Appendix O:

Pipe Cleaning Review Reports

From: rebecca pope (4/23/98)
To: hurh@fnal.gov

Mail*Link® SMTP report

April 18, 1998

Mr. Peter Mazur
Fermilab
P.O. Box 500
Batavia, IL 60510

Dear Mr. Mazur:

This short letter report provides my comments on the materials provided for review regarding the repair, operation and monitoring of the LCW water system for the Main Injector. Please let me know if you have any questions regarding this material, or if I can be of further assistance.

Sincerely,

Daniel H. Pope
President

COMMENTS ON MATERIALS PROVIDED FOR BTI'S REVIEW REGARDING THE MAIN INJECTOR LCW SYSTEM AND PLAN FOR REPAIR, TREATMENT AND MONITORING.

Provided by Dr. Daniel H. Pope, President
Bioindustrial Technologies, Inc.

1.0 Evidence for MIC in the LCW

The evidence provided by Nalco, BTI and others all strongly suggest that the corrosion of stainless steel pipes, primarily at welds and heat affected zones is microbially influenced.

2.0 Proposed Repair

Proposed repair seems, to this microbiologist, to be appropriate.

3.0 Proposed Cleaning and Treatment of Repaired Welds

I agree that chemical cleaning followed by an acid wash is preferable to mechanical cleaning. If mechanical cleaning must be used efforts should be made to remove as much weld spatter/tint etc. as possible.

4.0 Proposed Water Treatment Method

UV treatment of only 2% of the water will do little to reduce the population of microbes on the metal surfaces. These are the microbes that cause MIC. I believe that UV treatment alone will result in re-colonization of the internal surfaces of the stainless steel pipes. Chemical disinfection of the piping after repair should be considered. The idea of using heat (60C) to reduce microbes in the system is a good one, and if used properly (frequently enough and for long enough periods

of time) should be of considerable use in controlling microbes.
Monitorin
g of coupons in the system before, during and after a heating cycle
should be done to determine duration of heat cycles.

5.0 Monitoring

Monitoring of coupons and waters is essential. Monitoring should be done using media capable of detecting aerobic and low nutrient bacteria as these are the primary components of the biological communities in the LCW system..

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April 27, 1998

Peter O. Mazur
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VIA FACSIMILE TO 630-840-8032 AND U.S. MAILS

RE: Remediation of corroded welds in the Main Injector Low Conductivity Water System: microbiologically influenced corrosion.

Dear Dr. Mazur:

Here is my final report on this matter. There are no fundamental changes in my position, but I have chosen to emphasize some points.

Some anaerobic sulfate reducing bacteria were found by Nalco, and the corrosion deposits had significant quantities of sulfur and carbon, which is indicative of the presence of such bacteria. I note that adirect connection or causality was not established, and some of the corrosion morphology apparently was not consistent with localized attack due to microbial colonies. Low pH is not of itself evidence that the corrosion was microbially induced. Pitting or crevice corrosion in stainless steels will always lower the local pH, sometimes to 2 or below; for stainless steel this is due to the accelerative ("auto-catalytic") nature of pitting and hydrolysis by the released chromium ions and subsequent hydroxide precipitation, leaving the H^+ ions in solution. Consequently some of the observed corrosion may not be the result of microbial induction. For that matter, the correlation of microbial action with the welds may be due to ionic release by the corroding welds, and the corrosion mechanism may be complex and interactive. In short: we cannot blame it all on microbial action.

The poor quality of the installation welds may well be a continuing problem. We can only hope that, because the environment will be flowing deionized water, a much less aggressive medium than the stagnant well water used for the hydrostatic testing, the problem will disappear or at least be attenuated to a tolerable level. In fact, the operating environment should decrease (and possibly eliminate) corrosion due to metal quality and also microbial action. However, continued vigilance will be necessary, e.g. during any shutdown, when the environment will again degrade.

According to the analytical data supplied by you this morning (April 27), which applies to water upstream of the chlorinator, the chloride level is about 22 ppm, which is, as municipal supplies go, not bad (there are municipal systems here and in Florida which have had over 100 ppm) and about 160 ppm of sulfate ion (consistent with the bacteriological character of at least some of the corrosion). Missing information here is of two kinds: the resultant level of chloride after chlorination and the composition of the stagnant water after it sat in the system for some time. The "free" chlorine referred to in your letter is the equivalent residual Cl_2 after chlorination (e.g. in the form of hypochlorite or whatever they add), i.e. whatever has not reacted with the organic and other matter in the water. Because stainless steel is generally welded by inert-gas (TIG or MIG) equipment, I do not expect welding fluxes to be a problem. However, other residues may be present, e.g. cleaning agents, and these would be important in the stagnant water. The bottom line: you need to know the water composition as it exists in your system, and you need to monitor it as operating conditions change.

In general it will not be possible to completely repassivate most corrosion pits by mechanical or by chemical action. In principle, acid cleaning accompanied by vigorous agitation and then an appropriate series of rinses, will completely clean up the surface. In practice, especially given the constraints on this system, the result can be very different. I expect there will be residues in the corrosion pits and intrusions into the weld metal, and even when completely "clean," the pit geometry will predispose to further corrosion. The hope of controlling the process lies with control of the environment, that is the water flowing over the pit. With this in mind, I recommend that you put in place some capacity for continuous monitoring of water composition in addition to microbial monitoring, as described in the 4/13/98 document ("Description of Start-Up, Prevention & Monitoring Plan"). In addition, you should try to ozonate (or add H_2O_2) any makeup water without excessive perturbation of the conductivity or oxidation of the copper components. When monitoring water chemistry, do measure copper (cupric) and dissolved oxygen concentrations, in addition to other species.

In answer to the specific questions on the second page of your letter:

1. My commentary is above. With regard to remediation, I cannot say that the acid cleaning technique will be superior to the "Scotch-Brite" approach, and it may well be inferior. See my last paragraph above.

Yes, you do need to do mechanical cleaning. The oxide and bacterial residues and corrosion products will cause and accelerate further corrosion. The cleaner the interior surfaces are, the better off you will be.

2. It is impossible to say what the failure rate will be on the welds you cannot reach, except to say that the operating environment (fast flowing deionized water) will be much less aggressive than the standing well water which was present previously. Therefore, expect a significantly lower failure rate, but don't expect it to evaporate. (It could happen, but don't expect it!) If you can, isolate those parts of the system and kill off as much of the bacteria as you can before restarting. Here again, constant monitoring of the water quality would be very useful, if only as an early warning that something is happening. I do not believe that ongoing corrosion in these welds will accelerate corrosion elsewhere in the system, at least under the operating conditions which will prevail, i.e. flowing deionized water. Stray current effects should be negligible, and ionic release due to the specific mechanisms involved here (crevice/pit corrosion) should not be large enough to have any effect on corrosion (before it gets that large in any case, it would probably raise your electrical conductivity to a level that would preclude operation of the magnets).

In summary: the aqueous environment is the crucial component of the corrosion mechanism in your case. As stated above, it is possible that, in fast flowing deionized water (even with dissolved oxygen) your problem may disappear. It follows that any change in environment (e.g. shutdown) may have disagreeable consequences. Vigilance is essential.

Yours truly,

Robert M. Rose, Sc.D., P.Eng.
Professor of Materials Science
and Engineering