Report on the Furs Warehouse Plumbing Failure

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Conclusions

The 2" x 3/4" bushing failed due to a galvanic corrosion cell set up between the cast iron bushing and the brass gate valve. A contributing factor was the fact that the bushing was screwed only about 1/4" into the gate valve rather than the proper 1/2". Corrosion consumed the threads on the bushing from the end in, until nothing but iron oxide was holding the pieces together. After this, water pressure or any small shock was enough to finish the job. The failure almost certainly would not have occurred had the plumbing from the gate valve to meter been of copper and/or brass, or had the bushing been part of an all iron plumbing system, or had the bushing been screwed 1/2" into the gate valve. The failure was probably quite sudden.

Background

Galvanic corrosion has been known at least since 1910. The deleterious effects of connecting two bare dissimilar metals in a water line and the intensifying effect of having a larger area of the more noble metal (brass) than the less noble (iron) was known long before the valve and bushing were assembled in 1947.

Purpose

The main purpose of this investigation was to determine the cause of failure of the 2" x 3/4" blank bushing from the furs warehouse. A second purpose was to ascertain the state of knowledge of galvanic corrosion before and after the installation of the failed plumbing in about 1947.

Discussion of the Failure

The failure is shown in Fig. 1. The failure took place between the brass valve and a 2" x 3/4" gray cast iron blank bushing. The plumbing carried cold water.

The failed bushing, still connected to the 3/4" galvanized nipple and elbow, was given for examination. The assembly was photographed (Figs. 2 and 3), then sawed in half to reveal the extent of corrosion on the interior. One-half was polished on a belt sander and successive grades of emery paper, then etched with nital to reveal the extent of oxidation on the inner surface and within the metal (Figs. 4 and 5).

The photomicrograph in Fig. 5 shows a selected area of the polished and etched specimen. The black area penetrating the blank bushing at A is an oxide of iron (magnetite), and this oxide has reached the thread roots on both sides. From Fig. 3, it is apparent that only iron oxide was holding the bushing to the valve at failure. The fracture surface is completely non- metallic.

The corrosion pattern is typical of a galvanic cell. The penetration into the threaded region is seen to be greatest near the brass gate valve and less at greater distance. The relative lack of penetration at the right angle within the bushing may be due to low oxygen supply at that point. The flow of water is relatively small at such locations.

Although some corrosive attack is seen on the nipple and throughout the assembly (Figs. 4 and 5), failure is not imminent other than at the failed locatioh. The corrosion of the nipple is quite possibly also due to the large amount of brass in the system.

A sample of the remaining thread portion was polished and etched. The material was seen to be gray cast iron.

Possible Causes of Failure

It is obvious from examining the assembly that failure was due to corrosion of the male portion of the bushing. We must, however, inquire as to what metallurgical, environmental or human factors contributed to or accelerated the failure.

Possible causes of failure are:

1. stress induced corrosion,
2. faulty materials that corroded at an excessive rate,
3. improper installation, i.e., too little of the blind bushing threaded into the brass valve,
4. corrosion due to sewerage seeping into the water line, and
5. rapid galvanic corrosion due to coupling the iron to brass in the presence of a conducting fluid (water)

Possibility (1) is very unlikely. The weight of meter and pipes is modest, and the copper pipe on the property owner's side of the meter is flexible, so the bushing was not subjected to excessive stress. It is not clear whether or not the cardboard boxes behind the meter (Fig. 1) were there prior to the failure or were inserted to separate the failed pieces for the photographs. In any event, the cardboard could not transmit much stress to the bushing.

Possibility (2) seems unlikely. Microscopic examination of a section of the threaded region showed the bushing to be of gray cast iron, and neither macroscopic or microscopic examination gave any indication of inferior material.

Possibility (3) concerns only screwing the bushing a few threads into the valve, so that minimal corrosion would cause failure. This is probably a contributing cause, as a similar bushing has 3/4" of threads compared to 1/2" of threads remaining on the failed piece. Therefore, the bushing was threaded about 1/4" (three threads) into the valve and corrosion had to progress only 1/4" from the most severe point of attack at the end of the threads to give failure.

Possibility (4) enters because the sewer and water lines leave the building side by side and are apparently laid in the same trench. According to sources, the case iron sewer pipe typically extends out about five feet from the building, where it connects to concrete pipe. Seepage from the concrete pipe could enter the water line through any holes or cracks and accelerate corrosion. It is not possible at this time to tell whether or not seepage contributed to the failure.

Possibility (5) is straight galvanic corrosion due to connecting the iron bushing to the brass pipe in the presence of water. Examination of the failure indicates extremely even corrosion around the flange circumference, with the 2" flange oxidized to magetite as shown in Fig. 3. The intense attack that oxidized through to the thread roots next to the brass gate valve is characteristic of galvanic corrosion.

Galvanic corrosion is thus the most probable cause of failure for the following reasons:

1. Iron connected to brass in the presence of water has a strong tendency to corrode.
2. The large brass valve connected to the small iron bushing would accelerate the corrosion.
3. The uniform attack around the thread circumference proceeding from the end of the threaded region and from the flange (Paths A and B in Fig. 5) is characteristic of galvanic attack, as is the intense attack on the threaded end nearest the gate valve. The bushing was screwed only about 1/4" into the gate valve.

History of Galvanic Corrosion

Was galvanic corrosion known in 1947, the time the iron bushing and brass gate valve reportedly were connected? The answer is yes. The accelerated corrosion of iron in contact with copper or brass has long been known, as has the additional accelerating effect of iron from having a large piece of copper in contact with a small piece of iron.

F. N. Speller in Corrosion, Causes and Prevention, An Engineering Problem (McGraw Hill, New York (1926) p. 8) discusses both galvanic corrosion and the relative size effect.

R. J. McKay and R. Worthington in Corrosion Resistance of Metals and Alloys (Reinhold Publ., New York (1936) ACS Monograph Series No. 71, p. 26) does likewise.

The oldest available reference, by A. C. Cushman and H. A. Gardner in The Corrosion and Preservation of Iron and Steel (McGraw Hill, New York (1910) p. 80), states, "If two metallic elements are joined in a structure, the more electropositive one will be corroded rapidly while the more electronegative will be protected." The authors cite an experiment wherein the corrosion of iron is more than tripled by connecting it to brass, as compared to iron alone for the same period of time.

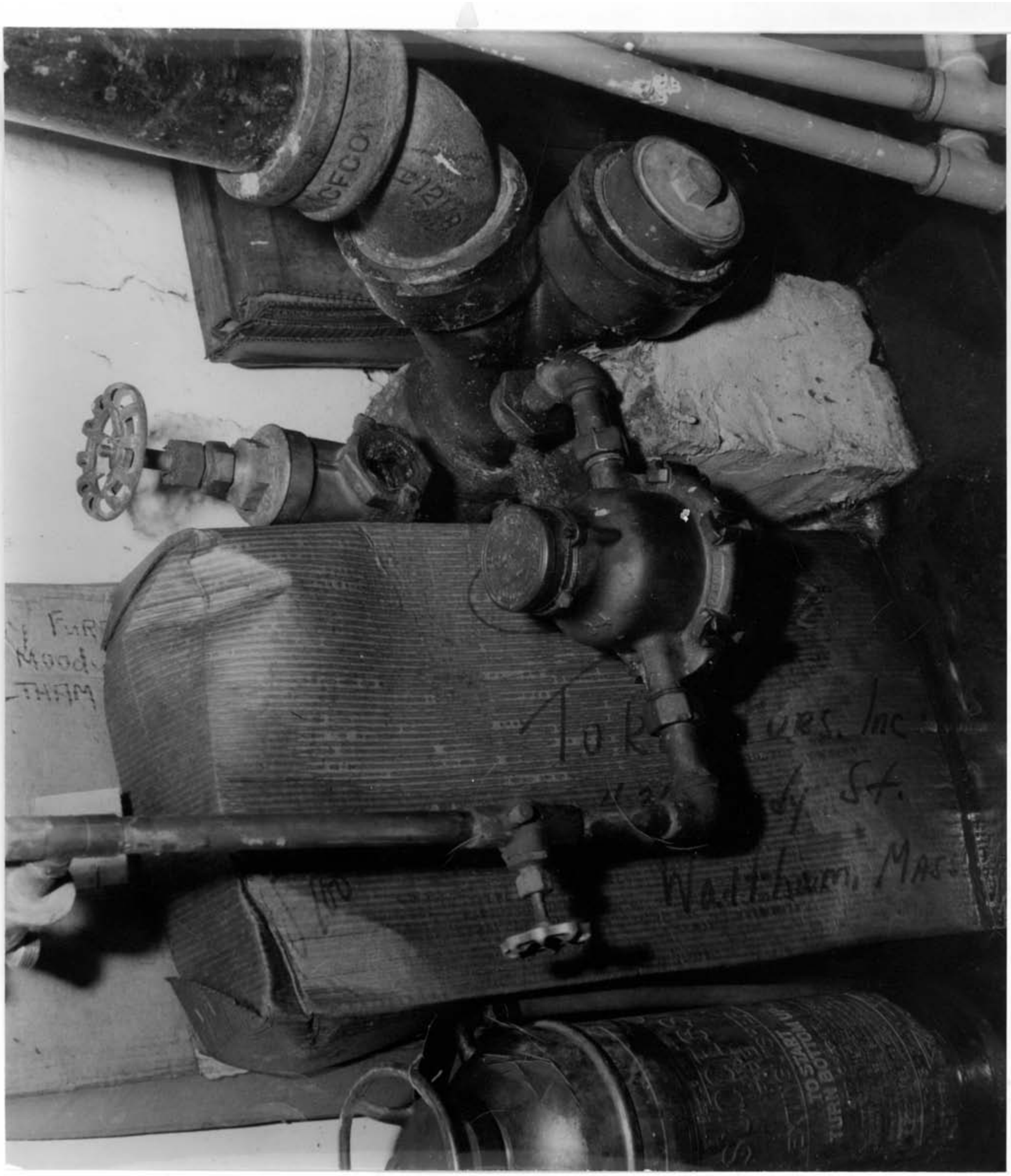

Figure 1: Failed pipe assembly.

Figure 2: Failed bushing, showing corrosion.

Figure 3: Failed bushing, from the other side.

Figure 4: Sliced in half, the corroded bushing has been polished and etched.

Figure 5: A closeup of the etched metal shows magnetite at the valve.