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ROBERT M. C. ROSE
OF COUNSEL

June 30, 1999
VIA HAND DELIVERY

Blanca S. Bayo, Director
Division of Records and Reporting
Florida Public Service Commission
2540 Shumard Oak Boulevard
Tallahassee, Florida 32399

Re: Aloha Utilities, Inc.; Docket No. 960545-WS
Our File No. 26038.17

Dear Ms. Bayo:

Attached in accordance with the requirements of Commission Order No. PSC-99-0514-PCO-WS and PSC Order No. PSC-99-1233-PCO-WS are the original and fifteen copies of the Direct Testimony and Exhibits filed on behalf of Aloha Utilities, Inc. in the above-referenced docket. Enclosed are the Testimonies of Stephen G. Watford, David W. Porter, P.E., and Robert C. Nixon, C.P.A. along with their respective exhibits.

Should you or any members of the Commission staff have any questions in this regard, please let me know.

Sincerely,

ROSE, SUNDSTROM & BENTLEY, LLP

F. Marshall Deterding
For The Firm

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cc: Ralph Jaeger, Esquire (via hand delivery)
Harold McLean, Esquire (via hand delivery)
James Goldberg, Esquire (via U.S. Mail)
Representative Mike Fasano (via U.S. Mail)

Watford

ORIGINAL

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

DOCKET NO. 960545-WS

WATER QUALITY INVESTIGATION OF ALOHA UTILITIES, INC

PRE-FILED DIRECT TESTIMONY OF STEPHEN G. WATFORD

Q. Please state your name and employment address.

A. Stephen G. Watford, Aloha Utilities, Inc., 2514 Aloha Place, Holiday, Florida 34691.

Q. By whom are you employed?

A. I am employed as the President of Aloha Utilities, Inc.

Q. How long have you served in that capacity, and what are your duties as the President of Aloha Utilities, Inc.?

A. I have served Aloha in one capacity or another for over 20 years. As the President of Aloha, I serve as the chief officer overseeing day-to-day operations, accounting, customer service, billing collections and administration, as well as negotiations of contracts and agreements, financing and planning.

Q. What is the purpose of your direct testimony in this proceeding?

A. To update the Florida Public Service Commission on what Aloha has done to ensure that we are providing a high quality of water service to our customers and to show the Commission we are providing an excellent quality of service overall.

Q. Are you familiar with the Commission's Order No. PSC-97-0280-FOF-WS issued in March of 1997?

A. Yes, I am. That Commission Order raises several questions about the quality of water service provided by Aloha and it is my intention to try and demonstrate to the Commission that Aloha is providing excellent quality of water service and that it has taken all reasonable steps in order to improve the quality of water service provided to its customers. I also want to show the Commission what we at Aloha have done since the issuance of that Order to correct any problems that did exist and/or to further demonstrate to the Commission that Aloha is and has been doing the right things, and all it can do to ensure that the customers are receiving high quality of service from their water Utility.

Q. Please address the issue of corrosion control and copper sulfide.

A. As the Commission will recall, several customers testified at the hearings almost three years ago that they were receiving black residue in their water at times and they believed (and possibly even the Commissioners believed), that this was a result of something which Aloha either was doing incorrectly, or failing to do. After extensive study by both Aloha, its engineer, the Florida DEP, and the Commission's own engineers, it was conclusively established that the black residue which the customers were experiencing, was the result of a reaction between their copper pipes and hydrogen sulfide which naturally occurs in Aloha's and most other utilities' water in Florida. We provided information to the Commission and to DEP to demonstrate that the Utility was in compliance with all applicable standards related to this problem and that the Utility was continuing, at the time of the last hearing, its efforts to reduce the corrosivity of the Utility's water, which was the only factor within the Utility's control that could have contributed to the occurrence of copper sulfide in some customers' homes. While this problem was not widespread, it was significant enough to raise concerns by Aloha, the DEP, and the PSC.

In keeping with the Utility's compliance with the Lead and Copper Rule, the Utility began utilizing a corrosion inhibitor injected into the Utility's water in order to help resolve this problem. We began this additional treatment process in early 1996. We have now optimized the utilization of that corrosion inhibitor as of August 11, 1998, and our corrosion levels as measured by required DEP testing now indicate that the Utility's corrosivity is below the required action levels. We have recently received correspondence from DEP that states that we are now allowed to reduce the frequency of our monitoring under the Lead and Copper Rule because of the successful results that we have received in our corrosion control program, and as such we are now going to reduce our monitoring to once yearly. In fact, as of the most recent data we have, our corrosion level is below that experienced currently by Pasco County, which I note strictly for the purposes of comparison.

It should also be noted that there are several other factors that contribute to the occurrence of copper sulfide in a customer's water. Among the most important of these is the use of home treatment units, which many of Aloha's customers were using and continue to utilize. These home treatment units strip off the corrosion inhibitor which Aloha is injecting into the water and also strip off chlorine. In addition, they change the pH of the water delivered by Aloha. Each of these factors contributes to corrosivity of the water and the likelihood that copper sulfide will be present in the water. As I believe we have noted previously, the EPA and the DEP require testing for corrosivity under the Lead and Copper Rule and do not even allow the utilization of homes with home treatment units for testing of these factors, mainly because of the effects of these home treatment units on the ability of the Utility to treat and provide water which meets these corrosivity requirements.

In addition to the scientific evidence demonstrating that the occurrence of copper sulfide in some customers' water was the cause of the black residue complained of by some customers, we also provided the Commission a copy of a University of Colorado study dealing with this issue. This study has been subjected to extensive peer review and has now been published in the Volume 90, July 1998 edition of The Journal of the American Water Works Association. A copy of this article is attached as **Exhibit SGW-1**. This article clearly demonstrates that the occurrence of copper sulfide in drinking water is relatively common and can occur in any system where hydrogen sulfide exists, as it does in most Florida ground water. This is the first scientific study and the first significant article on the subject which

I have seen.

It is certainly possible that this problem which some of the customers were experiencing, is still being experienced by them even though we have optimized our corrosion control program and now show corrosion levels well below the action levels required by the environmental regulatory authorities. Before and after the last Order, the Commission, the DEP and our engineer, all worked to try and find if there were other alternatives available to Aloha to help reduce the copper sulfide formation which some of the customers had noted. Among other things, adjustment of the pH of the water was suggested as a possible alternative to explore. Mr. David Porter, P.E. as part of his analysis of potential solutions, prepared an extensive engineering study dated June of 1997 which was submitted to the Commission and which Mr. Porter is sponsoring in this proceeding. Mr. Porter further showed the Commission staff that pH adjustment was not a viable alternative available to the Utility to further help in the corrosion control program and is now further supported by the findings of the study published in the AWWA Journal article (**SGW-1**). His study submitted in June of 1997 did provide analysis which indicated some additional treatments that would assist the Utility in further reducing the likelihood of occurrence of copper corrosion in customers' homes. While the Utility will within the next few years probably have to do many (if not most) of the things recommended within Mr. Porter's report from June of 1997, to do so prior to their being required by DEP and EPA regulations would require an increase in rates of the customers prior to when those facilities were actually required by new drinking water requirements. The Utility offered in the Summer of 1998 to undertake those improvements earlier than otherwise required in order to try to address the concerns raised by the Commission and by some of the customers. The Commission in its PAA Order PSC-99-0061-FOF-WS did not acknowledge that those improvements,should be undertaken immediately. I am attaching hereto as **Exhibit SGW-2**, a copy of a letter from our attorney to the PSC noting our willingness to move forward with those improvements from last Summer. We believe that those improvements help with these corrosion concerns. We have no new evidence about the number of homes that may be continuing to experience such copper corrosion, however, our customer complaints on water quality in recent months are down to lower levels than they have been in the last four years when we first began to hear the customers complain of the black water residue. In addition, the scientific evidence would indicate that the frequency of copper corrosion in customers' homes should be reduced substantially as a result of our now having optimized our corrosion control program. However, to the extent that the Commission or the customers still deem that further improvements are needed, the only scientifically proven method to further reduce copper corrosion, taste and odor concerns is to move forward with the construction of the new treatment facilities that will be required at some time in the future in any case. We at Aloha stand ready to begin construction of these additional treatment facilities, if that is the desire of the Commission and the customers. While certainly such improvements will have a significant rate impact, our current water rates are substantially lower than the great majority, if not all, of the other Utilities within our immediate area.

Q. Was the issue of odor, which was also addressed in Commission Order No. PSC-97-0280-FOF-WS reviewed by Aloha as well?

A. Yes. As we told the Commission at the last hearing, the only conceivable cause of the odor complaints which a few of the customers noted, is the occurrence of hydrogen sulfide. Hydrogen sulfide is the naturally occurring constituent in Florida water, and Aloha's levels of hydrogen sulfide are by no means unusual for water systems within the State of Florida. Aloha's water is by no means high for our area, or above-average for the state as a whole. In fact, the last time we checked, our sulfate levels (the best indicators of hydrogen sulfide levels) were lower than those contained in the water of Pasco County, the primary water provider other than Aloha within our general geographic area.

Our proposal for plant improvements contained within Mr. Porter's study, (which are the same as those proposed in our letter from the Summer of 1998), will certainly help in reducing the level of hydrogen sulfide through the implementation of packed tower aeration facilities. This reduction of hydrogen sulfide will certainly occur once those facilities begin to be placed in service in the next three to six years. It will be expensive to undertake these improvements in major part because of the required centralization of treatment facilities, and therefore it is not our intention to undertake these improvements until required by other environmental regulatory requirements or by the Commission, as we have previously offered to do. Because of the resulting rate increase, the Commission noted in their PAA Order that they did not believe it was appropriate at this time to direct the Utility to make those improvements now. Aloha believes that this is the only thing that we can do at this time to further address the copper corrosion, taste and odor concerns that the customers have raised. If this Commission feels it is necessary to address those at this time, Aloha stands ready to proceed with that construction. Certainly the construction will eliminate the great majority, if not all, of the taste and odor complaints and based upon the reduction in sulfides that we know will occur, we feel confident, and logic suggests, that the copper corrosion will also be substantially reduced.

Q. Were there unresolved issues related to pressure from the last full Order over two years ago?

A. No, I do not believe so. I believe we demonstrated to the Commission and its staffs' satisfaction that the Utility was providing water to all of its customers well above the required pressure levels at all extremities of the system. Certainly, every pressure test done by us, or anyone else, has concluded that is the case.

Q. The Commission's Order from early 1997 also raised some concerns about Aloha's customer relations and its record keeping related to customer complaints. Do you have any further evidence to provide to the Commission at this time concerning that issue?

A. Yes. First I would like to address the issue of record-keeping concerning customer complaints. As noted during the last hearing, Aloha was and continues to be in full compliance with the applicable Commission Rules related to logging and keeping record of customer complaints. We provided as a late-filed exhibit from that prior hearing, some information accumulated by me on that issue. We have further reviewed our policies and procedures to ensure that we continue to be in full compliance with all applicable requirements related to record keeping on customer complaints, and I have verified that in fact we are in such full compliance. Attached hereto as **Exhibit SGW-3**, is a copy of the information which I provided as part of late-filed Exhibit 24 from the prior hearing, which I believe addresses this issue in somewhat more detail.

We have also taken additional measures to ensure that all customer inquiries and complaints are properly processed and that all are addressed and that there is appropriate record-keeping. Since the last hearing, we have added a new computer system that allows us to track customer complaints more effectively, efficiently and precisely. We are also able to trace much more quickly and readily the results of our investigation of all customer complaints in the data base and to program the computer to recognize frequently occurring complaints, or complaints within a given area so that we can recognize trends and possible problems more quickly.

In addition, we made a change to make sure that all water quality complaints go through a single customer service representative, once it is determined that that is the nature of the complaint. In this way, no customers are left in a position of having talked to two or three different people at different times, and possibly receive answers that seem, to the customer at least, to have been different for the same problem.

Q. What about the issue of your staff's appropriately responding to customer concerns?

A. As noted above, we have reviewed our existing procedures and have incorporated some additional procedures which we believe have substantially aided us in properly responding to customer concerns. After the hearing at which some customers raised concern about the way they were treated by Aloha's personnel, we have undertaken to discuss with all of our staff members their responsibility to treat all customers with courtesy and dignity and to ensure that all of their complaints are thoroughly checked out to determine what, if anything, Aloha can do to resolve the problems. We have undertaken to have regular staff meetings to discuss recurring customer concerns and problems and how to deal with them to ensure that the customers receive a satisfactory answer, and that the problems are resolved to the best of our ability.

We have also prepared an informational packet, put together by us, which has been reviewed by both the DEP staff and the Commission staff for accuracy and that is provided to each and every customer whose complaint is determined to be related to copper sulfide. This packet includes extensive explanation and possible solutions that the customer can undertake to alleviate the occurrence of copper sulfide within their home.

Since these problems are the result of factors beyond our point of delivery and beyond our control, this was not something we were required to do. However, we want our customers to be happy with their water service and do what we can to help them achieve that, even when the problem is the customers' responsibility. We have certainly gone the extra mile in our opinion in trying to assist those customers who have continuing problems, even though many times these problems are caused by factors beyond Aloha's point of delivery and, therefore, the area of Aloha's responsibility. We have done such things as agreed to send people out to actually flush the customer's internal system, to attempt to assist some customers who had experienced copper sulfide problems, as well as other measures which we believe are above and beyond the call of duty. I have tried to ensure that any persons who have a problem or question concerning the quality of service provided have those problems resolved by our staff.

Q. Is Aloha currently in compliance with all water quality regulations imposed by the applicable regulatory authorities?

A. Yes we are and we have been throughout the time that this docket has been open. There was some suggestion that Aloha was out of compliance with the Lead and Copper Rule during the early phases of this proceeding some three years ago. However, that is an inaccurate statement. Aloha was not out of compliance with the Lead and Copper Rule. In fact, the Lead and Copper Rule requires a Utility to test the water inside a customer's home to determine if the lead and copper levels are above a certain point called an "action level." If the test showed levels above the action level, a Utility is required to come up with a plan to reduce the corrosivity of their water. If a Utility did this, they were considered to be in compliance with the program. That is why the rule refers to it as an "action level" instead of a "maximum contaminant level" or MCL. Aloha has been and still is in compliance with the Lead and Copper Rule. We took immediate action once we determined that we were above the action level, and have worked diligently to ensure a maximization of the benefits of the corrosion control method which we have utilized, which is the injection of the corrosion inhibitor. Pinellas County, as an example, is using the exact same method for its corrosion control program. We have now optimized the level of injection of the corrosion inhibitor and therefore, are below the action level for corrosivity. Most Utilities in Florida were required to implement corrosion control after the first round of testing. I believe that the Commission staff has fully verified this during their extensive investigation into the various issues raised by the Commission Order in March of 1997 and since that time. Our lead and copper corrosion program has worked effectively to reduce the corrosivity of our water to below the required "action level." In fact, our system was deemed fully optimized by the Florida Department of Environmental Protection on August 11, 1998. On June 28, 1999, the Florida Department of Environmental Protection granted us permission to go to reduced monitoring on our lead and copper program due to the continual success our program has demonstrated.

Q. The Utility was also criticized in the March 1997 Commission Order for its failure to have undertaken an extensive study of the Utility's water quality for the past five years. How do you respond to that criticism?

A. There was no reason for the Utility to undertake any extensive study at that time. While there were certainly some water quality concerns raised by customers during the hearings, the number of complaints prior to the initiation of this water quality proceeding in early 1996, were very few. The copper sulfide complaints were not identified, nor did they reach a significant level until the end of 1995 and early 1996, right at the time this investigation was begun. The Utility asked DEP for authorization to immediately begin injection of the corrosion inhibitor to try and address these concerns right after the discovery of copper sulfide in some customers' homes.

The scientific evidence has always demonstrated that this was the best course of action. While several persons, including the customers and even the Commission and its staff at times, have suggested that the Utility at least review other alternatives, our engineers as well as the people at DEP have recognized throughout that we were pursuing the appropriate course of action and the only one that we could reasonably undertake without a substantial increase in rates.

David Porter, P.E. did perform the study for Aloha as required by the Commission to review what could be done to improve water quality. That was submitted to the PSC approximately two years ago. That report did conclude what we have been telling the Commission all along about the reasonable alternatives that the Utility could undertake at this time to help in some of these areas of concern raised by the customers. As noted in that report, such improvements would also cause rates to increase. We have agreed to undertake these improvements substantially sooner than is otherwise required, and we continue to take that position now.

The staff of the Commission and DEP have performed extensive studies and analysis of Aloha's water which I believe are unprecedented in the history of private water and sewer Utilities regulated by the Florida Public Service Commission. The conclusions are still the same as those which we asserted at the last hearing. That the Utility's corrosion control program was the best method to try and address the concerns, and that the majority of the problems are the result of factors inside the customers' homes (including the use of home treatment units) which Aloha has no control over . As noted very specifically within the Commission's own rules, Aloha's responsibilities end at the point of delivery as defined within Rule 25-30.225(5) and 25-30.231, Florida Administrative Code. The Utility cannot be placed in a position to try and maintain or address water quality beyond that point, because of the customers' sole right and ability to determine the nature of facilities beyond that point and to change the chemical makeup of the water through use of home treatment facilities.

The only other thing that could be done are the plant improvements that we have outlined in Mr. Porter's June 1997 study. We believe, to the extent that the Commission wishes the Utility to take further measures to improve water quality, that these are the measures that should be undertaken because they are the only measures that have been scientifically shown by testing or by review of competent engineers to help in the areas of the customers' complaints.

Q. Did the Commission require that Aloha undertake a Survey of Customer Satisfaction?

A. Yes, they did by Order No. PSC-97-1512-FOF-WS issued in the Fall of 1997. This action by the Commission was unprecedented. However, Aloha went along with the Survey and worked with the Commission and the customer representatives in drafting the appropriate Survey questions and wording. However, the final decisions were made by the Commission staff. After the Survey was responded to, we accumulated the results. Certainly the Survey received a high level of response. However, as the Survey specifically noted on its face in bold language, those people who found the water quality and service satisfactory were told that they need not respond. As such, we felt that the analysis of the Survey results as provided by the Commission staff to the press and the way in which they were described in a later Order of the Commission were unfair to Aloha, because they did not compare the Survey results to the total number of people surveyed. We provided the Commission with our own analysis showing the way the Survey results should be characterized, and I am attaching a copy of those letters to my testimony as **Exhibit SGW-4**.

Q. Did the number of Survey responses surprise you?

A. No. This was the first Survey of its kind issued by the Commission, so there is nothing to compare it to. While some people have suggested that you could compare it to the response to an extended area service questionnaire (which the Commission has undertaken in the past), it is not in any way, shape, or form comparable to those type of surveys based upon what I understand that those Surveys included. The Commission to my knowledge has never before had a Utility undertake a Customer Satisfaction Survey, or even any kind of extensive Survey like this one. Certainly the level of our customer complaints have been relatively minor after the hearing of the reuse case over 2 ½ years ago. The level of complaints jump at times around such events as the 1996 hearings, the Survey, the Commissioners' visit, or the Commission's final action on these proceedings. However, in all, our customer complaint level is very low at the present time. In fact, our water quality complaint level for the last twelve months is lower than it has been in five years and is back to or below the levels which existed prior to the filing of our reuse case with the Commission in 1995.

Q. Did members of the Commission actually visit the Utility's service area to review the quality of water provided by Aloha.

A. Yes. In the Summer of 1998, Commissioners Deason, Johnson and Clark arranged to visit Aloha's service territory and view several customers' homes and the water provided by Aloha into those homes. Unfortunately, do to a family emergency, Commissioner Deason was not able to attend. However, Commissioners Clark and Johnson were escorted around to several predetermined customers' homes to view the water provided to those customers. In each and every case, we arranged to take a sample of water from outside the customers' homes in order to show the Commission the quality of water that was actually being provided at the point of delivery by Aloha. We still have those samples and will provide them at hearing if the Commission so desires. In each and every case, they showed that the water being provided to the customers' homes was clean and clear at the point of delivery. Certainly, the Commission's visit revealed that as of last Summer, there were still some customers receiving some copper sulfide in a few homes. We at Aloha still believe that the total number of homes experiencing this copper sulfide problem is less, only a fraction of a percent of total customers served. Secondly, we believe the optimization of our injection of the corrosion inhibitor and our corrosion control program in general, should have substantially helped in reducing the level of copper sulfide which customers are experiencing. However, homes with home treatment units are much more likely to continue to have both corrosion problems and odor problems because of the effects that these systems have on the water delivered by Aloha after our point of delivery. Aloha cannot treat water that is unaffected by these systems and therefore, it cannot be held responsible for what occurs as a result of utilization of these systems. DEP and the environmental regulators have certainly recognized this fact.

In all, I believe while the Commission's visit showed them that there were some problems continuing at that time with copper corrosion in customers' homes, it also showed them that in the one case where the copper pipe was completely replaced (the home of Mr. Vinto) that the problem immediately and completely disappeared. In addition, I believe it showed the Commission that the water as delivered by Aloha is completely clean and clear with no copper sulfide, or any other discoloration.

Q. Do you have any further testimony to provide at this time?

A. No, other than to say that hopefully, we can resolve this case once and for all and bring it to a close after over three and one-half years now of reviewing these matters. The level of investigation of Aloha, the things required of Aloha, and Aloha's voluntary actions in response (above those required of us by the environmental regulators), have been unprecedented. The primary issue here concerns a building material used in the construction of homes, i.e. copper pipe. While the focus throughout this proceeding has been water quality, the better focus all along would have been copper plumbing systems. Representative Fasano recently asked Pasco County to enact an ordinance to prohibit the use of copper in plumbing and should be commended for that. It is time to bring this case to a close based upon the scientific and engineering evidence, which we believe fully supports that Aloha is in compliance with all environmental regulatory requirements and all customers complaint requirements of the Commission's Rules and that the Utility is doing and has been doing what it should be doing in order to ensure that the best quality of service is being provided to its customers. If the Commission wishes Aloha to do more, then we need to have an order laying out specifically what needs to be done and Aloha will move forward with those improvements.

ALOHA UTILITIES, INC.
Article from The Journal of the American Water Works Association

Exhibit SGW-1

Sulfide-induced copper corrosion

Sulfides can accelerate the corrosion of copper pipe and elevate concentrations of copper in drinking water.

Sara Jacobs, Steve Reiber, and Marc Edwards

Although extensive research documents that sulfides corrode copper alloys in seawater,[1] almost no sulfide corrosion research applies directly to drinking water utilities and homeowners. The possible corrosive effects of sulfur species on copper can be predicted by comparing the Pourbaix diagram for the copper–water and copper–sulfur–water system (Figures 1 and 2).[2] The copper–water system contains a large pE–pH region in which copper metal [Cu(s)] is the thermodynamically stable species; i.e., under certain water conditions, copper is immune to corrosion because the oxidation reactions involved are ther-

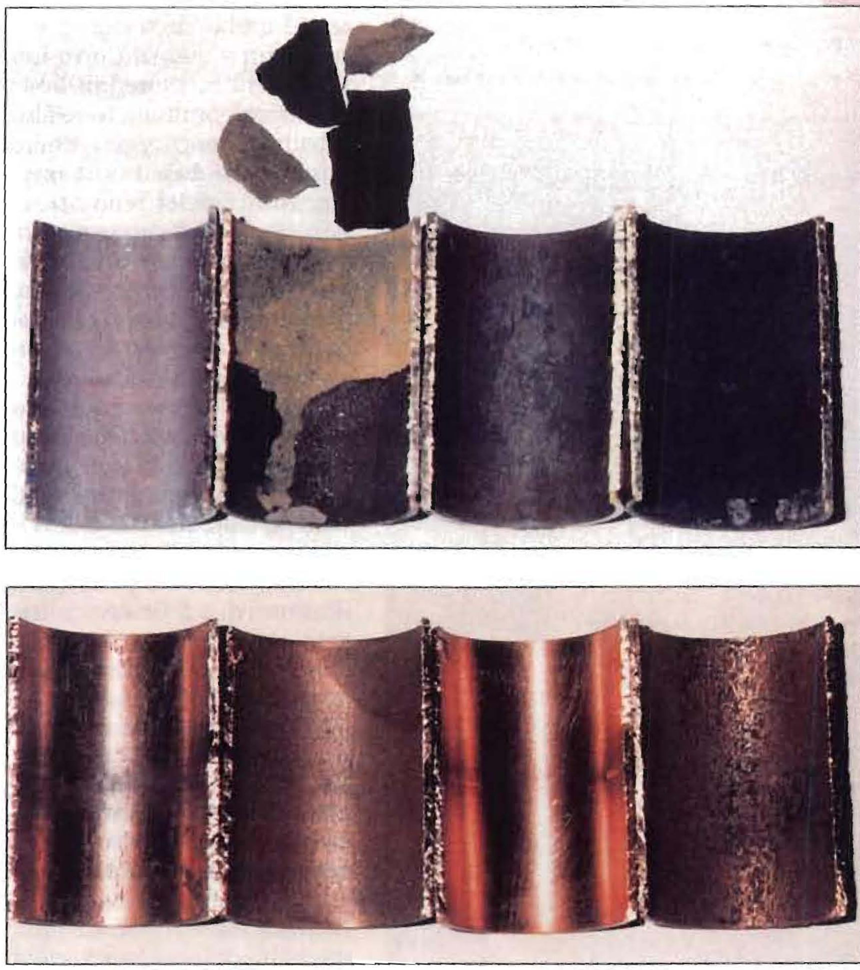
The presence of sulfides in potable water increases copper pitting and the release of copper corrosion by-products. After 3 h of stagnation in a copper pipe, the average by-product release of a synthetic drinking water that contained sulfides was 8.0 mg/L at pH 6.5 and 4.4 mg/L at pH 9.2. These concentrations represented a 5- and 50-fold increase compared with water without sulfides. Sulfide-induced corrosion problems might be ameliorated by removal of sulfides from the water, mechanical removal of the sulfide scale, chlorination, or deaeration. However, in the laboratory only mechanical removal of the sulfide scale and removal of sulfides from water were effective within a month. Utility case studies strongly support a relation between sulfides and increased copper corrosion problems.

For executive summary, see page 163.

modynamically impossible. However, introduction of sulfur species to this system greatly diminishes this region of immunity.

Moreover, pitting of copper by potable water has been circumstantially linked to sulfides.[3] A study of this problem concluded that "these [soft water] pitting failures are characterized by the identification of sulfides in the corrosion products and [scale] layers. It is still premature to comment on the importance of this fact, although the influence on the properties of the [scale] layer might obviously be considered."[3] Recently this link has been strengthened.[1] In laboratory experiments using low-alkalinity potable water at pH values of 6.5 and 9.2, the authors demonstrated that the presence of sulfides increased copper corrosion rates one to two orders of magnitude compared with the same water without sulfides. The 4.3–18.8-μA/cm^2 (3.9–17.2-mils/year) corrosion rates recorded in the presence of sulfides, which may be the highest ever recorded for copper in potable water at these pH values, did not decrease significantly during eight months of exposure.

Corrosion rates recorded in the presence of sulfides may be the highest ever at these pH values.



These coupons show the scale formed on copper (top) and the copper surface beneath the scales (bottom). The first two coupons in each row are at pH 6.5; the last two coupons in each row are at pH 9.2—both without (coupons 1 and 3) and with (coupons 2 and 4) sulfides.

Sulfide-containing rust or scale layer was shown to cause these increased corrosion rates. In previous research, black copper-sulfide scale was removed from a coupon that had been exposed to sulfides for eight months and coated onto a new copper pipe that was placed in sulfide-free water. The corrosion rate of the coated coupon equaled that of coupons exposed to sulfides for months. Additionally, mechanical removal of the scale layer reduced the high copper corrosion rates to normal levels. The scale catalyzed both anodic and cathodic redox reactions occurring at the copper–pipe surface. In the presence of this scale, reducing the concentration of dissolved oxygen from 16 to < 0.2 mg/L only slightly decreased the overall corrosion rate.[1]

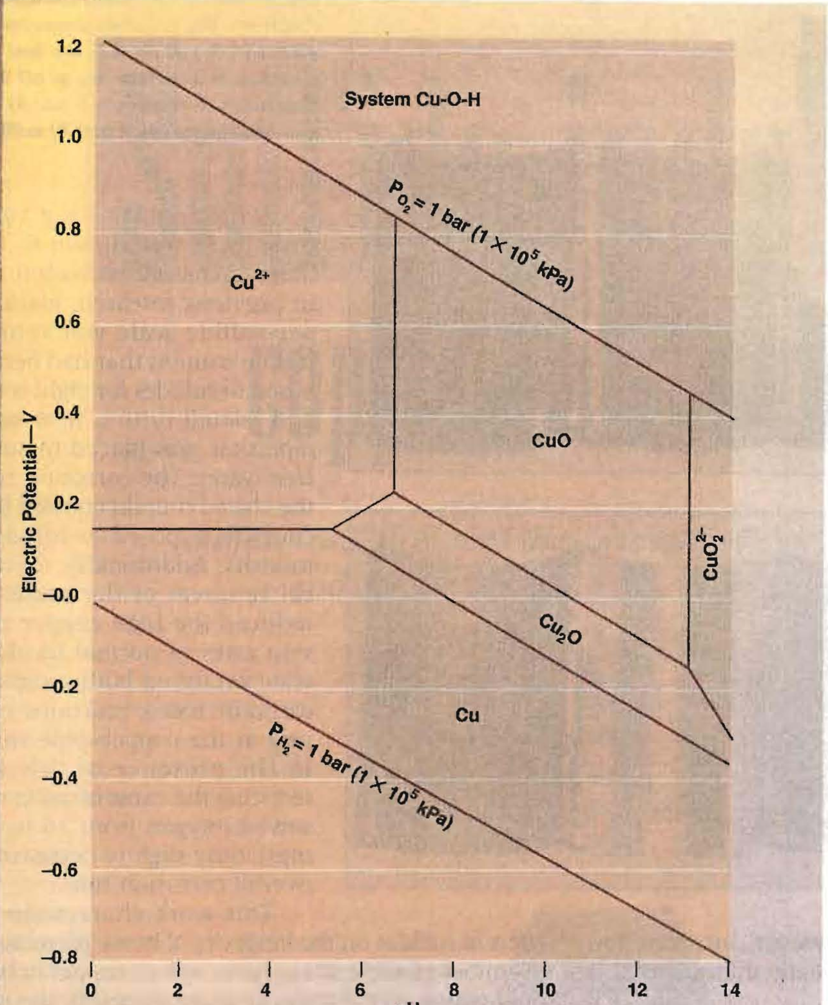
This work characterizes the effect of sulfides on the longevity of home plumbing and examines possible strategies to reduce copper in household water. As the corrosion rate increases, the rate of by-product release and of pitting failures may also increase. Because these problems are of concern to utilities and homeowners, experimental results are reported that delineate the role of sulfides in these problems. A literature review and case studies highlight the problem in practical situations.

Typical pH range studied

The base solution used in all laboratory experiments contained 23 mg/L sodium chloride, 30 mg/L sodium sulfate, and 25 mg/L sodium bicarbonate in deionized water.* These solutions—with and with-

*Milli-Q, Millipore Corp., Bedford, Mass.

FIGURE 1 Potential-pH diagram of the copper-water system at STP



From Brookins, D.G. E-pH Diagrams for Geochemistry. Springer-Verlag, Berlin (1988).

out sulfides—were tested at pH 6.5 and 9.2 to capture effects throughout the pH range of typical drinking water. Sulfides were added as $Na_2S \cdot 9H_2O$ at a concentration of 5 mg/L as sulfide twice per week. Equimolar sulfur concentrations were added to the solutions without sulfides as Na_2SO_4, and the solutions were completely changed each month. Sulfides were detectable up to three days after sulfide addition at the beginning of the experiments. Solutions were open to the atmosphere, and experiments were conducted at a temperature of 22 ± 3°C (71 ± 5°F).

The copper coupons used for all experiments were ⅝-in.- (16-mm-) diameter nominal copper couplings with an internal surface area of 20 cm^2 (3 sq in.) and an actual inner diameter of ¾ in. (20 mm). Water from 16-L (4.2-gal) reservoirs was circulated through the coupons at a flow rate of 1 gpm (0.06 L/s) for 30 min every 12 h. Corrosion current and potential measurements were determined using the Reiber electrochemical cell[4,5] and a corrosion-measurement system.* Corrosion rates were measured in units of µA/cm^2, but they were also calculated and reported here as mils/year based on a one-electron-transfer redox reaction. Details of the exposure apparatus, electrochemical cells, and quality assurance–quality control of the electrochemical measurements are described elsewhere.[1,4]

By-products were released under stagnant conditions in coupons filled with fresh solution and allowed to sit sealed with parafilm for 3 or 6 h. The water was then decanted from the coupons, and, after acidification with 5 percent nitric acid, copper concentration was measured with an inductively coupled plasma emission spectrophotometer.†

Sulfides decrease plumbing longevity, induce release of corrosion by-products

During exposure to water containing 5 mg/L sulfide, thick, black, poorly adherent scales formed at both low and high pH values. This black scale layer developed in as little as 4 h and grew to a thickness of about 0.4 mm (0.02 in.) during nine months of exposure to sulfides. Upon drying, the underlying scale produced at pH 6.5 was orange and powdery; that produced at pH 9.2 was gray and shiny, similar in appearance to graphite.

When the scale was mechanically removed from the coupons using gentle abrasion with a synthetic scouring pad, the copper beneath the sulfide scales was slightly pitted, whereas the coupons not exposed to sulfides looked like new copper. The underlying metal surfaces of the coupons exposed to sulfides at pH 9.2 were less uniform than those exposed at pH 6.5. Thus, different values of pH induced different types of attack in the presence of sulfides.

After 11 months of exposure, the average weight loss of copper coupons exposed to sulfides was 11 percent at pH 6.5 and 5 percent at pH 9.2.[1] In contrast, the coupons placed in the sulfide-free solutions lost < 0.5 percent of their weight. Corrosion rates in sul-

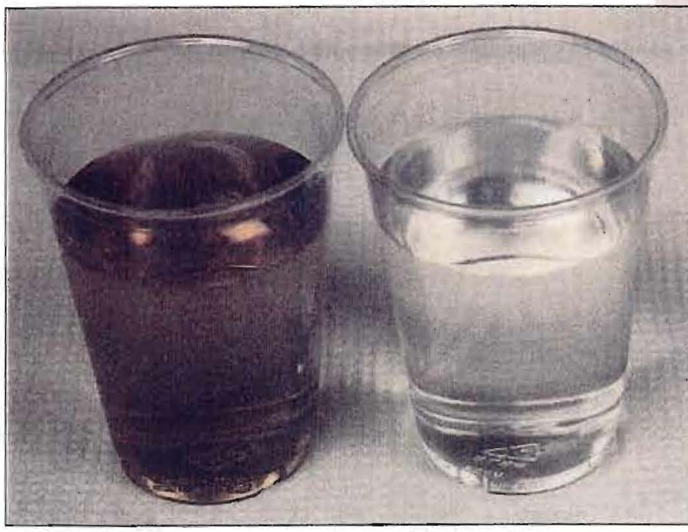
*CMS100 Corrosion Measurement System, Gamry Instruments, Inc., Longhorne, Pa.

†Varion Liberty 150 AX, Palo Alto, Calif.

fide-free water were 1.0 and 0.2 µA/ cm^2 (0.89 and 0.18 mils/year) at pH 6.5 and 9.2.[1]

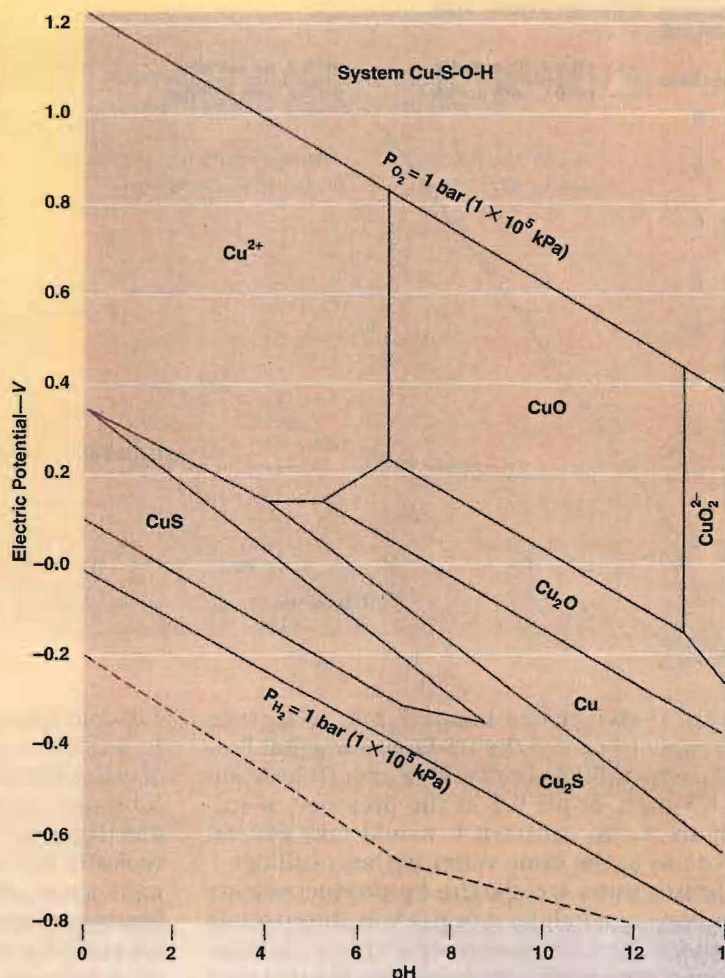
Based on these results, sulfide-bearing water would be expected to significantly decrease the lifetime of copper plumbing and increase the release of corrosion by-products into drinking water. The authors calculated how long it would take to completely corrode the metal of a typical pipe, on the basis of weight loss (in sulfide-bearing systems) and of electrochemical measurements assuming a one-electron transfer (in systems without sulfides). Uniform corrosion was assumed for all systems. A ¾-in.- (20-mm-) inner-diameter Type K copper pipe, of 65-mils (approximately 1/16-in. or 1.6-mm) wall thickness, would take more than 500 years to completely corrode at pH 9.2 in sulfide-free water (Figure 3). In contrast, an identical pipe in water at the same pH but with sulfides present would take less than 18 years to completely corrode through. Only 13 years would be required to completely corrode thinner Type L tubing at pH 9.2 in the presence of sulfides (wall thickness of 45 mils [0.045 in. or 1.1 mm]). These estimates likely represent maximum elapsed times, because the nonuniformities of pitting corrosion will cause pipe failure long before all of the metal has corroded. However, these calculations demonstrate the practical implications of sulfides for pipe longevity.

The authors calculated by-product release by assuming that sulfide-induced corrosion proceeds uniformly during stagnation and by using the known volume of water within a ¾-in.- (20-mm-) inner-diameter pipe and the same corrosion rates used to calculate the lifetime of that pipe (Figure 4). If all corroded copper were released to solution (in fact some copper is incorporated into a growing



Tap water with 5 mg/L of copper sulfide as Cu can be significantly discolored.

FIGURE 2 **Potential–pH diagram of the copper–sulfur–water system at STP**



From Brookins, D.G. E-pH Diagrams for Geochemistry. *Springer-Verlag, Berlin (1988).*

FIGURE 3 Time needed to completely corrode a pipe through uniform corrosion

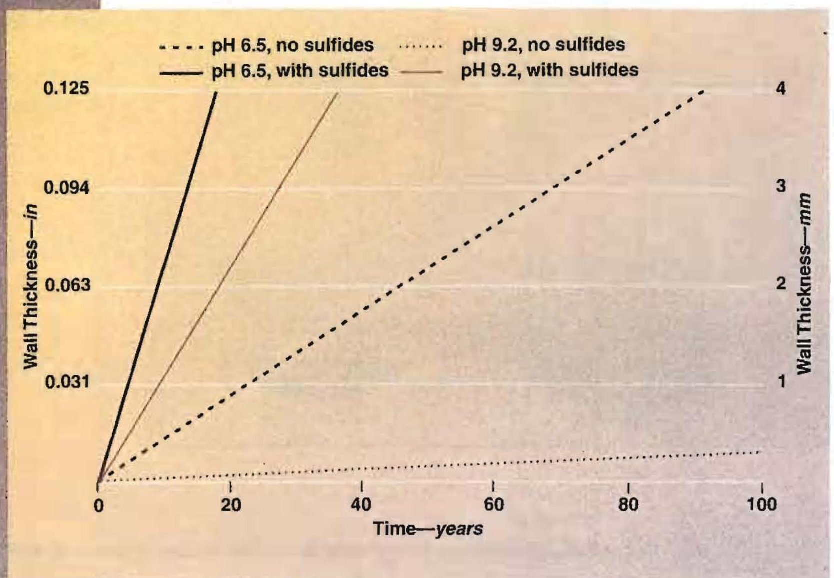
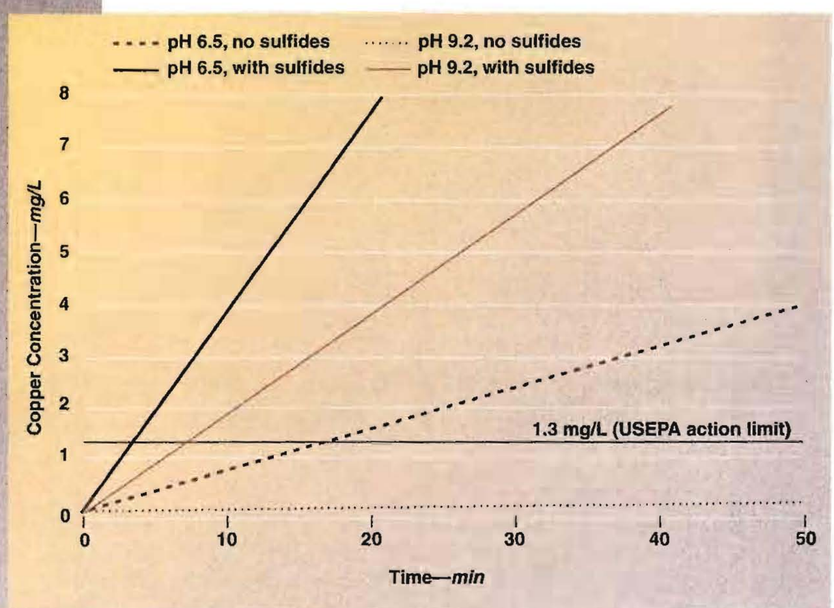


FIGURE 4 Predicted copper by-product release within a ¾-in.- (20-mm-) diameter copper pipe



scale layer), then it would take < 7 min to corrode enough copper to exceed the US Environmental Protection Agency (USEPA) Lead and Copper Rule action limit of 1.3 mg/L at pH 9.2 in the presence of sulfides (Figure 4). In contrast, it would take several hours to do so in the same water without sulfides.

To confirm these trends, the by-product release from coupons aged eight months was determined after 3 and 6 h of stagnation (Figure 5). Similar amounts of copper were released during the two time periods, apparently because of a rapid approach to pseudoequilibrium. The actual by-product release values in Figure 5 are the average of the 3- and 6-h measurements. The copper coupons exposed to sulfide-free water at pH 9.2 released an average of < 0.1 mg/L Cu. The average copper by-product released by coupons exposed to sulfide-free water at pH 6.5 (1.5 mg/L Cu) was higher than the regulated level of 1.3 mg/L, but this value is typical for drinking water at this relatively low pH. However, the by-product released by coupons exposed to sulfides was much higher—an average of 8.0 mg/L total Cu at pH 6.5 and 4.4 mg/L total Cu at pH 9.2. The 3-h copper release predicted on the basis of corrosion-rate measurements was much higher than the release measured at all four sets of experimental conditions (presence or absence of sulfide at pH values of 6.5 and 9.2). This observation suggests that a large portion of the corroded copper formed scale or that corrosion rates were substantially lower during stagnation. Nevertheless, trends in the data were consistent with expectations based on corrosion rate measurements.

As a longer-term measure of cumulative copper by-product release, copper concentrations in the 16-L (4.2-gal) reservoirs were measured after a month of exposure and before the solutions were changed and replaced with freshly prepared solution. Because each of the four coupons held a volume of 9.5 mL, the 16 L (4.2 gal) of water in the reservoir represented a 420-fold dilution of water that would fill the coupons. To normalize the copper concentration to the volume of water within the coupons, the measured copper concentration in the reservoir was increased by a factor of 420 (Figure 6). During one month, sulfide-free solutions typically released only 4 mg/L Cu at pH 9.2 and 78 mg/L Cu at pH 6.5. In the same time interval, sulfide-bearing solutions released an average of 1,060 mg/L Cu at pH 9.2 and 1,320 mg/L Cu at pH 6.5. (Release at pH 9.2 during the five months was unstable.)

To characterize the corrosion by-products, the authors filtered samples through a disposable nylon-membrane (0.2-µm pores) syringe filter. Between 85

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and 90 percent of the copper in sulfide-bearing solutions passed through this filter, a surprisingly high percentage given the low solubility of copper sulfides. Perhaps this copper was present as very small colloids. At least partly because of their black color, copper sulfide corrosion by-products were visible to the naked eye at concentrations as low as 1 mg/L and could be disturbing to consumers at higher concentrations.

FIGURE 5 **Predicted and actual by-product releases by copper coupons**

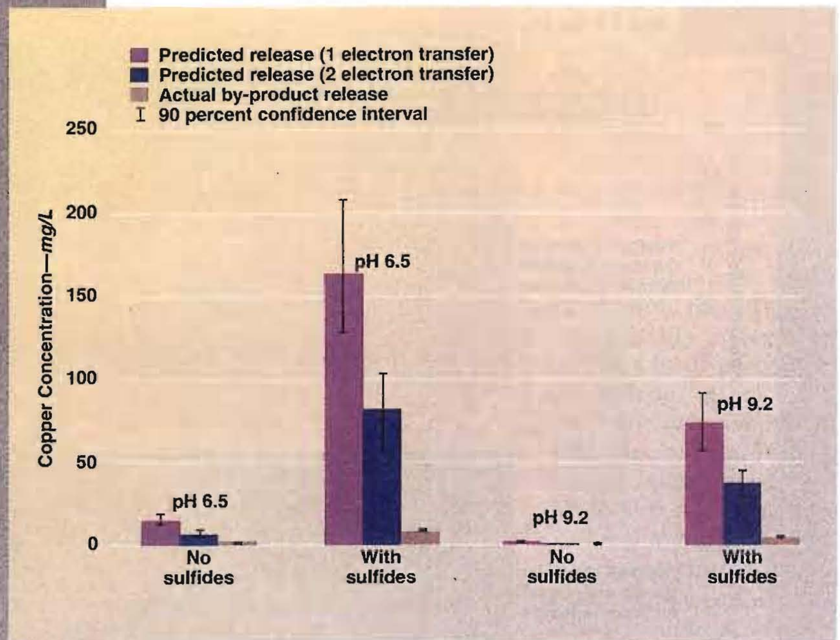
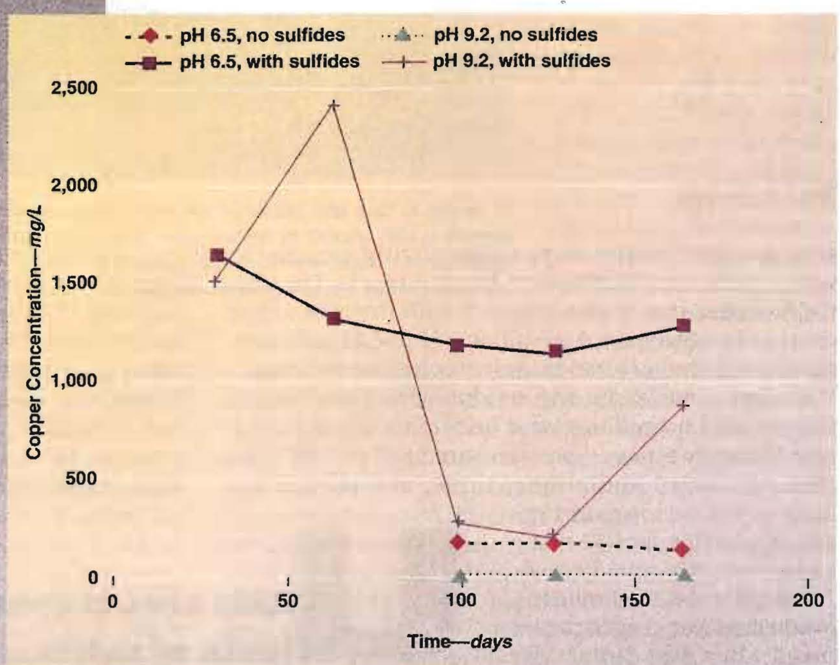


FIGURE 6 **Total copper released to reservoirs expressed as the equivalent concentration of copper in the coupons**



Possible remediation strategies examined

Four remediation strategies were investigated: removal of sulfides from the water, chlorination, superchlorination, and deaeration. Another strategy, mechanical removal of the scale, was shown to be effective[1] but is not likely to be practical for home plumbing.

Remove soluble sulfides from water. After nine months, copper coupons that had been immersed in sulfide-bearing water were placed in series with coupons that had been immersed for nine months in sulfide-free water. All coupons were then exposed to sulfide-free water for 68 days. At pH 6.5, the corrosion rate of coupons that had been previously exposed to sulfides fluctuated between 6.0 and 11.5 $\mu A/cm^2$ (5.3 and 10.2 mils/year), but no definite trend in corrosion rate was established (Figure 7). At pH 9.2, the corrosion rate of sulfide-exposed coupons began to decrease after the first four days. This decrease may reflect a statistically insignificant trend toward lower corrosion rates at pH 9.2 over time, a continuation of what was observed even when sulfides were present.[1]

After the coupons spent two months in sulfide-free water at both pH 6.5 and 9.2, the corrosion rates of the coupons coated with sulfide scale remained an order of magnitude greater than the corrosion rates of coupons never exposed to sulfides. If the corrosion rate of the sulfide-coated coupons at pH 9.2 were to continue decreasing linearly when plotted against the logarithm of time, it would still take about 400 days before the corrosion rate fell to a rate comparable to that of copper in the absence of sulfides.

Chlorinate. In order to examine the effect of chlorination as a possible remediation strategy, two coupons used in the preceding experiment (on sulfide

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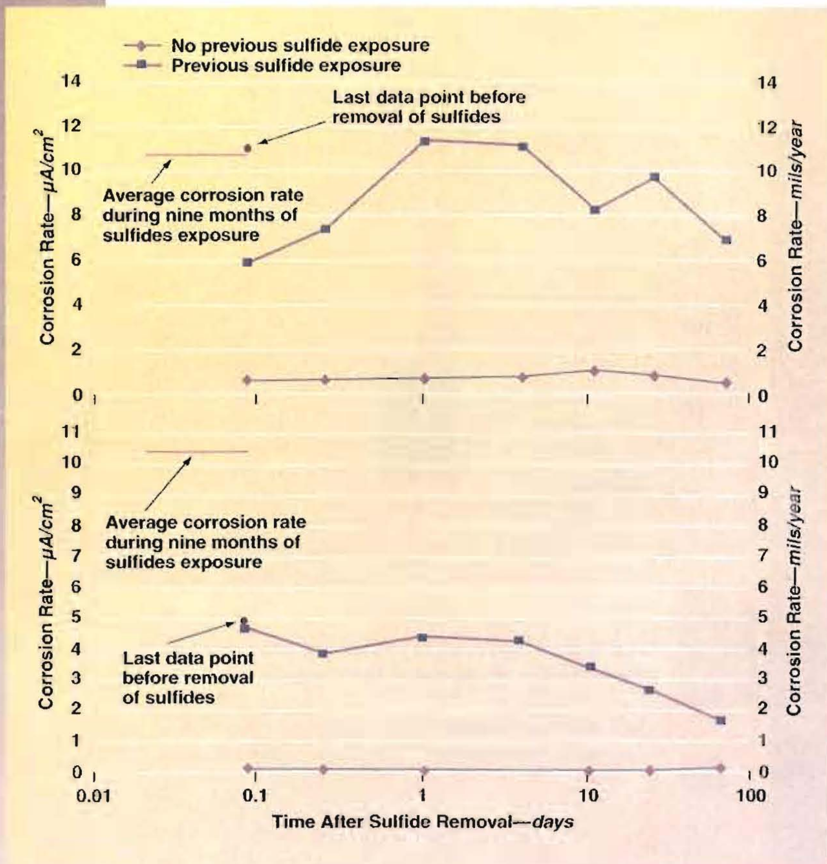
FIGURE 7 Rate of corrosion of copper coupons after nine months of sulfide exposure, followed by abrupt removal of sulfides at pH 6.5 (above) and 9.2 (below)



removal from water) were subsequently exposed to water with 1 mg/L chlorine for one week. The corrosion rates were then compared with those of a new coupon never exposed to sulfides. Liquid bleach containing 5.25 percent sodium hypochlorite by weight was used to maintain the residual chlorine concentration, and no sulfides were added during chlorination. Corrosion rates were measured just before chlorine was added and at one, three, and seven days after chlorination had begun. The coupons were then exposed to a single dose of 100 mg/L chlorine, and corrosion rates were again measured after one month. It was expected that the chlorine might favorably alter the nature of the sulfide-containing scale formed during sulfide exposure.

The average corrosion rate during the week of exposure to 1 mg/L of chlorine was calculated and compared with the corrosion rates before chlorination (Figure 8). In the presence of chlorine, corrosion rates increased markedly under all four sets of experimental conditions, possibly because chlorine is a stronger oxidant than oxygen. These findings are consistent with previous work that demonstrated chlorine can increase the corrosion rate of copper.[5] After superchlorination and one month of aging, the coupons were exposed to a fresh, chlorine-free solution for 15 h before corrosion rates were again measured. The only substantial reduction in corrosion rate occurred at pH 9.2 in the coupon previously exposed to sulfide (Figure 8). Even so, this reduction was not sufficient to lower the corrosion rate to levels typical of copper never exposed to sulfides. Thus, neither chlorination nor superchlorination effectively eliminated problems of sulfide-induced copper corrosion during relatively short time periods.

Deaerate. Deaerating water might reduce corrosion rates by removing the oxygen that fuels corrosive attack. However, even an hour of purging nitrogen through water and reducing oxygen to undetectable levels did not significantly decrease the corrosion of pipes exposed to sulfides.[1] Apparently, even trace concentrations of oxygen can sustain high corrosion rates in the presence of the catalytic sulfide-containing scale. On the other hand, in previous research the harmful effects of sulfide-induced corrosion did not occur in completely deaerated seawater.[6–8] Taken as a whole, the results of this and other studies suggest that increases in oxygen concentration resulting from aeration for sulfide removal at utilities that already have oxygenated water sources might not worsen sulfide-induced corrosion. However, aeration for sulfide removal at utilities supplied by water sources that contain sulfides but not oxygen may pose problems. That is, aeration could trigger severe sulfide-induced corrosion that had previously been suppressed by the absence of oxygen. Additional research is needed to define the interplay between oxygen and sulfide-in-

Utilities should consider the possible effects of sulfides whenever copper corrosion problems are encountered.

duced copper corrosion in drinking water and to identify effective remediation strategies.

Case studies show effects of sulfide-induced corrosion

Although laboratory work has demonstrated that sulfide-induced copper corrosion can harm potable water plumbing, its relevance to real systems remains uncertain. Sulfate-reducing bacteria appear to be present in all distribution systems,[9,10] and sulfide-induced corrosion can be initiated at concentrations as low as 0.007 mg/L sulfide.[11] Thus, on the one hand, sulfides could be a major cause of copper corrosion. On the other hand, other constituents in drinking water, such as natural organic matter,[12] that were not investigated in the previous experiments might inhibit sulfide-induced corrosion. Although reality is somewhere between these two extremes, the authors attempted to compile case studies from the literature and from utility contacts in which copper corrosion might have been induced by sulfides. (With the exception of the Texas case study, which was conducted as part of this work, sulfides were not initially investigated as a primary cause of the observed problems.)

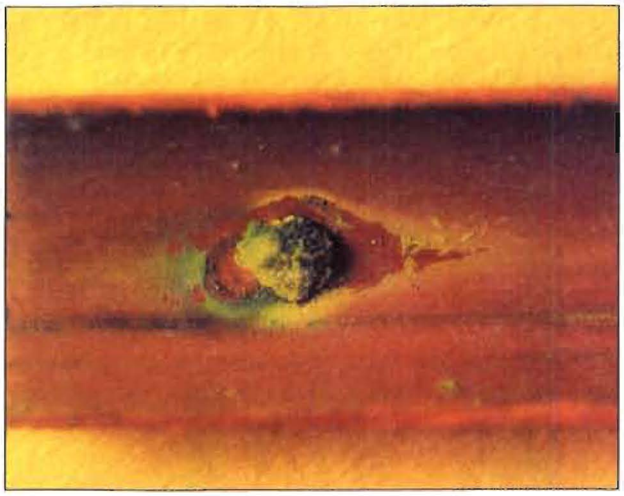


PHOTO: STEVE REIBER

This pit (top), with the tubercle cap still in place, is typical of the Mission system in Texas. The scanning electron micrograph (bottom) shows the pitting structures underlying the tubercle caps.

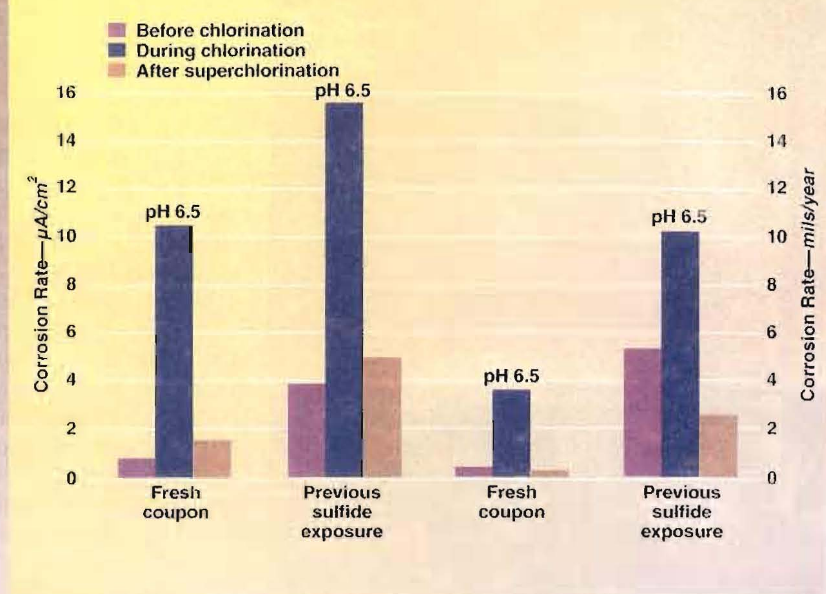
Sulfides may cause copper action level to be exceeded. In a case that must remain confidential for legal reasons, a utility with raw water sulfides received vehement consumer complaints because of high concentrations of black particles at the tap. Copper pipe sections from the affected homes contained a thick coat of soft, mushy, black scale. The black scale and particles were identified as cupric sulfide.

The magnitude of the problem varied markedly from one section of the distribution system to another, and even from home to home within a section, suggesting that factors other than raw water quality were important in this instance. This utility typically removed sulfides to below detection levels (< 0.2 mg/L) by aeration. However, because even brief exposure to low concentrations of sulfides can induce long-term copper corrosion,[11] sulfide removal techniques must be extraordinarily consistent and efficient to be successful. It is possible that this utility's aeration system did not completely remove sulfides from the raw water all the time.

Sulfides might also cause problems in relation to compliance with the Lead and Copper Rule (Table 1). In a recent study, the Orlando (Fla.) Utilities Commission exceeded USEPA's 90th percentile action level of 1.3 mg/L Cu.[13] The water supply in Orlando is moderately hard groundwater that has a sulfide concentration of 0.44–2.5 mg/L, fairly typical for many groundwater sources in Florida. Analyses of water samples monitored to meet the Lead and Copper Rule showed 90th percentile Cu levels of 1.85 and 1.76 mg/L for the first and second rounds of testing. Treatment by aeration removed 40–60 percent of hydrogen sulfide from raw water, and chlorination removed the remainder. The utility received about eight or nine copper-related complaints a month, including blue water, pitting failures, and metallic taste.

Three additional Florida utilities, all of which treat sulfide-bearing raw groundwater, initially exceeded the copper action level but later came into compliance.[14,15] At least one of those utilities reported frequent problems with copper pitting corrosion. The three utilities used different strategies to reduce copper concentrations below the USEPA action level—adding phosphate inhibitor, adjusting pH, or adjusting both pH and alkalinity (Table 1). For comparison, the table also reports the average 90th percentile copper values at utilities in the United States that have similar pH and alkalinity values.[16,17] Utilities that treat sulfide-bearing raw water have 90th percentile copper values about three to six times the national average for utilities with similar pH values and water quality. After pH was adjusted or phosphate inhibitor was added, the 90th percentile copper concentrations at utilities 1 and 2 decreased to below the action level, but they were still three to four times the national average. Utility 3 markedly improved its sulfide removal concurrent with instituting corrosion

FIGURE 8 Rate of corrosion of copper coupons before and during chlorination (1 mg/L chlorine) and after superchlorination (100 mg/L chlorine)



control; its reported 90th percentile copper subsequently dropped to the national average.

Sulfides may hasten pipe failure. Instances of copper pitting corrosion in the presence of sulfides have already been noted.[3] Rapid pitting can cause pipe failure in less than a year, and the damage can result in great expense to the homeowner.[1,18] The following case studies from utilities in Florida, Ohio, Texas, and Scotland suggest a connection between severe pitting corrosion and the presence of sulfides.

Florida. Several instances of copper pitting have been reported in Cape Coral, Fla.[19] Water entering the distribution system has a sulfide concentration of 0.3 mg/L (Table 2). Its pH is higher and its alkalinity is lower than other Florida groundwater sources described in this article (Table 1). Loosely adherent layers of black deposits with small amounts of sulfur-containing products ringed the pits. Voluminous green tubercles covered the pits, and the larger the tubercle, the larger the underlying pit.

Ohio. A relatively new subdivision in Lima, Ohio, experienced severe pitting corrosion problems beginning in 1978. The sulfide concentration of the source groundwater was 0.063 mg/L, and, after treatment and aeration, the sulfide concentration was 0.022 mg/L. This trace concentration of sulfide is approximately three times as high as that determined to cause sulfide-induced corrosion problems in seawater.[11] Friable green tubercles containing sulfur compounds covered the pits. The problem was mitigated when the utility raised the pH to around 8.3 by adding sodium carbonate.

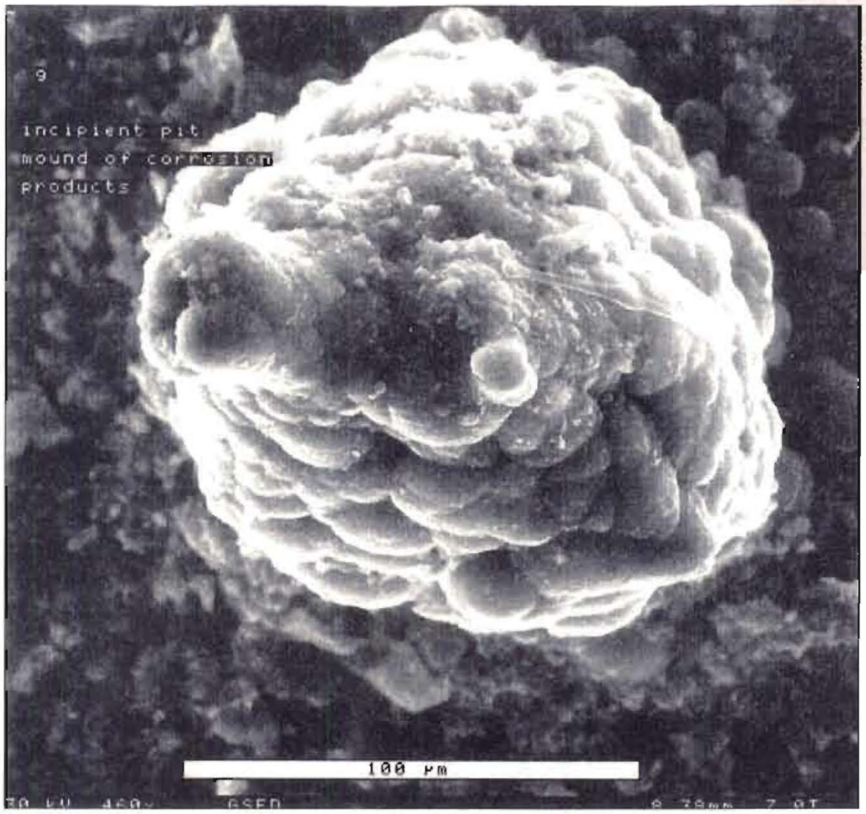
Texas. The Rio Grande is a well-buffered, moderately hard, heavily mineralized source water (Table 2). Turbidity is high, and water quality varies seasonally. Although this water is considered difficult to treat, the Mission Water Treatment Plant consistently meets all water quality and operational criteria, including chemical and microbiological standards.

In several residential developments constructed in the past decade, copper tubing has failed at unexpectedly high rates—during the past five years, one residential development recorded more than 120 fully penetrating pits and associated leaks. A sizable majority of the affected homes appear to have been unoccupied for more than a month each year. Pitting reported in continuously occupied homes tended to be in pipes that served infrequently used bathrooms.

Pitting predominated in the cold water pipes (approximately 70 percent of reported pits). Pits formed on both the crown and the invert of the tubing and on tubes that received both softened and unsoftened water. Pitting morphology was the same throughout the distribution system. Full-penetration pits were generally isolated; no other pits (small or large) were in the immediate vicinity. Also, the tubing surrounding the pitted section was generally free of corrosion scale and appeared to possess a well-passivated surface with minimal corrosion.

The pits had protective tubercle caps, and a reticular biological structure covered the surface. Although the microbial mass was translucent and uncolored, the corrosion products collected in it appeared to consist largely of cupric carbonates (malachite and azurite)

Established sulfate-reducing bacteria may inoculate new pipe or detached cupric sulfide scale may infect new pipe downstream, catalyzing severe corrosion.



This scanning electron micrograph shows a tubercle cap on an incipient pit (100-µm diameter). The tubercle is saturated with biomass.

and possibly a cupric hydroxy-sulfate (brochantite). These blue or blue-green minerals gave the tubercle cap its distinctive color.

The microbial nature of the biomass was characterized using a set of analyses collectively referred to as the biological activity reactivity test series. Sulfate-reducing bacteria were present in the standing water in pipe specimens and were indicated in the tubercle caps of copper pits. Some pipe specimens showed evidence of sulfide in corrosion scales. Chlorine residuals were persistently low or undetectable (during stagnation) in the pipes associated with pitting problems.

Scotland. Several cases of severe pitting corrosion and blue water occurred in a few hospitals in Glasgow, Scotland, starting in the early 1980s.[21] The city's water supply is extremely soft, poorly buffered, and highly colored with natural organic matter (Table 2). Water in distribution pipes was aerobic during the day but anaerobic during stagnation at night. Sulfate-reducing bacteria were present in large black nodules over penetrating pits, as indicated by an anaerobic medium test.[21] Corrosion appeared to be infectious because sections of pipe that had been replaced were identically corroded in a matter of months. A study of this problem concluded that "Where a biofilm containing SRB [sulfate-reducing bacteria] is established, no remedial action is likely to be effective. In severely hit hospitals, complete replacement of the hot water system would be indicated."[21] It is possible that established microorganisms inoculated the new pipe or that cupric sulfide scale detached from infected pipes

TABLE 1 **Possible by-product release by sulfide-induced copper corrosion before and after treatment change[15–18]**

Water Parameters	Orlando*	Utility 1	Utility 2	Utility 3
Sulfides in raw water—*mg/L*	0.44–2.5	1	5	2–3
Treatment change		Phosphate inhibitor added	pH adjusted	pH & alkalinity adjusted
pH				
Before	7.8	7.4	7.3	7.5
After		7.4	8.0	7.9
Alkalinity—*mg/L*				
Before	98–137	80	106	50
After		91	105	120
Sulfide—*mg/L*				
Before		<0.5	<0.1	0.7
After		<0.1	<0.1	<0.1†
90 percent Cu—*mg/L*				
Before	1.8	2.18	2.74	1.52
After		1.0	1.06	0.35
Average 90 percent Cu for large US utilities—*mg/L*				
Before	0.284 ± 0.255	0.575 ± 0.478	0.938 ± 0.827	0.326 ± 0.271
After		0.380 ± 0.312	0.824 ± 0.255	0.824 ± 0.255

*No treatment change
†System treated groundwater with tray aerator and chlorination, then changed to forced-draft aeration to remove sulfide.

TABLE 2 Quality of treated water distributed by selected utilities reporting copper pitting

Parameter	Florida	Ohio	Texas	Scotland
pH	8.8	7.3–8.0	7.2–7.6	7.4–9.3
Alkalinity—*mg/L*	41	290–349	<150	6.2
Total dissolved solids—*mg/L*	318	819	750	81
Sulfide—*mg/L*	0.3	0.022	NA	<0.003
Sulfate—*mg/L*	31	206–330	300	3
Sulfate-reducing bacteria	NA*	NA	Yes	Yes
Color (Hazen)	NA	NA	NA	13
Copper (at the tap)	NA	NA	0.5 (90 percentile)	0.3
Evidence implicating sulfides	Sulfur in pipe scale	Sulfide in pipe scale	Sulfide in pipe scale	Black scale with sulfate-reducing bacteria

*Not available

TABLE 3 Generalizations about sulfide-induced corrosion

Oxygen Concentration	Source of Sulfide: Raw Water	Source of Sulfide: Sulfate-Reducing Bacteria
0 mg/L	Corrosion problems unlikely Oxygen added by aeration may be of concern	Corrosion problems unlikely Oxygen added by aeration may be of concern
Low or high	Uniform corrosion High concentrations of by-product released Some pitting corrosion	Pitting corrosion problems Some by-product released

and attached to new pipe downstream, catalyzing a severe corrosive attack.[1]

Corrosion programs should assess effects of sulfides

This assessment of the role of sulfide in copper corrosion problems is subject to several caveats. First, the 90th percentile copper values reported in these case studies are variable and depend on many factors; thus, they cannot be used to draw definite conclusions about the role of sulfides in the observed copper corrosion. Similar considerations apply to case studies involving copper pitting. Nevertheless, the laboratory phase of this investigation demonstrated significant increases in copper corrosion from sulfides under well-controlled conditions, and the case studies support the idea that sulfides can induce severe copper corrosion under real-world conditions as well.

In all case studies in which copper scale was analyzed, either sulfate-reducing bacteria, sulfur-containing corrosion products, or sulfide-containing corrosion products were identified. Although some water sources naturally contain sulfides, in others the sulfides were produced by sulfate-reducing bacteria on the pipe wall. These results are relevant to many utilities, and potential effects of sulfides should be carefully considered whenever copper corrosion problems are encountered. This is especially true given the extensive experience of Cohen in analysis of cold water pitting problems: in all cases in which he analyzed pit tubercles for sulfides, they were always present.[19]

When this information is synthesized and some speculation is applied, several generalizations can be put forth (Table 3). Research conducted using seawater[6–8] suggests that if oxygen concentrations approach zero, sulfide-induced corrosion is likely to be suppressed. However, deleterious sulfide scales can still develop on pipe walls and induce corrosion if water is later aerated. If both oxygen and sulfides are present in the water, high uniform corrosion rates and by-product releases can be anticipated. The sulfides, and thus the sulfide scale, will be distributed uniformly throughout the copper pipe systems. However, in a few cases, pitting corrosion seemed to result if sulfate-reducing bacteria were present, possibly attributable to a locally high concentration of sulfides within or near the pits. Pitting corrosion and copper by-product release problems are not mutually exclusive. Even if one form of corrosion is dominant, the other may still be present.

Incorporation of sulfides into the scale layer has been shown to dramatically increase copper corrosion rates.

Conclusions based on laboratory experiments about the success of remediation strategies may be overly pessimistic. Some utilities in Florida did successfully reduce the extent of sulfide-induced corrosion, at least in the context of 90th percentile copper release. It is also likely that uncharacterized interactions between sulfides and natural organic matter, pH, alkalinity, and other parameters may control the type and magnitude of copper corrosion observed in real systems. For instance, in the laboratory phase of this investigation, higher pH (9.2 versus 6.5) led to lower corrosion rates and lower corrosion by-product releases but more pitting.

Collectively these findings demonstrate that mitigation of sulfide-induced corrosion might be important for improving the performance of copper in domestic plumbing.

Conclusions

• In laboratory experiments using low-alkalinity drinking water at pH 6.5 and 9.2, addition of sulfides produced some of the highest corrosion rates ever recorded for copper. At these rates, which did not decrease with time, all the copper in a pipe of 1/16-in. (16-mm) wall thickness would completely disappear (corrode) in less than nine years at pH 6.5 and 18 years at pH 9.2. Pipes in homes would fail much sooner given the nonuniformities of pitting corrosion.

• Pipes exposed to sulfide released more copper corrosion by-products to drinking water than pipes never exposed to sulfides. During a 3-h stagnation time, sulfide exposure elevated copper release by about five times at pH 6.5 and about 50 times at pH 9.2.

• Sulfide-induced corrosion initiated in the laboratory proved difficult to stop. Removing sulfides from the raw water, adding chlorine, or deaerating water did not mitigate the problem in a relatively short time (one week to two months). Although some utilities were able to successfully reduce 90th percentile copper concentrations and pitting corrosion problems with typical corrosion remediation strategies, others, such as the hospitals in Scotland, were not.

• Utilities and homeowners should be alert to a greater likelihood of copper corrosion problems whenever sulfides are present.

Acknowledgment

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About the authors: *Sara Jacobs is a water quality intern at the Alameda County Water District, 43885 South Grimmer Blvd., Fremont, CA 94537. Jacobs has researched blue water copper corrosion in Melbourne, Australia. Steve Reiber is director of water research at HDR Engineering, 500 108th Ave. NE, Bellevue, WA 98004. Marc Edwards is associate professor in the Department of Civil Engineering at Virginia Polytechnic Institute and State University, 407 NEB, Blacksburg, VA 24061-0246.*

12

ALOHA UTILITIES, INC.
Copy of a Letter From our Attorney to the PSC

Exhibit SGW-2

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ROBERT M. C. ROSE
OF COUNSEL

June 5, 1998

VIA HAND DELIVERY

Blanca S. Bayo, Director
Division of Records and Reporting
Florida Public Service Commission
2540 Shumard Oak Boulevard
Tallahassee, FL 32399-0850

Re: Docket No. 960545-WS;
Investigation of Aloha Utilities, Inc.

Dear Ms. Bayo:

As the Commission and its staff know, there has been an investigation of the quality of water service delivered by Aloha Utilities, Inc. in the above-referenced docket for over two years. The Utility has demonstrated in formal administrative hearings, and through various other means, that it is fully in compliance with all regulatory requirements concerning water quality.

Partly in response to customer concerns, the Commission has taken the unprecedented step of imposing two requirements on Aloha Utilities, Inc., despite full compliance with all regulatory requirements for water quality.

The first of these was a requirement that the Utility undertake an analysis of the possible improvements that could be made to the utility system to improve water quality. On June 10, 1997, the Utility submitted its Water Facilities Upgrade Report ("Report") outlining in great detail possible system improvements, the benefits of each, and cost of such improvements. Despite requiring the Report, the Commission has not ordered that any identified improvements be undertaken or any other alternatives be considered.

The second requirement imposed on the Utility by the Commission was a customer satisfaction survey of all of its customers within the Seven Springs system. That survey has now been completed and the results are now being analyzed. However, it seems clear that a substantial number of customers responding to the survey had some water quality concerns with taste, odor, color, or pressure. The next step will be a visit by the Commission to view facilities and customer homes tentatively scheduled for July 13.

Since filing the Report, EPA regulatory requirements related to the disinfection by-product rule (THM, etc.) have become clearer and more immediate. In addition, the recent survey results indicate that there is some dissatisfaction with current water taste, odor and pressure. In order to satisfy these two concerns, over the next several years, the Utility proposes to undertake improvements similar to, if not exactly the same as, those proposed in "Alternative 2 - Centralized Facilities" of the June 10, 1997 Report.

In order to address customer concerns and comply with the fast approaching disinfection by-product regulatory requirements, Aloha Utilities, Inc. has determined that it is appropriate to immediately begin construction of three packed-tower aeration type water treatment plants. The Utility intends to immediately begin permitting, design and construction of these new plant facilities as follows:

<u>Phase I</u>

Pilot testing, design and permitting of the initial water treatment plant ("Mitchell plant"); and

Pilot testing and design of the second water treatment plant ("Wyndtree plant") (completion March, 1999).

<u>Phase II</u>

Construction of Mitchell plant; permitting of Wyndtree plant; and pilot testing, design and permitting of the third water treatment plant ("Industrial Park plant") (completion - December, 1999).

<u>Phase III</u>

Construction of Wyndtree and Industrial Park plants (completion - March, 2001).

However, in light of the lengthy, on-going investigation into the Utility's water quality, and the unprecedented requirements of this docket, it is reasonable for the Utility to require some assurance from this Commission that this course of action is considered prudent, and that no alternative or conflicting course of action will subsequently be ordered by the Commission.

To that end, the Utility is requesting that the Commission issue its order recognizing that the proposed improvements outlined in Section 7 of the Report are appropriate, and that it will recognize the reasonable cost thereof upon the Utility's filing of appropriate Applications for Limited Proceedings. Our proposal would be to file a limited proceeding for each of the 3 phases in sufficient time prior to the completion of each phase such that increased rates can be effective immediately after each phase is completed. We believe this phasing of rates would minimize rate shock and reduce overall carrying costs significantly over the life of the projects.

We look forward to meeting with the staff to discuss the details of this capital improvement plan. We would also be willing to provide the Commissioners and staff with a very brief overview of this plan at July 13th visit to the Utility office.

Sincerely,

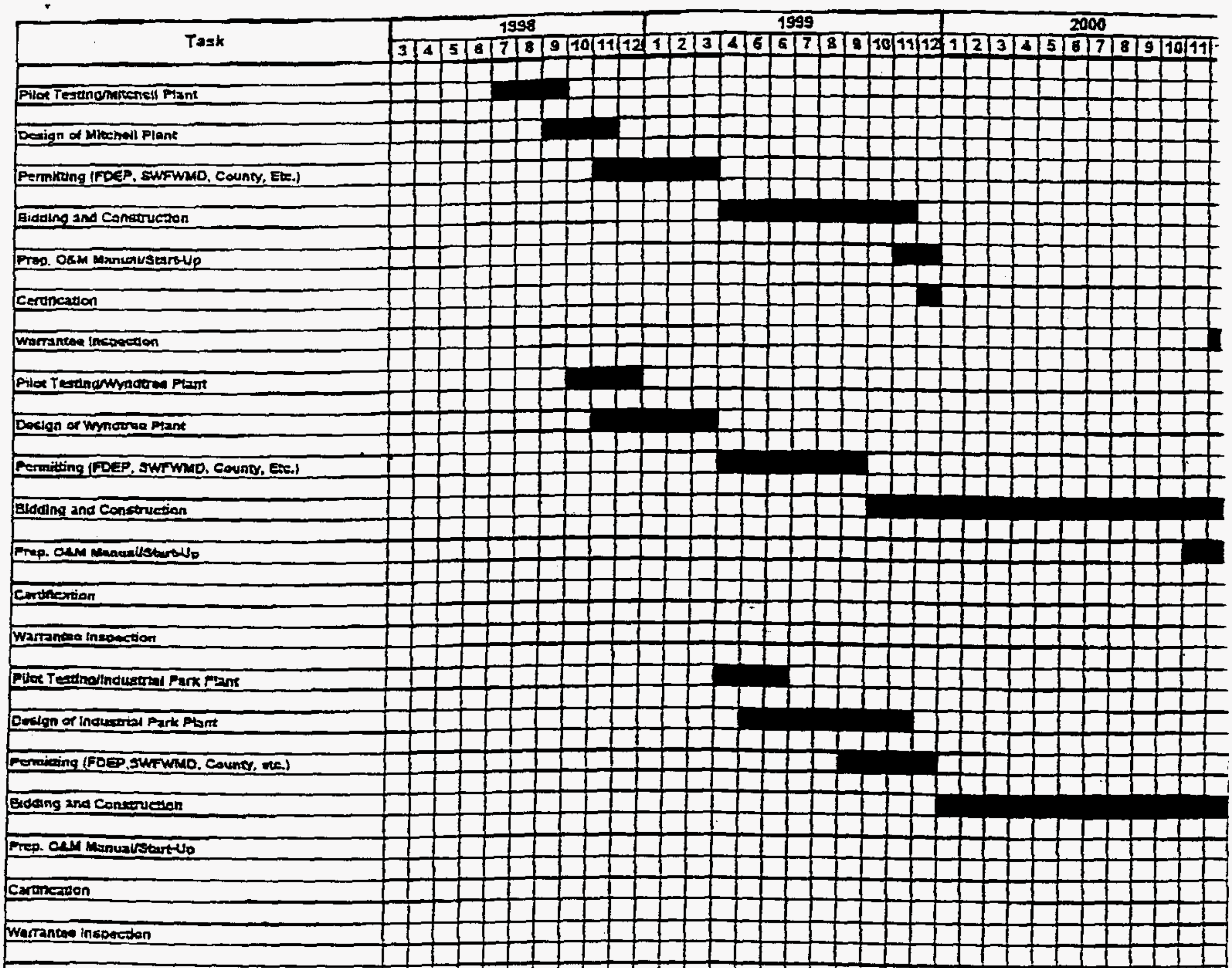
ROSE, SUNDSTROM & BENTLEY, LLP

F. Marshall Deterding
For The Firm

FMD/lm
cc. Ralph Jaeger, Esq.
Bob Crouch, P.E.
James McRoy
John Starling

aloha\17\62bayo.let

Project Schedule



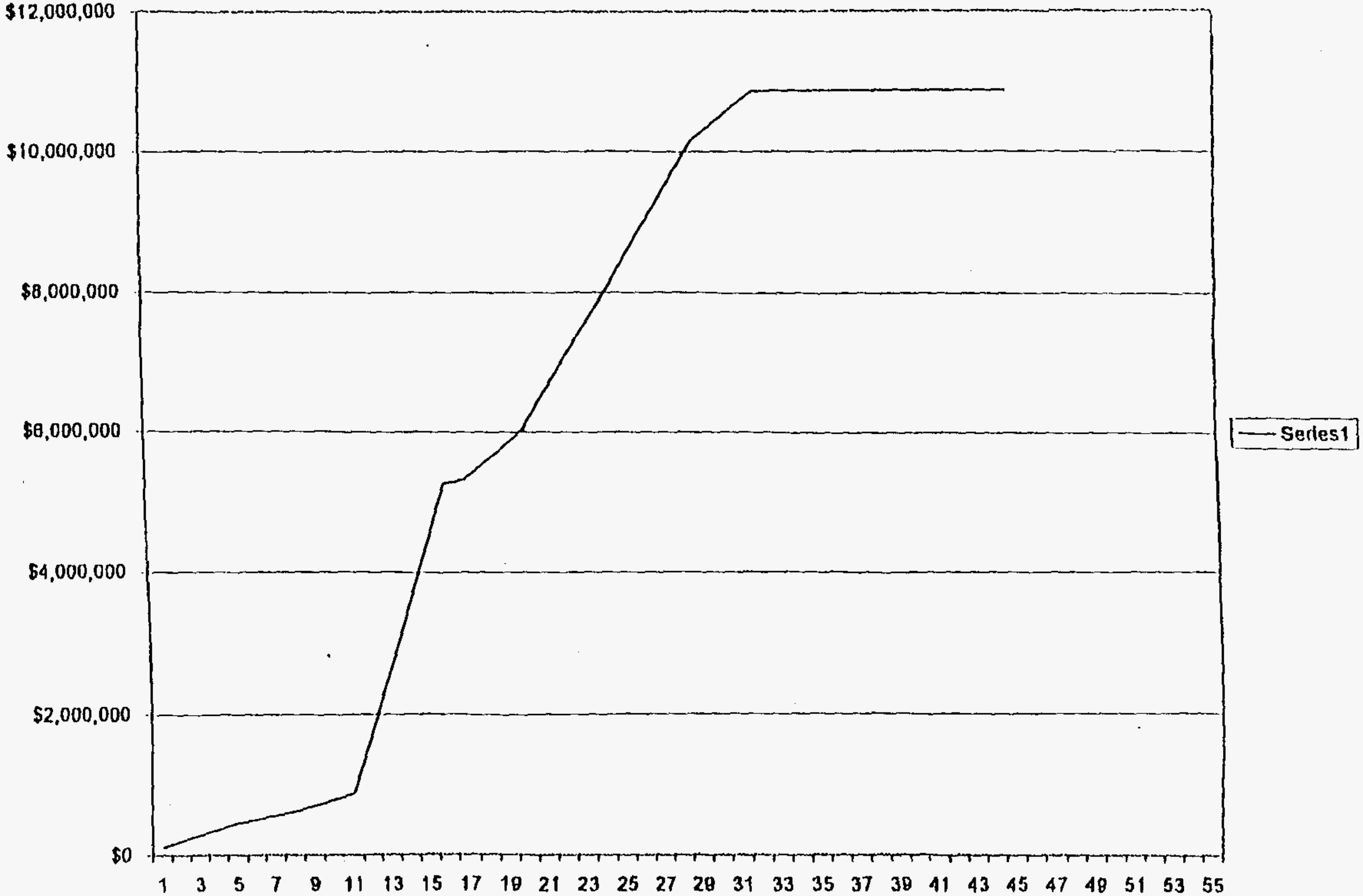
	1998									
	3	4	5	6	7	8	9	10	11	12
Pilot Testing Costs					$75,000	$33,125	$33,125	$33,125	$33,125	$33,125
Engineering							$53,100	$53,100	$53,100	$53,100
Construction										
Total Cost Per Period					$75,000	$33,125	$86,225	$86,225	$88,225	$88,225
Cumulative Cost					$75,000	$108,125	$194,350	$280,575	$366,800	$453,025

	1999											
	1	2	3	4	5	6	7	8	9	10	11	12
Pilot Testing Costs				$33,125	$33,125	$33,125						
Engineering	$53,100	$53,100	$53,100	$53,100	$53,100	$53,100	$53,100	$53,100	$53,100	$53,100	$53,100	$53,100
Construction							$822,453	$822,453	$822,453	$822,453	$822,453	
Total Cost Per Period	$53,100	$53,100	$53,100	$88,225	$86,225	$88,225	$875,553	$875,553	$875,553	$875,553	$875,553	$53,100
Cumulative Cost	$506,125	$559,225	$612,325	$698,550	$784,775	$871,000	$1,746,553	$2,622,106	$3,497,659	$4,373,212	$5,248,765	$5,301,865

	2000											
	1	2	3	4	5	6	7	8	9	10	11	
Pilot Testing Costs												
Engineering	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000
Construction	$224,930	$224,930	$224,930	$447,785	$447,785	$447,785	$447,785	$447,785	$447,785	$447,785	$447,785	$447,785
Total Cost Per Period	$236,930	$236,930	$236,930	$459,785	$459,785	$459,785	$459,785	$459,785	$459,785	$459,785	$459,785	$459,785
Cumulative Cost	$5,538,795	$5,775,725	$6,012,655	$6,472,440	$6,932,225	$7,392,010	$7,851,795	$8,311,580	$8,771,365	$9,231,150	$9,690,935	$10,150,720

Total Project Cost	$10,887,285

	2001												2002												2003											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
$12,000	$12,000	$12,000	$11,000									$500			$500																					
$222,855	$222,855	$222,855																																		
$234,855	$234,855	$234,855	$11,000	$0	$0	$0	$0	$0	$0	$0	$0	$500	$0	$0	$500																					
$10,385,575	$10,620,430	$10,855,285	$10,866,285	$10,866,285	$10,866,285	$10,866,285	$10,866,285	$10,866,285	$10,866,285	$10,866,285	$10,866,285	$10,866,785	$10,866,785	$10,866,785	$10,867,285																					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6

Press Release for Aloha Utilities, Inc.

The Florida Public Service Commission ("PSC"), as part of it's review of Aloha Utilities' water quality, has taken the unprecedented step of requiring Aloha to distribute a Water Quality Customer Satisfaction Survey to all of its customers in the Seven Springs service area. Those Surveys are now in and the results are being tabulated by the PSC.

There are a broad range of responses to various questions on the Survey. Approximately 57% of the Utility's customers did not respond at all to the Survey. As was boldly and plainly stated on the face of the Survey: **"If you do not return the survey, it will be presumed by staff to mean you are satisfied with the quality of water service you currently receive."** To the extent that statistics are reported which fail to recognize that satisfied customers would not return their Surveys, those statistics are wholly misleading as to the Survey results.

However, Aloha recognizes that almost 30% of the customers reported some discoloration of water with more than sixty different variations in the type of discoloration. This alone demonstrates that the discoloration is occurring within the homes. Approximately 17% of the customers reported pressure concerns and 25% reported taste and odor concerns. The great majority of customers who reported any one of these problems were those with home water treatment units.

It is clear from all of the evidence presented to date by any person with knowledge in the area of water analysis, that Aloha has continually met all water quality standards applicable to it. All such evidence and the regulators agree that any discoloration problems occur in the customers' homes and not in Aloha's system. The Utility can take steps which will help to improve taste and odor concerns. Those same improvements may help to lessen, and perhaps in some cases, eliminate some of the discoloration concerns.

Therefore, in order to address customer concerns and comply with the fast approaching EPA disinfection by-product regulatory requirements, Aloha Utilities, Inc. has proposed to the PSC that it immediately begin construction of three packed-tower aeration type water treatment plants. The Utility intends, immediately upon direction by the PSC, to begin permitting, design and construction of these new plant facilities which will take almost three years to complete. A copy of the Utility's letter proposing such improvements is attached.

Aloha Utilities, Inc. wishes to provide the best quality of water it can at a reasonable cost. In the past the Utility has been hesitant to impose on its customers the cost of providing treated water far exceeding the standards established by law. It is now evident that the customers desire a much higher quality of water than is currently available from Aloha or than is required by any regulatory standards. Aloha hopes to satisfy customer concerns by moving forward with those substantial projects immediately upon approval by the PSC.

ALOHA UTILITIES, INC.
Information From the Prior Hearing Regarding Customer Complaints

Exhibit SGW-3

Water Discoloration, Cause & Fix

From time-to-time, we receive questions from customers regarding water quality issues. Our staff makes every effort to answer our customer's questions, however, at times the answer is quite complicated and is not easily answered over the telephone. Therefore, beginning with this issue, we will select one water quality question that has been posed by our customers and provide a more detailed discussion of the concern and how we are addressing it.

In this issue we will address water discoloration. Intermittently, we receive calls from customers reporting discolored water. When discolored water occurs, it seems to be associated with hot water more often than cold. The problem, which rarely affects more than a small number of customers at one time, seems to be localized in a small section of our service area (made up of a few subdivisions).

When a customer notifies us of discolored water, we send a member of our field staff to determine if the discoloration exists in the water prior to its entrance into the customer's home.

If the water in our pipelines is discolored, we flush the main lines to remove any silt buildup which may have gathered on the pipeline and may be causing the discoloration. This silt, which is normally found in most water pipelines, poses no health risk and for the most part consists of common minerals (mostly silicon and calcium).

If the water entering the customer's home is clean and clear but the water inside the home is discolored, then, something in happening to the water after it enters the customer's piping system in his home. This type of problem is more difficult to solve because we have little control over what happens to the water after it enters our customer's home.

Earlier this year a number of our customers, located in a small section of our [illegible] they were experiencing hot water discoloration. We sent our field staff out to investigate and found that the water discoloration was found in some homes in the area and not in others, in fact, in most of the homes affected, the problem was intermittent.

We asked our consulting engineer to look into the matter and try to determine what was causing the problem. Also, we discussed this problem with the Florida Department of Environmental Protection (FDEP) to enlist their help in identifying the cause of the discolored hot water being experienced by some customers.

We began a month long joint study of the problem with the FDEP which included interviewing customers experiencing the problem, conducting discussion with other water utility operators and FDEP offices throughout the State, extracting hot and cold water samples in a number of customer's homes, collecting samples of water before it entered customer's homes and raw water at the well sites. After the study was completed, the data was analyzed and further discussions were held with the FDEP and our consulting engineer.

Sample Location	5/8/96	6/5/96	7/3/96	7/17/96
Davenport Drive	1.10	0.31	0.13	0.08
Mitchell Boulevard	0.51	0.23	0.16	0.10
Hideaway Court	0.57	0.26	0.13	0.09

Figure 1 - Copper Concentration in mg/L

This study indicated that the water in our mains, prior to it entering our customers homes, met all State and Federal standards and was clear and clean. None of the samples of water extracted at the well sites or in the mains outside our customer's homes was discolored.

Concentrated samples of the discolored water was analyzed by the FDEP. They found that the discoloration was largely composed of copper. This is consistent with similar problems reported by other water companies in the State. Based on the data collected, discussions with FDEP staff and other water utility operators, we came to the conclusion that the discoloration was caused by a compound known as copper sulfide. This compound forms when copper and sulfur (in the form of sulfide) combine in the water heater and copper piping in your home.

Where does the sulfide and copper come from? How will this problem be solved? Sulfur (in the form of sulfide) is a natural ingredient found in the ground water in our area. At our water well facilities, we add chlorine to convert this sulfide to sulfate and elemental sulfur that will not combine with copper to form copper sulfide. However, in home hot water tanks and piping, under the right conditions, sulfate and elemental sulfur can be converted back to sulfide by sulfur reducing bacteria. When this occurs, sulfide is produced and is made available to combine with any available copper and cause the discolored water. Copper, the other necessary ingredient, is leached into the water when it comes into contact with your copper water piping. The reason that the discolored water problem is most often found in hot water as opposed to cold water is that the chemical reaction that combines copper and sulfide into copper sulfide happens a very high rate when the water temperature is increased to that found in your hot water heater.

If the leaching of copper in to the water from the home piping can be eliminated, the formation of copper sulfide should no longer occur and the discolored water problem should be greatly reduced or eliminated.

We began adding a corrosion inhibitor to the water in late April to prevent copper leaching. To date, monitoring of special copper test racks has indicated that the level of copper being leached into the water has fallen dramatically as illustrated in Figure 1.

As we continue to add the corrosion inhibitor chemical, the concentration of copper in the water in your home will continue to reduce until the formation of new copper sulfide can no longer take place. After existing copper sulfide, which has built-up in your hot water tank and piping, is flushed from your hot water system, water discoloration should be greatly reduced.

Hopefully, within the next few weeks the discolored water problems being experienced by some of our customers will be history.

DESCRIPTION OF THE COMPLAINT HANDLING PROCESS

What follows is a detailed description of the complaint handling process that we employ at Aloha Utilities. The procedure that has been employed since 1989, for the handling and processing of customer complaints was structured around chapter 25-30.355 (1), (2) and (3), Florida Administrative Code. Subsection (2) states, **for the purpose of this rule, the word "complaint" used in this rule, shall mean an objection made to the utility by the customer as to the utility's charges, facilities or service, where the disposal of the complaint requires action on the part of the utility.**

We have three customer service representatives that can receive an incoming call to the utility's main number. We use no voice mail or any sort of electronic gearing devices during normal business hours of the utility. When our customer's call they get to speak to a living, breathing customer service representative. All three customer service representatives are capable of handling whatever complaint a customer might have. We do have all calls concerning water quality directed to a single service representative. This was done so that any trend that developed in certain areas would not be overlooked due to multiple people being involved. She is charged with the duty of handling all water quality complaints. When a call is received at our office that pertains to a quality of water issue, the call would be directed to this customer service representative. She will then attempt to determine, based upon her conversation with the customer, the nature of the customer's problem. The purpose of that is, primarily, to allow her to communicate to the field representative, with as much detail as possible, the nature of the complaint that the customer has voiced. She does not attempt to diagnosis customer service problems over the telephone. In the course of discussing the problem with the customer, it is not uncommon for the customer to ask questions, to which to the best of her ability based upon the information given by the customer, she would attempt to respond to that question. This in no case, is in lieu of a field representative going to the customer's home. For instance, if a customer called and said, " I had discolored water but it's only in my hot water," there would be a work order sent to the field to investigate that. However, during the course of her conversation with the customer, she might very well advise the customer or ask the customer if they had flushed their hot water heater recently. It is impossible for a customer service representative sitting in an office to be able to definitively diagnosis a problem existing within a customer's home. She will on occasion, share information that she is aware of with the customer, generally because the customer solicits that through a question. As another example, if a customer were to contact our office, stating they had read the article published in the newspaper concerning the implementation of the corrosion control program, she would attempt to answer any questions they might pose to her. However, if there were questions she did not know the answer to, the request would be forwarded to my assistant and ultimately, if necessary to me. However, during the initial conversation with the customer, the customer would have been asked if they had a problem with the service at their home. If the answer were yes, a service order would have been created and sent to a field representative for handling, prior to pursuing the additional information that the customer was requesting. In any event, any customer who expresses any problem that they are having with the service at their home will cause the creation of a service order that goes to the field for handling by a field representative. The only instance, in which a service order would not be generated, is in the instance of a main line break. In the event of a main break, where several hundred customers may be without water during the break and experience pressure fluctuations while the system is being restored, during those instances, because of the volume of calls that would come into our office immediately upon interruption of service, work orders would not be created for each and every call. During times such as these, we attempt to handle those calls as quickly as possible by informing the customers as we take the calls of what has occurred in the system and when we anticipate service will be restored. The customers would also be advised, that after the restoration of service, if they experience any further problems, to contact us. During those events, which we have no way of anticipating, it seems prudent to attempt to disseminate the information as to the status of the system as quickly as soon as possible.

All service orders are tracked in an on-line computerized service order system. One of the required procedures in our billing system is to run a pending service order list prior to beginning the billing run. If in the event, a service order were lost or misplaced, the computer system, prior to allowing any updates to billing records, would require that all service orders be accounted for and processed through the system. That procedure occurs at least every fifteen days, due to our billing cycles. The billing run is not executed until after all pending service orders are completed and processed through the service order update system.

When a complaint concerning water quality is received after the service orders have been sent to the field in the morning, the service order is prepared, however, the complaint is called out into the field immediately to a field representative for handling as soon as possible.

The field representative will handle the complaint as soon as possible and complete the service order and return it to the office. If he is working in response to a radioed call, he will write up his response and return it to the office for attaching to the service order.

We believe that we have an excellent system in place for handling customer complaints. We also, as the testimony reflects, have an excellent response time to complaints.

ALOHA UTILITIES, INC.
Aloha's Survey Analysis

Exhibit SGW-4

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OF COUNSEL

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June 19, 1998

VIA HAND DELIVERY

Blanca S. Bayo, Director
Division of Records and Reporting
Florida Public Service Commission
2540 Shumard Oak Boulevard
Tallahassee, Florida 32399

Re: Aloha Utilities, Inc.; Docket No. 960545-WS
Water Quality Survey
Our File No. 26038.17

Dear Ms. Bayo:

As you know, Aloha Utilities, Inc has recently completed a Survey of customer satisfaction with the quality of water provided by the Utility. The Public Service Commission staff has been analyzing the results of that Survey and has now issued a "Preliminary Tabulation" of customer responses to the Aloha Survey dated June 17, 1998.

We at Aloha Utilities have now had an opportunity to review the "Preliminary Tabulation" which we received late Wednesday afternoon and we find them to be even more troubling and misleading than the information which the "Suncoast News" reported in its June 17 edition based upon conversations with the PSC staff the previous day. This is especially upsetting in light of the fact that Wednesday morning I hand delivered a letter to the staff stating my concerns with the "Suncoast News" article, in advance of the release of the "Preliminary Tabulation".

The Commission initiated and configured this unprecedented customer satisfaction Survey to elicit responses from customers who were dissatisfied with their water service. In fact, the only bold language in the entire Survey is the provision that provides "**If you do not return the survey, it will be presumed by staff to mean you are satisfied with the quality of water service you currently receive**". In full recognition of this language, approximately 60% of the Utility's customers did not respond to the Survey. Yet the information contained within the staff's "Preliminary Tabulation" does not even mention the assumption that not only must be inherent, but which is also plainly and boldly stated on the face of the Survey itself. In fact, the "Preliminary Tabulation" documents published Wednesday deal almost exclusively with statistics based upon a comparison of answers to responding customers, versus a comparison to surveyed customers. This "Preliminary Tabulation" only mentions the number of persons who did not return the Survey in passing, while giving absolutely no weight whatsoever to the bold language of the Survey coversheet, and therefore the majority of Aloha's customers. Would the PSC staff have issued numerous pie charts and graphs which appear to show 70% dissatisfaction if only 10% or 5% of the customers had responded to the Survey? I certainly hope not.

As a result of the way in which the Survey results are being published in the staff's "Preliminary Tabulation", the staff has violated the conditions under which Aloha agreed to undertake the Survey and the good-faith agreements as to its terms. More importantly, the staff's "Preliminary Tabulation" allows for substantial misinterpretation of customer reaction to the Survey and misinforms the public about the results of that Survey.

Aloha Utilities, Inc. has obtained copies of all of the Survey responses from the Commission and has tabulated its own results. Some of these results have previously been provided to the staff and are being provided as an attachment hereto.

While we would certainly agree that the significant number of responses, and the significant amount of customer concerns with discolored water, taste and odor are cause for further review, the way in which the staff's "Preliminary Tabulation" of those results has been published substantially overstates the level of that dissatisfaction and misleads those who review it.

We are therefore very disappointed and upset at the way in which this information will be received and misunderstood. The manner in which the Survey results are presented by the Commission staff effectively ignores the majority of Aloha's customers who no doubt relied on the bold language at the beginning of the Survey indicating that their voices would be heard if they chose to intentionally not return the Survey.

Sincerely,

ROSE, SUNDSTROM & BENTLEY, LLP

F. Marshall Deterding
For The Firm

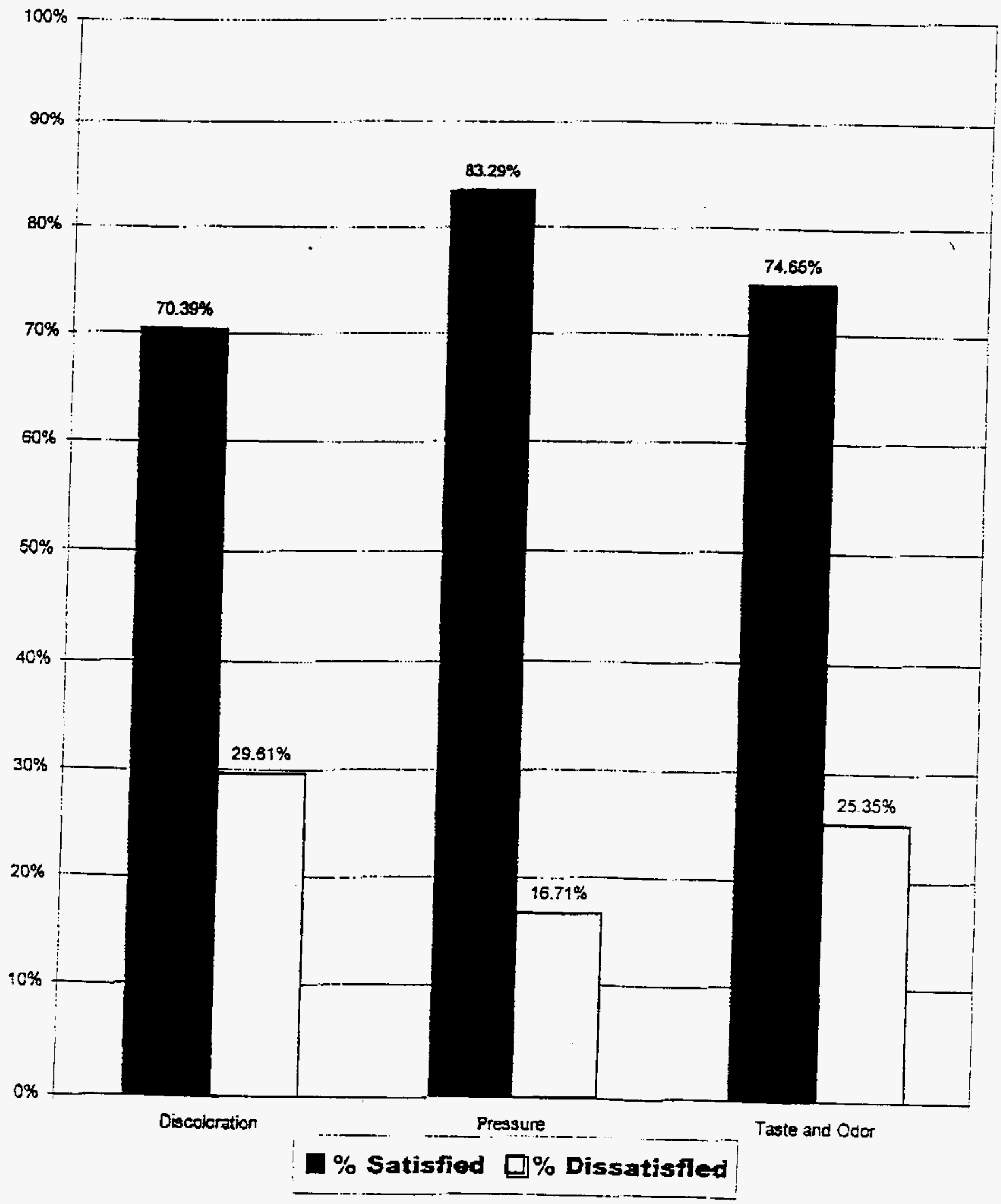
FMD/tmg

Enclosure

cc: Ralph Jaeger, Esquire
Charles H. Hill, Director
Mr. James McRoy
Mr. John M. Starling
Mr. Bob Crouch, P.E.
James Goldberg, President

aloha\17\2bayo.fmd

Summary of Water Quality Survey Results



Summary of Survey Results

		Percentage of Customer Base	Percentage Satisfied
Total Number of Surveys Mailed	8643		
Total Number of Surveys Returned	3707	42.89%	
Total Number of Surveys Reporting Discolored Water (Yes Answer to Question #1)	2559	29.61%	70.39%
Total Number of Surveys Reporting Taste and Odor Problems (No Answer to Question #2)	2191	25.35%	74.65%
Total Number of Surveys Reporting Pressure Problems (No Answer to Question #3)	1444	16.71%	83.29%
Customers Willing to Pay Increased Rates	505	5.84%	
Customers Willing to Pay Increased Rates Above 50%	35	0.40%	
Respondents Who Have Home Treatment Units (Percentage of Respondents Only)	2098	56.60%	
Resondents Who Don't Know if They Have Treatment Units	36	0.97%	