms:

- high levels of zinc or iron in tap water,
- a “metallic“ taste of the water
- poor water flow due to blockage from mineral buildup
- discolored water (brown, red or yellow water)

Copper pipes

ABOVE: Interior view of pitting, which leads to pinhole leaks in a copper pipe.
BELOW: Exterior view of pinhole leaks in a copper pipe.



Copper is widely used for plumbing pipes because of its excellent corrosion resistance and safety. It is also very easy to work with, being malleable and easily joined by fittings or soldering. Copper plumbing pipe comes in three types: K, L, and M. Type K tube has thicker walls than Type L tube, and Type L walls are thicker than Type M, for any given diameter. From a corrosion point of view all three types should corrode and age at the same rate, but type M tube should have the shortest lifetime because it has the thinnest walls. Type M is a hard tube, not easily bendable and is only supplied in straight 20 ft lengths. It is most commonly used as the lowest cost tube in new buildings.

Despite its success as a plumbing material, copper pipe has sometimes failed well before its design lifetime, mainly because of pinhole leaks, and this subject has been extensively studied for many years. Dr. Marc Edwards of the Virginia Polytechnic Institute and State University (Virginia Tech) believes and has testified during hearings of the U.S. House of Representatives and at City Council Hearings of the District of Columbia government that pinhole leaks in copper tubing are a major national problem.

Pinhole leaks:

- May cause water damage to plaster and sheetrock walls, electrical systems, flooring, ceilings or furniture;
- Undetected water leakage may result in mold growth;
- Repairing or replacing copper pipe, because of limited access, is generally costly;
- Water damage claims may result in homeowners' insurance premiums being raised, or non-renewal of policies.

Water composition

There are over 75,000 public water systems in the US and every one of them has a unique source of water. Water of course falls as rain and is collected by water systems either as surface water from streams, rivers and lakes or is pumped as ground water from underground aquifers. This water is not the pure H_20 that we read about in our chemistry textbooks – it is a complex mixture of water plus many dissolved and suspended materials such as: dissolved gases like oxygen and carbon dioxide; minerals, organic matter and impurities picked up from industrial wastes; agricultural run-offs; and sewage systems. Water treatment is necessary to lower the level of contaminants to the government-mandated standards. In 1974, Congress passed the Safe Drinking Water Act (SDWA), requiring the EPA to set mandatory standards for the quality and safety of water at the tap. The National Drinking Water Regulations[5,6] set maximum primary and secondary contaminant levels (MCLs) for metals, inorganic chemicals and organic chemicals for public water systems. The MCLs most relevant to contaminants in plumbing systems are:

pH	6.5 to 8.5 ppm*
Copper	1.3 ppm
Lead	0 ppm
Iron	0.3 ppm
Zinc	5.3 ppm

**Parts Per Million*

Another important regulation under the SDWA is the Disinfectants and Disinfection By-Products Rule. This amendment reduces health risks by regulating the allowable concentration of disinfection by-products in the drinking water.

Compliance with these standards and regulations is a key aspect in assuring safe drinking water. However, even with these standard and treatment, there are still several features of the water that can affect the quality of the water that we receive at the tap. Many processes are used to treat water including coagulation using alum or ferric chloride, carbonate or bicarbonate treatment to increase pH, addition of orthophosphates or silicates to minimize pipe corrosion, aeration to lower CO_2 levels, and disinfection using chlorine or chloramines.

The major factors that affect plumbing systems are:

- The pH of the water
- Oxygen content
- Alkalinity
- Chlorine and chlorinated by-products
- Temperature

In water, the essential “driving force” for corrosion is generally dissolved oxygen. However, this role can be taken over by acidity. The pH level of drinking water reflects how acidic it is. pH is a scale that measures the concentration of hydrogen ions in the water. pH is measured on a scale that runs from 0-14. Seven is neutral, indicating there is no acid or alkalinity present. A measurement below 7 indicates acid is present and a measurement above 7 indicates alkalinity. The EPA recommends but does not mandate that public water systems maintain pH levels of between 6.5 and 8.5. Low pH water, commonly referred to as “soft” water, is particularly aggressive to metal plumbing systems. It can rapidly corrode galvanized and copper piping. In fact, NSF does not certify copper for use in water with a pH of less than 6.5. Copper can corrode rapidly and uniformly at low pH values, causing metal thinning. At higher pH values (above about pH 8), copper corrosion problems are almost always associated with non-uniform or “pitting” corrosion processes, causing pinhole leaks. Copper pitting in potable water is not a completely understood phenomenon. If it were completely understood, it should be ideally reproducible, and thus predictable and hopefully preventable. Dr. Marc Edwards believes that the pitting is caused by a combination of high pH, chlorine, trace aluminum in the water, and the absence of natural organic materials, which have been reduced in drinking water by direction of the EPA. Both Dr. Edwards and researchers at the EPA have also shown that changing from chlorine to chloramines for disinfection (intended to reduce chlorine by-products in the water) dramatically increases lead leaching from pipes and fittings to unsafe levels.
Although the effect of temperature on corrosion of plumbing systems has not been fully investigated, it is generally accepted that hot water will be more aggressive because of the increase in rates of chemical reactions at higher temperatures. However, this effect is reduced somewhat by the lower concentration of dissolved oxygen in the water at higher temperatures.

What are the symptoms of typical pipe problems?

- Contaminants in the water
- Low water flow/pressure
- Leaks
- Stains and colors

The materials present in the distribution system determine which contaminants are most likely to be found at the tap. Copper, iron, lead, and zinc are the principal contaminants of concern that can leach from materials in metal drinking water distribution systems..

It should be noted that there are no perceived health risks from relatively high levels of metals such as copper, zinc and iron. The EPA limits are more concerned with the aesthetics of the water – taste, odor and color. High levels of these metals in tap water are however, an indication of the poor condition of the pipes.

Poor water flow through pipes is caused by the build up of solid deposits often called “scaling” or “liming”. This can be caused either by the simple deposition of minerals in the water or by corrosion by-products. The scale that forms on the surface of the metal may range from highly soluble and easily dissolved to adherent and protective (sometimes, when scale forms, it provides a barrier so that the metal pipe no longer comes in contact with the water, and therefore no further corrosion can occur).

The phenomenon of colored water or stains on sinks or tubs is usually caused by high levels dissolved or suspended metallic corrosion products and often described as “blue water”, “red water” or “brown water”.

Alternatives for repairing or upgrading pipe systems

Re-piping with copper

Re-piping has been the traditional approach to solving problems caused by leaking metal plumbing systems. Re-piping requires the cutting open of many walls and ceilings throughout the common and private areas of a building, complete or partial pipe replacement, followed by restoration of drywall, tile work, and repainting. In many instances, residents are subjected to many days of water system shutdowns. In addition, if new copper pies are installed but still subject to contact with water, pipe deterioration will begin all over again.

Re-piping with plastic

This of course has the same inconvenience problems as re-piping with copper, although plastic pipes are somewhat more flexible and easier to install than copper. Plastic piping has been available for over 30 years with much success in replacing copper, as well as some notable failures. Plastics that have been used over the years include PVC, chlorinated PVC (CPVC), polybutylene, polyethylene and cross-linked polyethylene (PEX), with PEX now having around a 15% market share of the total plumbing pipe market. Catastrophic failures using polybutylene pipes in the1980's and early-to-mid 90's made some potential users nervous to use plastic pipes. However newer plastics like CPVC and PEX are now approved to all national and most state plumbing codes. The State of California has been the notable exception. It recently approved the use of CPVC pipes, although PEX is still not approved. The state has been under pressure from plumbing trade groups and environmentalists who are opposed to the use of plastics because of potential – although unproved – extraction of organic chemicals. This political pressure has prompted litigation by the pipe manufacturers.

Epoxy lining

The modern alternative to costly re-piping is to line plumbing pipes with an epoxy coating. The internal coating of water pipelines was pioneered in the UK and Japan in the 1970s. Although the UK experience is well documented[7], there is little documentation of the Japanese experience but we do know that products for potable water were approved by the Japanese Government in 1981[8]. The technology was introduced in the UK in 1979 and received Government approval in 1985. In the US, the American Water Works Association Research Foundation (AWWRF) conducted a demonstration study using the epoxy lining technique in 1993 that confirmed its viability for water main rehabilitation[9] but approval by ANSI/NSF Standard 61 did not happen until several years later, thus delaying the development of the process in the US.

The U.S. Navy experimented with the development, testing the installation of epoxy linings inside piping systems on aircraft carriers between 1983 and 1993[10]. The US Army issued a Public Works Technical Bulletin in 2001 for coating metallic piping at Army installations to enhance corrosion protection[11].

CuraFlo® acquired equipment technology for blow through pipe lining in 1996 and has made substantial improvements to the technology over the last 11 years.

Benefits of epoxy linings:

- Protect against future corrosion and therefore prevent pinhole leaking in metal pipes
- Prevents the formation of colored water and stains from corroding pipes
- Extensive work by the US Naval Research Laboratory has shown that epoxy linings stop lead from leaching into drinking water piping systems and maintain lead levels below the EPA limits
- In 2007 the AWWRF issued a research report that showed that on steel water mains, epoxy lining is expected to have a service life of at least 40 to 60 years[13].
- Epoxy coatings decrease friction between water and the pipe, and therefore increase water flow (despite the slight decrease in internal diameter caused by the coating)
- Epoxies have a thermal conductivity approximately 800 times lower than copper. This makes epoxy coatings good insulators in hot water pipes
- Faster and more convenient than re-piping

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