Circular No. 53 1956

STATE OF ILLINOIS
WILLIAM G. STRATTON, Governor

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By

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Issued By

DEPARTMENT OF REGISTRATION AND EDUCATION

VERA M. BINKS, Director

State Water Survey Division

A. M. BUSWELL, Chief

Urbana, Illinois

(37616—5-56)

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JOURNAL AMERICAN WATER WORKS ASSOCIATION
Vol. 48, No. 1, January 1956

Corrosion of Brass by Chloramine

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CORROSION manifests itself in many ways. Some of these ways arc striking, some insidious; some are costly, some of purely nuisance value. Its mitigation is often accomplished by trial and error methods, other times by search for causative or preventive factors. Knowledge of corrosion is usually increased, however, by whatever means of mitigation are adopted.

Wire Drawing

In valves, impingement corrosion may be severe and is commonly referred to as "wire drawing." Impingement corrosion occurs under conditions of very high velocity and it results in a metal surface which appears to have been impinged or pitted by a high lateral turbulent velocity. Copper-zinc alloys, as well as copper, are notoriously subject to impingement attack. Not a new phenomenon, wire drawing in ordinary household faucet seats has existed as a nuisance type of corrosion not generally prevalent or recognized.

Impingement attack has frequently been reported as the result of high velocity with entrained air in the fluid stream, causing impingement of gas bubbles on the metal surface. From the results of this study, it might be concluded that this theory is not corroborated. It is more probable, however, in the type of water used in this study, that the influence of dissolved oxygen is negligible *(1),* compared to that of chloramine.

During the year 1952-53, there was an increase in the number of complaints and, in some communities, such as Champaign-Urbana, requests for information on how to avoid frequent replacement of faucet seats due to wire drawing were received from home owners, hotel maintenance men, apartment buildings, schools, and plumbing contractors. One of the larger plumbing contractors reported that during the years 1948-50, his annual orders for faucet seat replacements had been about 500, and that suddenly in 1951-52 they increased to 1,500. No data were available on the geographic location of the replacements.

In Champaign-Urbana the water supply was changed to a new well field in 1951, but with the possible exception of a somewhat lower ammonia content, the quality of the water was not greatly affected.

At about this time, to facilitate iron removal, the procedure for treatment had been revised to provide chlorination before filtration, whereas formerly split chlorination had been practiced. The prechlorination now provided more than 2 ppm chlorine residual in the water leaving the plant. This residual was established as chloramine, with no free chlorine present. The revised treatment, however, altered conditions in the distribution system so that both dissolved oxygen and chlorine residuals were recorded at the ends of the distribution system. Formerly, chlorine residuals were virtually absent in the outer part of the system.

Tests were made using cotton plug filters to determine whether the new treatment was releasing particles of silt from deposits and slime growths in the mains, thereby possibly causing such particles to lodge in faucet seats and promote the inception of wire drawing. No significant amount of silt content was noted at the ends of the system. An analysis of the tap water is shown in Table 1. These readings were taken at a temperature of 55°F and a pH of 7.4.

TABLE 1

Tap Water Composition

Item	Amount	
	ppm	epm*
Iron (Fe)	trace	
Manganese (Mn)	trace	
Calcium (Ca)	60.0	3.0
Magnesium (Mg)	24.0	2.0
Sodium (Na)	46.0	2.0
Ammonium (NH_4)	0.6	0.03
Silica (SiO_2)	19.0	
Fluoride (F)	0.3	
Chloride (Cl)	6.0	0.20
Nitrate (NO_3)	0.2	
Sulfate (SO_4)	9.6	0.20
Alkalinity (as $CaCO_3$)	330.0	6.60
Hardness (as $CaCO_3$)	250.0	5.00
Dissolved oxygen	6.0	

* Equivalents per million.

In June 1953 a series of six faucets was installed at the water plant. These faucets were adjusted daily to provide a specified drip rate. Failure was indicated by inability to stop the flow of water. Four of the faucets had pressed-fit removable seats of yellow brass and two were equipped with seats of Monel metal. At the end of 52 days all four of the brass seats had failed, but neither of the Monel seats, which were seats No. 5 and 6 in Table 2. Two of the brass seats, No. 14 and 15, having an adjusted drip rate of 200-400 ml per minute, failed within 14 days, whereas the other two, No. 16 and 17, having an adjusted drip rate of about 40 ml per minute, failed within 27 days.

No attempt was made to use stainless steel in this experiment. The University of Illinois' maintenance experience had found that it was no more satisfactory than brass, although Monel metal proved satisfactory at points where severe wire drawing had been continuously experienced. During this period a large hotel in Urbana attempted to use stainless steel for faucet seat replacements but also found it to be no better than brass.

In 1949-52, information appeared which indicated that chlorine and chloramine accelerated impingement attack and cavitation *(2-5)*. It became important, then, to determine whether air, free CO_2, or chloramine was the cause of the experiences noted in Champaign-Urbana. There was no reason to believe that a greater amount of CO_2 was present in the water. Furthermore, CO_2 or chlorine, could not, be eliminated from the water except at prohibitive expense. Also, because the major manufacturers of the faucets already in service did not choose to make Monel faucet seat replacements available, it became necessary to learn if a plated faucet seat would be satisfactory.

Testing

An opportunity was offered to test faucet seats in the University of Illinois Vivarium building, where the city water was dechlorinated by passing through activated carbon and reaerated to produce a high dissolved-oxygen content. Water leaving the activated carbon filter was of low dissolved-oxygen content. In the meantime, in December 1953, the chlorine residual at the city water plant was reduced to 1.3 ppm. Three series of tests were made at this location, using in each case the three types of water. Specified drip rates were adjusted daily except Saturday and Sunday. At these times determinations were made for chlorine and dissolved oxygen.

In the first test period, with water of no chlorine residual, faucet seats No. 1, 3, 5, and 9, whether brass or Monel, lasted for the entire 41 days of the test. Faucet seat, No. 2, in the chlorinated water, was plated electrolytically with 0.006 g silver.* This seat lasted for the 41 days as well as the Monel seat No. 6. Two brass seats, No. 1 and 3, which did not fail in the absence of chloramine, lost weight in the same order of magnitude as those which failed with chlorinated water. In this test, two faucets, No. 9 and 10, were installed with a movable seat and rigid washer.

The next period of tests lasted 91 days. Seat No. 10 was replaced by seat No. 11 and two faucets with red brass seats, No. 7 and 12, were included. Again the Monel and the electrolytically plated seats withstood the chlorinated water but the brass seats did not. Seat No. 1, in dechlorinated water with low-dissolved oxygen, failed after 132 days, the combined length of the two test periods. Seat No. 3, in dechlorinated and re-aerated water, failed at the same time.

The last period of tests ran for 147 days. The seats which had not previously failed were again installed and three additional seats were prepared. One of these, No. 18, was silver plated electrolytically. The other two, No. 19 and 20, had been dipped in silver cyanide to produce a silver coating. These seats failed in 47 and 72 days, respectively. They were then machined and replated. Seat No. 19 was plated electrolytically and was then referred to as No. 21. Seat No. 20 was plated by dipping again in silver cyanide and became No. 22. Sixty-three days after seat No. 20 had been redipped in silver cyanide, it again failed. The seat which had been electrolytically silver plated was still in service after 42 days. Experiments were concluded at this time. A summary of the results of these tests is shown in Table 2.

Brass seats in dechlorinated water with or without dissolved oxygen, lasted about three times as long as brass seats in the presence of chloramine at a concentration of 1 ppm. Red brass seats were found to be no better than yellow brass in chlorinated

* This process consisted of a 3-5-sec dip in 135 ml of H_2O containing 1 g of $HgCl_2$ and 0.5 g of NH_4Cl. The seat was immediately rinsed in warm water and then dipped again for 3-5 sec in 135 ml H_2O containing 9 g of KCN and 0.5 g of AgCN. An electric current of 0.5 amp (direct current) was applied for 10-15 min, with Ag or Pt electrode at a distance of 0.5 in. from the seat, in 135 ml H_2O containing 4.5 g KCN, 4.85 g AgCN, and 5.0 g of K_2CO_3.

TABLE 2

*Summary of Results**

Seat No.	Material	Avg. rate of drip *ml/min*	DO *ppm*	NH2C1 (as Cl_2) *ppm*	Wt. loss *g*	Service *days*
14, 15	brass	130-210	8	2 +	0.04-0.06	14
16, 17	brass	20	8	2 +	0.019-0.025	27
4, 13	brass	33	6	1	0.022-0.028	32, 35
12	brass (red)	37	6	1		63
10, 11	brass	34	6	1		34, 56
19, 20, 22	brass—	35-36	5	1	0.033	72
	silver plated					47
	(dipped)				0.032	63
2, 18, 21	brass—	28-35	5	1	0.008	147†
	silver plated				0.024	119†
	(electrolytic)				0.030	44†
6	Monel	33	5-8	1-2 +	0.0008	330†
1	brass	38	1	0	0.052	133
3	brass	32	7	0	0.075	133
7	brass (red)	28	7	0		278†
9	brass	29	7	0		232†
5	Monel	32	7	0	0.011	330†

* All seats were rigid with movable washer except No. 9, 10, and 11.
† Seats still in service at end of testing.

water but appeared to be more serviceable in dechlorinated water. It was interesting to note that brass in dechlorinated water lost weight before wire drawing. The appearance of these seats was bright red, indicating dezincification.

Summary

Electrolytically silver-plated brass faucet seats were satisfactory, but only when the plating was made on a clean surface and was complete enough to avoid weight loss. Seats No. 19, 20, and 22 were exposed for 5-30 min in 150 ml of water containing 1 g KCN and 1 g AgCN. Dipping in silver cyanide with no electric current did not provide a satisfactory plating.

Monel faucet seats were not subject to wire drawing. Although seat No. 6 had a weight loss of 0.0114 g, there was not even microscopic evidence of deterioration on the surface and no previous weight loss had been experienced. It is assumed that a small burr had been chipped off during removal with an Allen wrench.

It should be noted that the accelerated tests provided herein were quite severe, more severe, in fact, than the conditions usually encountered in normal household use. Where automatic flow regulators are employed or where careless handling is' experienced, however, such conditions might exist.

It was concluded that the excessive replacement of faucet seats resulted from the presence of appreciable chloramine residuals in a greater portion of the distribution system. The presence of dissolved oxygen in the water was not a contributing factor. The use of Monel or electrolytically silver-plated brass seats proved a satisfactory solution to the problem.

Acknowledgment

The authors are indebted to Frank Amsbary and to T. R. Dyer for permission and assistance in establishing the first series of tests at the filtration plant. Consent was also graciously provided by S. C. Kendeigh to conduct tests in the University of Illinois Vivarium Building.

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